



Spatio-Temporal Forest Cover Change Detection Using Remote Sensing and GIS Techniques: In the case of Masha Woreda, Sheka Zone, SNNPRS, Ethiopia.

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Spatio-Temporal Forest Cover Change Detection Using Remote sensing and GIS Techniques: a Case of Masha woreda, Sheka Zone, SNNPR. Ethiopia

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Dedicated to My Dear

Father

&

Mother

Who are big sources of inspiration throughout in my academic

Endeavor

I Wish Long Live to You and Love U!

DECLARATION

I hereby declare that the thesis entitled “**Spatio-Temporal Forest Cover Change Detection using GIS and Remote Sensing Techniques in the case of Masha woreda, Sheka Zone, SNNPR**” has been carried out by me under the supervision of Dr. K.N.Singh, Department of Geography and Environmental Studies, Addis Ababa University, Addis Ababa during the year 2015. It part of a Master of Social Sciences, Geography and Environmental Studies Specialization GIS and Remote Sensing stream. I further declare that this thesis is my original work and has not been submitted to any other University or Institution for the award of any degree or diploma and that all sources of material used for the thesis have been dully acknowledged.

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Acronyms

CBE: Convention on Biological Diversity

CSA: Central Statistical Authority

DEM: Digital Elevation Model

EAA: East African Agri-business

EMA: Ethiopian Mapping Agency

ETM: Enhanced Thematic Mapper FDRE: Federal Democratic Republic of Ethiopia

FAO: Food and Agriculture Organization of the United Nations

FCC: False Color Composite

GCP: Ground Control Point

GIS: Geographic Information System

GPS: Global Positioning System

GTZ: German Technical Cooperation

IFMP: International Forest Management Project

MCE: Multi-Criteria Evaluation

MSS: Multispectral satellite image

MELCA: Movement for Ecological Learning community action

NDVI: Normalized Difference Vegetation Index

NGO: Non-Governmental Organization

NIR: Near Infra-Red

NTFP: Non-timber forest product

PFM: Participatory Forest Management

SFM: Sustainable Forest Management

SNNPRS: Southern Nation Nationalities and Peoples Regional State

SZCTGCD: Sheka Zone Culture and Tourism and Government Communication Department.

SZARDO: Sheka Zone Agriculture and Rural Development Office

SRTM: Shuttle Radar Topographic Mission

TCC: True Color Composite

TM: Thematic Mapper

UN: United Nation

UNEP: United Nation Environmental Program

UTM: Universal transverse Mercator

USEPA: United Nation Environmental Protection Agency

WBE: World Biotic environment

WBISPP: Woody Biomass Inventory and Strategic Planning Project

WCFSD: World Commission on Forests and Sustainable Development

WLC: Weighted Linear Combination

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Abstract

The aim of this study was to detect the magnitude and rate of forest cover change over the last 42 years (between 1973 and 2015) and generate human disturbance risk map based on land use/ land cover of the area using Remote sensing and GIS techniques in case of Masha woreda. Forest Priority Area that covers the total area of around 6,835 ha and Post-classification comparison change detection methods and NDVI image differencing were employed. The major land use/ land cover types in the study area have been identified as: dense forest, moderately dense forest, Tea plantation, Wet land and rural settlement. The study made use of Landsat images of the year 1973, 1987 and 2015 to know forest cover changes and rate of deforestation during the different periods and the type of land cover to which the forest is changed to. In addition Multi Criteria Evaluation in a GIS environment was used to come up with the final human disturbance risk map. 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 declined from 6,372 ha in 1973 to 6,292 ha in 1987 and dropped to 4,635 ha in the year 2015 in the study area. In addition to this, forest cover risk map (susceptibility for deforestation) was done by considering factors such as Proximity to rural settlement, Proximity to road, proximity to tea plantation, proximity to river and elevation. In the meantime, three level of susceptibility to forest cover change compartment map was generated with the support of GIS technology. Based on the forest cover areas of the year 2015 (4,635 ha) of study area, about 744.17 ha, 587.4 ha and 2,992.74 ha of forest cover land are categorized under high, moderate and low susceptible to forest cover change respectively. The problem of forest cover change is directly linked with the activity of man such as expansion of rural settlements and tea plantation. In order to understand impact of forest cover change corrective measures are suggested.

Key Words:- *Masha Woreda, Remote sensing and GIS, Deforestation*

Chapter One

INTRODUCTION

1.1 General Background

Natural resources such as forests and wildlife were abundant on the earth but much concern was not given about its wise use. As human population continues growing rapidly, resources are becoming scarce. Obviously, these resources are changed or exhausted unless wisely used. In order to mitigate the scarcity or complete loss, mankind has started to become concerned about conserving natural resources, of which one is forest resource (NTFP, 2004).

Forest is one of the most essential types of resources that human beings and other animals depend on. It regulates environmental and ecological system soil, water, climate and rainfall. The presence of forest in Ethiopia is relevant at several levels. Apart from its intrinsic value for many indigenous and other forest-dependent people, forests are their livelihoods. Forests provide them with edible and medicinal plants, bush meat, fruits, honey, shelter, firewood and many other goods, as well as with cultural and spiritual values. Whether it is private or public property, forest is the nationally and globally mutual treasure. The value of forest resources to the world's human population is becoming increasingly evident (Tadesse, *et. al.*, 2011).

Socially and economically speaking, forests are a resource for local communities as a source for fuel wood and construction wood. In addition it is used for commercialization of non-timber product in some local market. Moreover, they represent pasture for domestic grazers.

Ecologically, forests are essential for the whole Ethiopian ecosystem, because they prevent the loss of top layers of fertile soil. Damages are already visible in deforested parts where the poor soil have considerably reduced agricultural performance and hinder reforestation possibility for the future (Tadesse, *et. al.*, 2011).

Despite this, forests have been subjected to over exploitations due to increasing of human population and other factors. Those forests have been either modified or converted. If modified, once dense stands of closed forests have been replaced by more open stands of secondary species that yet further changed into savanna of open grasslands and the whole

process frequently being a prerequisite to clearing for agricultural activities (Williams, 1990). However, human interference mainly for subsistence and forest centered investment opportunities are the most important reason for fast depletion and serious degradation of natural forest in Ethiopia.

Thus, even if using of satellite remote sensing for human use is complex and tiresome work, it has proved to be the most cost effective means of mapping and monitoring environmental changes in terms non-renewable resources mainly vegetation for developing countries. Remote Sensing (RS) and emerging GIS technology is the best tool in the hands of researchers of various disciplines of recent generation. The remote sensing provides digital format spectral data from the satellites without any physical contact with the object (Lillesand and Keifer, 2004).

This digital data is converted into visual image in the form of imagery. The imagery is the best and reliable source of data of the earth surface in various contexts like topography, biodiversity, land use, cultural aspects etc. Geographic Information System (GIS) is very recent technology in the hand of geographer. It is the computer-based system for collecting, storing, checking, integrating, retrieving, manipulating, processing, analyzing and displaying data, which are spatially reference to the earth.

Besides, Satellite Remote sensing plays a crucial role in determining, enhancing and monitoring the overall carrying capacity. The repetitive satellite remote sensing over various spatial and temporal scales offers the most effective means of assessing the environmental parameters and it has played a vital role in generating information about forest cover, vegetation type and land use changes.

One of the most complete of these methods is supervised classification. It is computer assisted classification which depends on prior knowledge of researcher to classify satellite image in to various land use system or training areas. Change detection through remote sensing has now been applied widely because of its quick analysis processes, accurate results and visual spatial information.

Information derived from remote sensing particularly in the form of land-use/land covers mappings, forest land changes and rate of deforestation is essential to detect changes, predict as well as monitor the results and useful for rational planning activities (Majid, Humayun, 2010 and Hellden, 1987).

Therefore, this research emphasized on mapping forest cover change using the integrated techniques of Remote Sensing and GIS technology in SNNPRS, Sheka Zone, Masha woreda, forested but high investment priority area.

1.2. Statement of the problem

Depletion of forests and their degradation “are a threat to global ecosystem diversity and have fundamental influence on the declining standard of living of many households.” (Els bogenetteau, *et al*, 2006)

The change in forest cover during the last three consecutive decades is the most severe human related problem that Ethiopia has seen. Researcher such as Reusing (1998) and (Tadesse *et al*, 2011) estimated that the closed high forest of South West Ethiopia dropped from 40% cover between 1971 to 1975 to only (around) 18% by 1997, which is loss of about 60%. Conversion of forestland to other land use types is the major cause of deforestation. Around 235,000 hectares of closed and slightly disturbed forest areas were deforested between 1971 and 1997, a loss of about 10,000 hectares of forest every year.

The continuous declining forest of cover of South West Ethiopia, which was in a relatively better state in the past, illustrates the magnitude of the problem of deforestation in Ethiopia. That is why the Former president of FDRE Mr Girma W/Giyorgis, on preceding international conference of Non-timber forest product (PFM), Biodiversity and livelihoods in Africa (2007) gave concern on environmental protection and sustainable development said that “There is no need to mention that there would not be sustainable development without the sustainable management of the natural resources that affect the lives of the rural population.”

In contrary with the above idea, the research results of Elias (2008) on forest of *Sheka* state the woredas of *Sheka* Zone (in south western Ethiopia):

“Dense closed forest decreased from about 55,304 hectares in 1987 to 43,424 in 2001. On the other hand, open forest decreased from 46,494 to 35,077 hectares during the same period. The study in six kebeles which borders tea plantation indicated that dense forest cover which was 70% in 1973 declined to 65%, 42% and 20% respectively in the years 1987, 2001 and 2005.” (P. 78).

The above research result illustrates the intensity of problem in the study area and initiate researcher to make study in that particular area using powerful techniques of remote sensing and GIS.

Forest areas on steep slopes, culturally called ‘*Gep Dinbaro*¹’, are traditionally protected. These forests, however, are also used for production of non-timber forest products especially honey and climbers for house construction. This has contributed to watershed protection of areas, which are otherwise highly vulnerable to erosion and risk of flooding in lowland areas.

According to Tadesse and Fite Getaneh (2011), *Sheka* Zone is one of the few areas with high forest cover in Ethiopia. Due to high level of dependency on forest resources, the local communities have developed traditional management practices based on religious taboos and customary practices. Such management practices have sustained the forests for centuries and contributed to the better condition of the forests in the area, as compared to other parts of the country. However, the rate of deforestation has aggravated in recent years due to increased rate of conversion to agriculture and monoculture plantations of coffee and tea.

The Ethiopian Central Statistics Agency (2007) estimated that about 38,115 and 25,726 traditional beehives are found in Masha and Andracha Woredas respectively, with annual production of over 520 thousand kilograms of honey. The importance of honey production alone for the livelihood of the local community is quite high. From this, one can realize the severity of the impact of deforestation for investments on the livelihoods of the local people, other than the known effects on the environment.

¹ **Gep-dinbaro** (Shekkinoono): Forest that found on steep slope(around border of River)

More than 43 investment projects were licensed and are currently operating in Sheka Zone of SNNP Regional State, Southwest Ethiopia. Large areas of natural forests were given to investors without sufficient studies (Zewude J. 2005).

The expansion of unchecked (in terms of environmental friendly) investment has a profound impact on the livelihood of the indigenous community and the biodiversity situation of the remaining natural forest. Investment in plantations, especially tea plantations, has created conflict with the interests of the local community.

An investment initiative that does not respect any form of available rule, be it national, regional or local, is not expected to bring meaningful benefit to the surrounding people. It can also endanger the traditional techniques of resource management that have been adapted and maintained for centuries which called in native language *kobo*²/*Gudoo*³/*Dedoo*⁴.

Melca Mahiber (2005) mentioned the following factors played critical role for declination of forest coverage in the area; “Investment project for new coffee and tea plantation, fast population growth due to immigration related to settlement and agricultural development projects and moreover, there were no research has been conducted on mapping the areal extent of forest cover around huge investment sites of the study area” Had resulted increasing pressure on forest

Besides to this, the research of Reid *et, al.* (2000) and Daniel M. (2008) agrees on the above factors and forwards that “the combined effect of population pressure, changes in settlement and land tenure policy, poor infrastructure development and expansion of large scale plantation, poor institutional and socio economic setting” are considered as the major drivers of the conversion of forest and shrub land to agriculture.”

Thus, the previous findings made analysis on prevailing problem on the study area and those studies give much concern from zonal prospective, they fail to apply GIS and Remote Sensing tools to show severity of the problem on the map. This study tries to apply these important tools for land use land cover change detection and it will provide relevant and easily accessible information for concerned bodies.

² **Kobo:** Large forest areas that are administered through customary right

³ **Guddo:** Cultural forest used as worship place

⁴ **Deddo:** Large tree under which prayer or religious ceremony is conducted

1.3 Objectives

In this work, general objective is “Identifying the Spatio-temporal forest cover change process by using GIS and Remote sensing techniques, in Masha woreda of Sheka zone, SNNPR”

Specifically the study emphasizing on:

- ✓ Understanding the integration of Remote sensing and GIS tools for forest cover change detection
- ✓ Making maps of 1973,1987 & 2015 by using various GIS tools & analyzing difference
- ✓ Quantifying rate of deforestation,
- ✓ Producing disturbance risk map by using various factor for forest change
- ✓ Forwarding clues for protection potential forest resources areas.

1.4. Research questions

1. What was significance of using integrated techniques of using Remote sensing and GIS tools forest cover analysis?
2. What was the area of natural forest land cover during the different period?
3. How much hectare of forest was deforested during 1973, 1987 and 2015?
4. What are the factors responsible in determining the forest land cover Change in study area?
5. What are the solutions for sustainable forest management 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 2000 E.C. 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 forwarded an important clue in filling of this information. Specifically, the result of the study had the following contributions:- For **Academics**: - May provide an insight towards an understanding of the use of integrated techniques of using GIS and Remote sensing tools for forest cover change detection. For **Policy Makers**: - Provide achievable solutions for those who are responsible and interested for taking measures to mitigate the problem. For **Researcher**: - Generate 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.

1.6. Limitation of the study

As the area is known by 12 month rainy season there was a problem on Satellite images, so the researcher selected two Rainey free months in some extent those are: January and February. 1973 Landsat images was blurred and have hazes which create difficulties during Classification of Land cover types and NDVI calculation but the researcher tried to solve by a method called image enhancement as much as possible. Also, this Landsat MSS image has resolution of 60x60 which was different resolution from the rest two the researcher tried to use Resampling method to handle this problem. The researcher tried to apply post classification techniques, NDVI and Field observation together to understand and solve challenges which exist on all satellite images.

2. LITERATURE REVIEW

2.1. Conceptual Review

2.1.1. Forest, Forest Cover and Change detection

Forest is one of the great inherited 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 (FAO, 2000).

World Bank funded woody biomass investment and strategy planning (WBISPP, 1992) 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.

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 (Hiywot M. G. and Rashid M. Hassan, 2008).

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection aim is to discover temporal differences of the same objects at different time.

2.2. Empirical Review

2.2.1. 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.

According to FAO (2012) and UNEP (2011) the world population become above 6.5 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 (FAO, 2010) 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 (FAO, 2010).

2.2.3. Global Causes of forest cover change or Deforestation

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 challenged 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.

According to Elijah (2007) the three main causes of deforestation in the world are; agriculture (including huge investment), infrastructure expansion and wood extraction. He 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(FAO, 2010).

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 have major effect on global climate change and loss of plant and animal species.

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 (Elijah, 2007).

Regarding to Turner II and Meyer's (1994) view, land cover transformation did not stop, but rather accelerated and diversified from the beginning of industrial revolution, due to the globalization of the world economy, the expansion of population and technological capacity.

According to the study by Mayaux *et al.*, (2005) based on Earth observing satellite image 1990, there were some 115 million ha of tropical rain forest with the area of the humid tropics deforested annually estimated at 5.8 million ha.

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. The forests of Africa are being converted at a similar rate to those of Latin America 0.4 to 0.5% per year. (ibid)

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.

By 2005, deforestation rate was about 13 million hectares per year. 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” (UNEP, 2007). Primary forests have no sign of past or present human activities and are considered to be the most biologically diverse ecosystems in the world (Butler, 2005).

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.

William (1990) 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.

2.2.4. 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 (Demel *et al.*, 2010).

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 (EARO, 2008).

In 2005, the forest cover had further declined and was estimated to cover 13.0 million ha. In other words, Ethiopia lost over 2 million ha of her forests, with an annual average loss of 140 000 ha between 1990 and 2005. 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 (FAO, 2010).

This indicates that the coverage forest resources are declining in 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 (WBISPP, 2004).

2.2.5. The causes of forest cover change in Ethiopia

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). Another aspect which has a negative impact on the ecological value of forests is conventional tourism.

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. Increased investment is welcomed by host country governments for its opportunity to stimulate rural economies while fostering national economic development (World Bank, 2011).

The major issue is the annual destruction of the natural forest for agricultural expansion. According to WBISPP (2004) 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 Kathleen and John (2011) 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.

For example, foreign investors work primarily with the Ethiopian Investment Authority in establishing their business operations, while government forestry specialists are housed in the Forestry Research Centre, a subdivision of the Ministry of Agriculture.

Forestry is marginalized by the current government as evidenced by budgetary allocations. In 2010, these amounted to approximately 6 million Ethiopian birr (₹226,110) to the Forestry Research Centre, as compared to the 90 million Ethiopian birr (₹3,391,792) allocated to Agriculture. This difference may be attributed to the political importance of agriculture (ibid).

Scaling up awareness of local community is important. To give full right and free access, decide on their environmental issue and to sustain it, So, the above and other critical issue evoke the interest of Local and international NGOs like NTFP, MELCA, JICA and others to participate in forestry sector, to apply what they call it “sustainable forest management”

2.2.6. Sustainable Forest Management in Ethiopia

The definition of Sustainable forest Management (SFM), according to FAO (2010), “is the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems”.

SFM has a growing international consensus. As a result, seven thematic areas of interest have been developed. They are on; 1) extent of forest resources, 2) biological diversity, 3) forest health and vitality, 4) productive functions and forest resources, 5) protective functions of forest resources, 6) socio-economic functions, and 7) legal, policy and institutional framework. They effectively provide a common, implicit definition of SFM (Patosaari, 2004).

SFM was recognized by the parties to the Convention on Biological Diversity (CBD) in 2004 to be a concrete means of applying the ecosystem approach. The CBD ecosystem approach is defined as “is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way”.

An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompasses the essential structures, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems (FAO, 2005).

Based on lessons learnt elsewhere, PFM was introduced to Ethiopia by some NGOs and donor agencies, notably FARM Africa, SOS Sahel, GTZ and JICA. These non-State actors attempted to respond to the prevailing forest management problems in Ethiopia through the introduction, adaptation and establishment of PFM projects (T.Gobeze, *et al.*, 2009).

Participatory Forest Managements (PFM) in Ethiopia was introduced as one of the solutions to solve the problem of open access to forest resources and promote sustainable forest management in the country through community participation. Some experiences from around the world show that shifts from state-centered policies toward solutions at the local level, So, the research result of Tibebu G. *et.al*, (2009) and Yonas M. *et. al*, (2010) and International conference of PFM (2007) shows PFM resulted in successful forest conservation and development. As the name “participatory” indicates local community or Indigenous people must take leading role in forest resource conservation and management.

2.2.7. Forest Investment: Opportunities and Challenges

Improving the livelihoods of forest dependent people is mentioned as part of one of the four global objectives for forests in the non-legally binding instrument on all types of forests adopted by the UN general assembly in December 2007 (UN, 2008).

The World Commission on Forests and Sustainable Development (WCFSD, 1997) and the World Bank (2002) produced the first global estimate of the number of forest-dependent people, suggesting that 350 million people depend almost entirely on forests for subsistence and a further 1 billion on woodlands and trees for their essential fuel wood, food and fodder needs.

According to Chao (2012) the most recent review of all of these estimates (suggests that the number of forest-dependent people is in the range of 1.2–1.4 billion people or just fewer than 20 percent of the global population.

Forest resource plays an important role in global carbon balance, as both carbon sources and sinks. According to Moges Y. *et al.* (2010) they have the potential to form an important component in effort to combat global climate change, but when forests transformed in to agriculture, subsequent land use system implemented determine the amount of potential carbon restocking takes place.

It is important to recognize that for developing countries with relatively large areas of natural forest, the question is not how to safeguard remaining forests, but rather how to ensure concrete benefits from forest conversion (that justify its costs).

And from the perspective of a government planner, environmental cost may not even be considered. However, the Ethiopian government expressed renewed interest in attracting foreign investment to the nation's forestry sector through its Forest Development, Conservation and Utilization Proclamation (Proclamation No. 542/2007).

Limited capacity to manage administrative and regulatory elements of foreign investments, pervasive tenure uncertainty and rural livelihood insecurity all point to the need for caution as the government proceeds with land deals involving forests (Kathleen Guillozet and John C. Bliss, 2011). Even if, Ethiopia a rapidly growing country in Africa, couldn't have much amount of land covered by natural forests to attract foreign investors to participate in conversion of forest to other land use system, Because of the existence of fertile ground in agricultural sector for investment, they want to intensively participate agricultural sector rather than supporting forestry.

Formally recognized private foreign investment in Ethiopia's forestry sector, defined here as activities involving afforestation, reforestation, and non-timber forest product market development, is currently limited. Concerns about feasibility, human resources, security of long-term lease arrangements and perceptions of political instability are commonly raised by foreign investors (ibid).

The above combined challenges create hostile environment to participate in forest investment, which favors illegal conversion of forested lands to agriculture by government actors, large-scale investors and rural people, threatening the livelihoods of households living at the forest-farm interface and limiting future afforestation and reforestation possibilities.

2.8. Remote Sensing and GIS

2.8.1. 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. (Lillesand, 2004) 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.

2.8.2. Geographic Information System (GIS)

Different authors defined GIS from different perspectives. Burrough (1986) 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”. On the other hand, Eastman (2001), 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 (Burrough, 1986).

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.

2.9. Forest cover change Monitoring using Remote Sensing and GIS

The potential of remote sensing and GIS 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.

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. 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.

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.

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.

2.10. 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 (Singh, 1989). And according to Lillesand, (2004) 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.

Singh (1989) 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 (Chen, 2000).

Digital change detection is a difficult task to perform. An interpreter analyzing large-scale aerial photography will almost always produce more accurate results with a higher degree of precision (Edwards, 1990). Nevertheless, visual change detection is difficult to replicate because different interpreters produce different results.

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 (Chen, 2000). However, they can be broadly divided into: post classification and spectral change detection approaches (Singh, 1989).

2.11. 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 (Lunetta and Elvidge, 1999).

Chen (2000) 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 (Chen, 2000). This approach can produce a large number of erroneous change indications as an error on either data gives a false indication of change (Singh, 1989).

2.12. Spectral change detection approach

According to Chen (2000), 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 Singh (1989) 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 Normalised Difference Vegetation Index (NDVI), because vegetation differentially absorbs visible incident solar radiant and reflects much of the infrared (NIR), data on vegetation biophysical characteristics can be derived from visible and NIR and mid-infrared portions of the electromagnetic spectrum (EMS).

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 (Lunetta and Elvidge, 1999). In general, the advantage of spectral change detection techniques is that they are based on the detection of physical changes between image dates.

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.

2.13. Multi-Criteria Evaluation Techniques (MCE)

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.

According to Eastman (2001) Multi Criteria Evaluation (MCE) 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.

2.14. Pairwise Comparison Matrix

Before using Pairwise Comparison Matrix on Edrisi software, factor maps were converted from raster and shape file to Imagine, Edrisi grid and tiff format using Arc GIS 10 software, and then factor weights are calculated by comparing two factors at a time using a scale with values from 7 to 1/7 or from 9 to 1/9 introduced by Saaty (1980). A rating of 7 or 9 indicates that in relation to the column factor, the row factor is more important.

Table 1: Saaty Rating scale

Intensity of Importance	Definition	Explanation
1	Equally important	Two factors contribute equally to the objective
3	Somewhat more Important	Experience and judgment slightly favor one over the other
5	Much more Important	Experience and judgment strongly favor one over the other.
7	Very much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in Practice.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2,4,6 & 8	Intermediate values	When compromise is needed

Source: The basic principles of the AHP (analytical higherarcy process), developed from saaty (1980)

Basic, but very reasonable, assumption is that if attribute **A** is **absolutely more important** than attribute **B** and is rated at **9**, then **B** must be **absolutely less important** than **A** and is valued at **1/9**. These pairwise comparisons are carried out for all factors to be considered, usually not more than 7, and the matrix is completed.

The next step is the calculation of a list of the relative weights, importance, or value, of the factors, such as cost and operability, which are relevant to the problem in question (technically, this list is called an **eigenvector**). If, perhaps, cost is very much more important than operability, then, on a simple interpretation, the cheap equipment is called for though, as we shall see, matters are not so straightforward. (Ibid)

The final stage is to calculate a Consistency Ratio (CR) to measure how **consistent** the judgments have been relative to large samples of random judgments. If the CR is much in excess of **0.1** the judgments are untrustworthy because they are too close for comfort to randomness and the exercise is valueless or must be repeated. It is easy to make a minimum number of judgments after which the rest can be calculated to enforce a perhaps unrealistically perfect consistency. (Ibid)

2.3. Literature 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.

However, in Ethiopia, like most developing countries, reliable information on the vegetation resources such as their spatial coverage, distribution, changes over time (deforestation or re-growth), growing stock in the standing vegetation, regeneration and recruitment status and other essential information are lacking or difficult to get because it is scattered (Demel, T., 2010).

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. And also 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 (Chen, 2000). And according to Lunetta and Elvidge, (1999) 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 was susceptible for forest degradation.

CHAPTER THREE

3. Description of the Study Area and the Research Method

3.1. Description of the Study Area

3.1.1. Masha Woreda

3.1.1. 1. Location

Masha Woreda is located in Southern Nation, Nationalities and People's Regional State (SNNPRS), *Sheka* Zone. This woreda has 17 Kebeles and one chartered town called *Masha* and it is capital of *Sheka* Zone. This study gives emphasis on three kebeles of masha woreda. And those kebele lays UTM WGCs 1984 Zone 36N between 861,000MN - 873,000MN and 105,000 - 120,000ME. Altitudinally, those kebele lies between 1650-2205m. The woreda is bounded to the west by *Sele- Nonno* Woreda of Oromia region, to the south by *Diddo-Lallo* Woreda of Oromia region and to the north by *Andracha* Woreda of Sheka Zone and has a total land area of 763.73km². Out of this land area, 47% is covered by forest including bamboo thicket (NTFP, 2008).

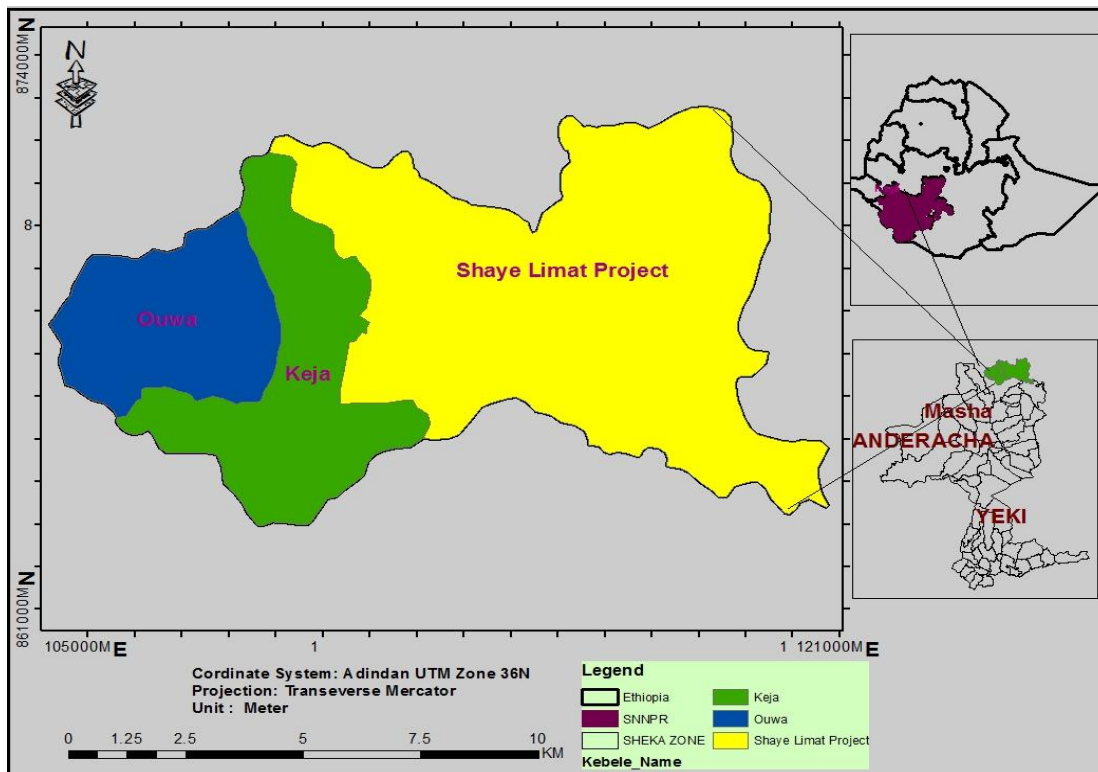


Fig.1: Map of Study area

Source: CSA (Central Statistical Authority)

Table 2, Distribution of population and density per square kilometer of Sheka Zone, 2011

Zone	Woreda	Area/sq.km	Population			D/Sq.km	%
Sheka Zone	Masha	763.73	M	F	Total	60.9	18.61
			22,929	23,566	46,495		
	Anderacha	1020.02	13,609	13,492	27,101	26.6	12.29
	Yeki	603.79	78,755	74,960	153,655	254.5	20.61
Total		2387.52	115,293	112,018	222,311	95.2	19.2

Source: CSA, 2011

3.1.1. 2. Topography

This Woreda lies between 1600-2400m above sea level and receives 2000mm rain fall annually. Agro climatically, the area is largely Woina dega type covering about 75% of the total area, 22% and 3% are in Dega and Kola zones respectively. The Woreda receives all the year round rainfall (MELCA, 2005).

There is large forest cover in the Woreda. The relief of the Woreda is a rugged terrain comprising hilly areas which impose their respective influence on agricultural practice and settlement patterns. The Woreda is drained by relatively bigger rivers in the Woreda like Meneshi, Wonani, Tatamayi and Gahamayi (SZCTGCD, 2008).

3.1.1. 3. Economic features

The majority of working population of Masha is Woredas engaged in Agriculture activities. Honey, enset, cereals such as maize, barley, teff, and beans, peas, and different kinds of spices are the major subsistence crops. Out of this land area about 23.9% is cultivated, 2.8% is grazing land, 40.5% is covered by forest, 5.5% arable land, 5.9% non-arable land and 21.4% is settled land area (NTFP, 2004).

Survey conducted in the area revealed that honey, enset, livestock, annual crops, sugarcane, liana, chat and gesho, cardamom, wild coffee, palm, banana and 'timiz' in descending order of importance were the major means of subsistence (ibid).

The area is also known for its significant meat and milk products from the domestic animals like goat, sheep, cow and others. In addition to agricultural activities, there are also transactions among rural dwellers in small Kebele markets in which people buy and sell products like coffee

and honey. The center of this Woreda is Masha town; it serves as a large market place, and seat of governmental institutions like Zonal administration and nongovernmental organizations like micro enterprises, MELKA Ethiopia Masha branch, NTFP, private clinics, hotels and the like.

Even though the inhabitants of this Woreda are economically self-sufficient, the infrastructural development is very poor. There is no electric supply except in the Woreda capital, telephone stations, health centers, pure water supply and other basic infrastructures. There is no high school in all the 18 Kebeles except one high school at Masha town and Yina kebele serving all the students of the Woreda.

There are 3 health centers dispersed among the Woreda to serve all the population of the Woreda. In addition, they are ill equipped and man power deficient health posts in all Kebeles.

3.1.1. 4. Demographic features

Masha Woreda has 19 Kebeles located around the capital Masha town. According to CSA (2011) Woreda has a total population of 46,495 (20.9% of zonal population): out of which 22,929 (51.8%) are males and the rest are females (see table, 2). This woreda has 37,840 (81%) and 8,655 (19%) of rural and urban population respectively. There is no any study done so far but it is believed that the majority of the inhabitants in the Woreda are indigenous residents of the area; i.e. the Shekacho people speaking Shekinnono. Keja,Uwa & Chewaqa-utto kebele (Shay limat project) have population of 1,902, 1,441 and 1,400 respectively (4,743 in total) (SZFEDD, 2010).

3.1.1. 5. Conservation of Biodiversity in Sheka

The area is rich in plant and animal species. There are over 300 higher plants, 50 mammals, 200 birds, and 20 amphibian species, inhabit in Sheka forest. There are also many endemic species, at least 55 plants, and 10 birds (Masresha, 2011). Altogether, there are over 65 endemic species of plants and birds. There are also over 38 threatened species (IUCN Red list) in the area, which include 5 bird, 3 mammals and 30 plant species. The number of threatened species is likely to be higher when the status of other species is determined (Ibid).

3.1.1. 6. Deep-rooted culture of nature conservation

The people of Shaka have deep-rooted culture of conserving species, ecosystems and natural habitats. In a recent eco mapping exercise by the community and MELCA-Ethiopia, around 209 sacred sites, 67 waterfalls, 74 mineral water springs, 13 historical sites, 17 cultural huts, 37 historical caves, 417 community kobo forests and 8 burial places were recorded, All these are considered as community conserved areas (MELCA, 2005).

Ecologically fragile areas like wetlands, lakes, rivers and steep slope areas are culturally protected from human disturbance. Forests and other natural landscapes have special cultural values among the people. Forest landscapes at lower altitude along the Baro River which found near behind study area are known as ***Kobo forests*** which support local community through honey production. Besides, they have culturally protected for malaria control.

The local communities believe that deforestation of these forests and settlement leads to malaria outbreak. Forests on steep slopes and hills in human-dominated areas, buffer areas of rivers and wetlands etc. are also protected as sacred forests called ***Guddo*** (Zewdie, 2007).

In Shekacho culture and belief system, steep slopes, water bodies and wetlands should not be touched or settled; they consider it as their naked eye and always be covered by forests or buffer areas of forest. Such areas are also places for worship.

3.2. Methods and Materials

3.2.1. Materials

3.2.1. 1. Satellite Imageries and Ancillary Data

Satellite imageries and ancillary data were collected in order to identify successive forest cover changes. The image data that was used for this study are **Landsat MSS & ETM+, Topographic maps** at the scale of 1:50,000 were 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 **Eridas Imagine** 2011 of raster tool using Interferometry tool box, which was 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 10.1 software. **GPS** recorder was also most important tool for ground assessment, or to make ground verification.

The majority of primary data necessary for the study has been extracted from satellite images. Forest cover types at various times have been extracted from Landsat MSS (1973), ETM+ (1987) and MSS (2015) images. Altitude and slope have been generated from DEM (Digital Elevation Model) 30m resolution data. Topographic maps of 1: 50,000 scales were obtained from Ethiopian mapping agency (EMA) and River and various road category networks were generated from topographic maps through manual digitizing and geo-referenced according to WGS 1984 UTM ZONE 36N.

Table 4, List of Data sources and Material

I. Satellite Data					
	Sensor	Path	Row	Spatial resolution	Date of accusation
Landsat 1	MSS	183	55	60x60 resolution(resampled to 30x30)	11,January 1973
Landsat 5	ETM+	170	55	30x30 resolution	01,February 1987
Landsat 7	MSS	170	55	30x30 resolution	14,February 2015
II. GIS Data					
Central statistical authority data was used to generate <i>Keja,Uwa and Chewaqa_utto</i> boundary					
DEM data was generated from SRTM image downloaded from global land cover facility					
Road and river are digitized from 1:50,000 topographic map (EMA)					
III, Software Used					
✓ ERDAS Imagine 2011(version 11): used for Resampling, and Image analyses. ✓ ArcView3.3 and ArcGIS 10.1: used for GIS analysis and mapping. ✓ EDRISI 2 version for pair wise comparison ✓ Other soft-were used in this research include Microsoft Internet, word, Excel and power point. ✓ During field work Global Positioning System (GPS) receiver and Digital Camera were used to collect field data.					

3.2.1.2. Criteria for Spatio-Temporal Identification (Site and Year selection)

As discussed broadly in introduction and problem identification part, currently, as many as 43 investors are investing in *Sheka* zone directly or indirectly on forest related priority areas (Zewude, 2005). So, from all monoculture tea plantation had severe impact on clearing of forest in *Sheka* zone, because, tea plantation in nature needs clearance of all plant species from the area and this investment is found in Keja, Uwa and Chewaqa kebeles (Shay limat Project).

The year 1973 is considered as demarcation for the capturing of satellite image, because, it was the year when the first satellite captured images of earth resources.

The year 1987 was chosen because of the expansion new road and rural settlements in the study area. Year 2015 was chosen because the researcher was able to find updated information about current Land cover types and also the expansion of tea plantation to its maximum extent (about 70%) (SZARDD, 2014)

3.2.2. Methods

The procedure followed in this study is presented using the flow chart (Figure 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.

Research Flow Chart

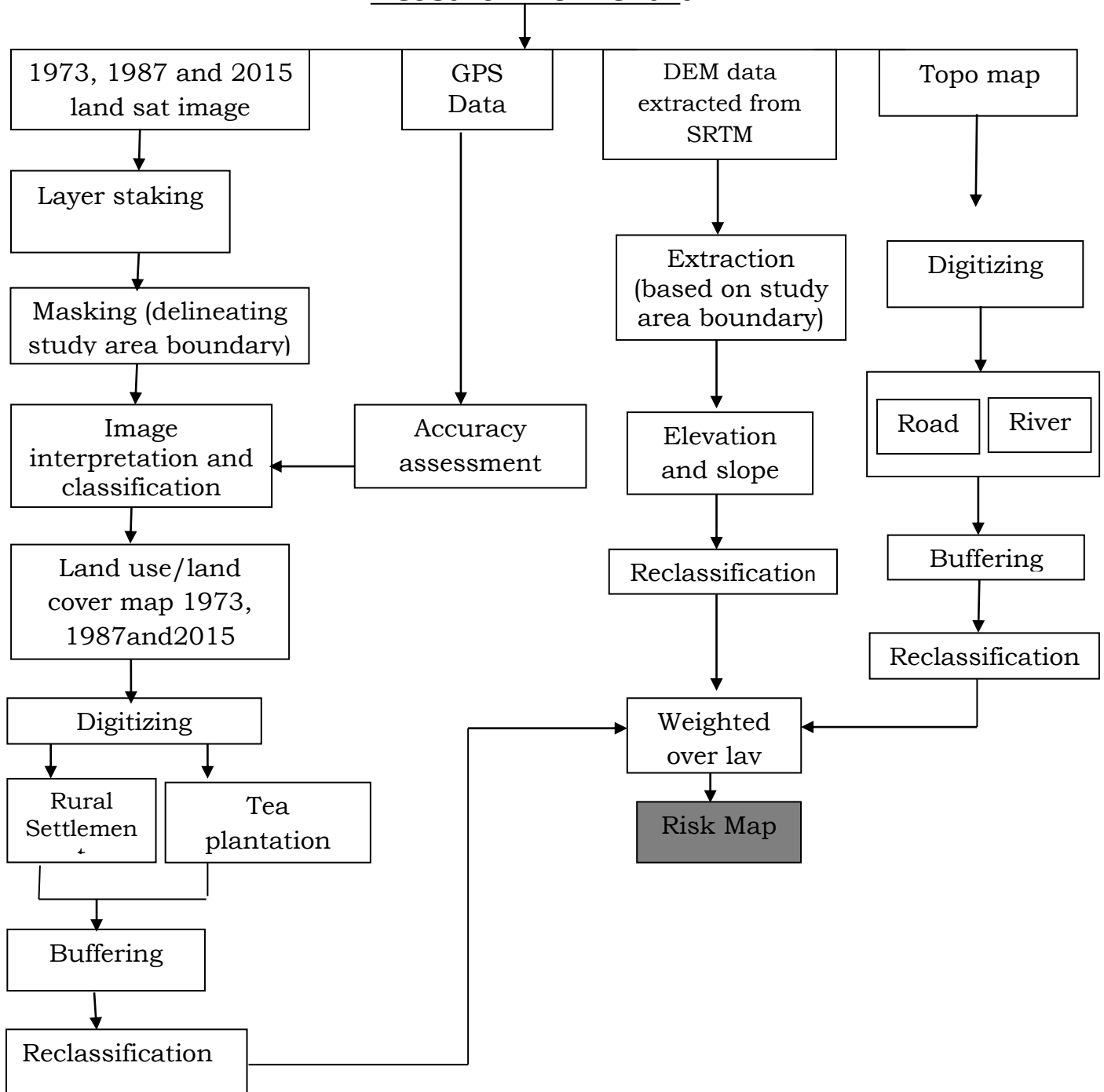


Figure 2: Research flow chart

The above figure (fig 2) clearly indicates research flow chart start from data extraction up to weighted overlay analysis and making of risk map. Landsat images of 1973, 1987 and 2015 were downloaded from global land cover facility in tiff format and bands are stacked together to form image which is compatible for Erdas imagine and Arc GIS software. Second, all images were masked (delineated) based on study area boundary then radiometric and geometric correction methods were applied to make suitable for further analysis. Third, land cover classification method was applied and based on classification result ground verification was done. Fourth, after accuracy assessment important land use land cover categories (factor maps) were digitized for weighted overlay purpose and those land use land cover types were (tea plantation and rural settlement) buffed and reclassified based on its proximity to dense forest. Fifth, elevation and slope were generated from DEM (digital elevation model) which were converted from STRM and reclassified according its effect on forest cover change, but the relative effect of both factor maps are more or less similar, so, elevation datasets was used for this analysis. Sixth, roads and rivers were digitized from topo-maps, geo-refernced, buffered and reclassified based on its proximity to dense forest. Finally, based on the above five reclassified factor data sets risk map of the study area was indicated by giving relative weight using AHP method. Then, Edrisi2 software was applied to obtain weights for each factor maps. And based on weighted over lay method risk map of the study area was made.

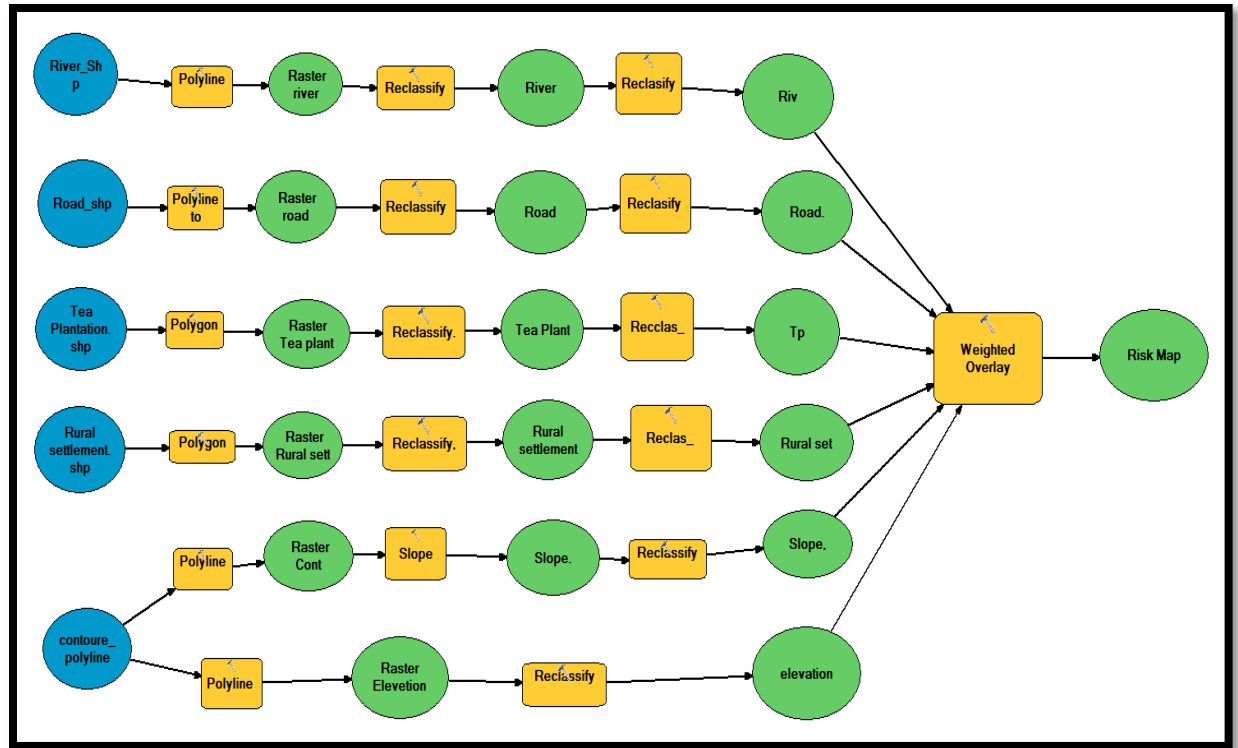


Fig 3: Model builder dialog box for forest cover Risk map

The above model builder figure (fig 3) shows the overall weighted overlay process start from extraction of necessary factor map up to final result showing forest areas which was susceptible for risk. Primarily, six shape files are extracted from various data sources and converted in to raster format. Secondly, river, road, tea plantation and rural settlement were buffered depend on its proximity to dense forest and all datasets including elevation and slope were reclassified, but during analysis only elevation data sets were considered for weighted overlay analysis purpose because both have relatively similar influence for forest cover change of the study area. The above all process was done in Arc GIS software model builder interface.

3.2.2.1. Pre-field work stage

3.2.2.1.1. Satellite image processing

3.2.2.1.1.1. Image selection

Image selection was one of the most difficult processes as the Masha areas have considerable cloud coverage with a whole year round rainfall. Two sets of cloud free images were selected that is for January and February 1973, 1987 and 2015 used in this analysis. This was used for generation of land cover data for selected kebeles in study area.

However, all images from 1973–2015 were used to extract data for the sensitive areas around the **Keja, Uwa and Chewaqa_Utto (*Shay limat*)** kebele which are highly affected by forest cover change induced by investment and other human related factors. And Successive land cover change processes had been identified accordingly.

3.2.2.1.1.2. Geo referencing, Enhancement of Image and Resampling

Comparing images of different periods requires a series of image enhancement activities and needs increasing its quality through image enhancement (Lillesand et al. 2004). All images were individually geocoded and geo referenced. Surprisingly, satellite images downloaded from global land cover facility was orthorectified (geo-referenced). Sufficient radiometric equalization was performed in order to minimize misidentification problems during signature generation for older images. Since, 1973 Landsat image had 60x60 resolutions; resampling process was performed using Data management tools in arc GIS software. So, it becomes equal resolution with the other two.

As well as EMA's topographic maps was used as inputs to extract shapfiles like, road & rivers. The True color composite and false color composites of the MSS 2015 images were subset by the study area boundary and were provided in Figure 4 and 5 respectively for evidence.

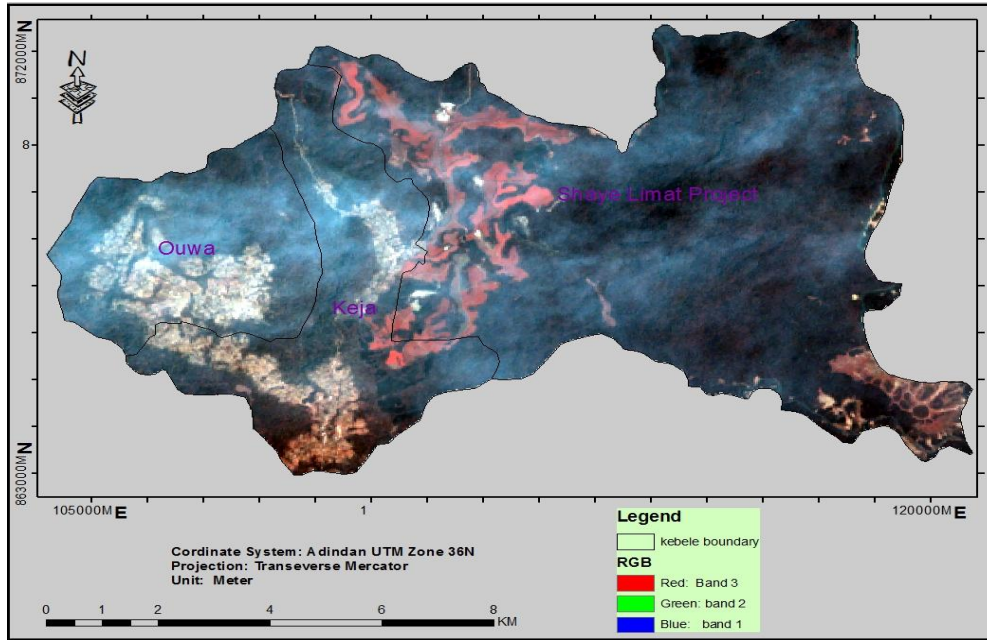


Fig 4: True color composite of MSS 2015 Image

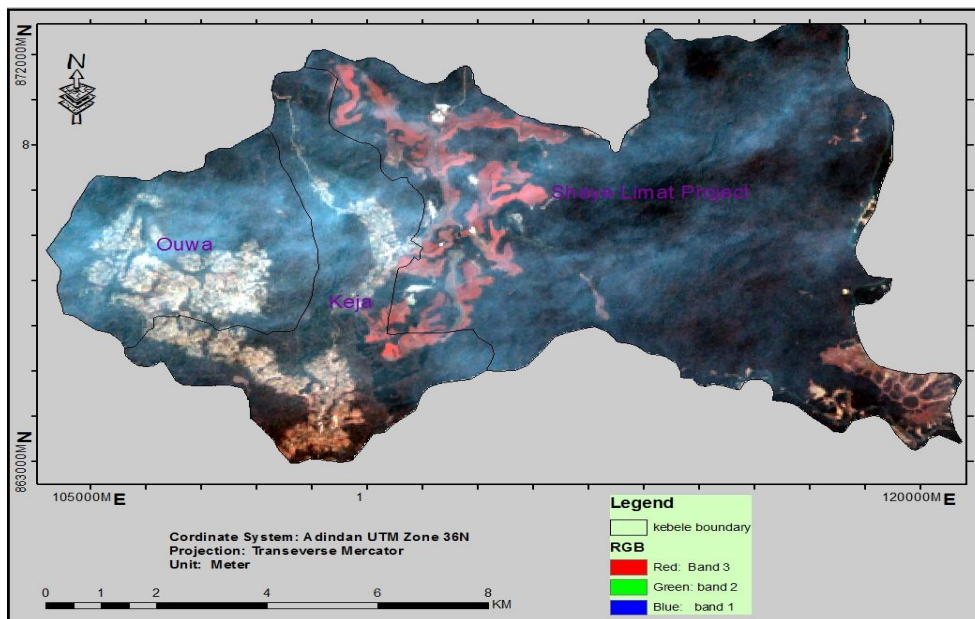


Fig 5: False color composite MSS 2015 Image

3.2.2.1.1.3. Classification and Reclassification of the image

As stated above, orthorectified (geo-referenced) satellite data was downloaded from global land cover facility in tiff format (compatible with Eridas imagine software). Then bands were stacked together. So, the area of interest was masked on shape files of study area boundary. Then, these masked images were ready for both unsupervised and supervised classification. Supervised

classification employs the Maximum Likelihood algorithm. Supervised training requires prior (already known) information about data, so we rely on our pattern recognition skill a prior knowledge of data to help the system determine the statistical criteria (signature). The algorithm clusters together land cover classes based on the field observation data. The classification process was designed in such a way that four land cover classes were identified which best fit with the objective of this study. The spatial extents and locations of these classes only cover the Masha Woreda *Keja*, *Uwa* and *Chewaqa_utto* (Shay limat) kebeles.

3.2.2.2. Data Collection

3.2.2.2.1. Primary Data

3.2.2.2. 1.1. Ground Truth/Field Visit

Field visit was carried out to get an overview of the study area, identify various forest cover types and to record GPS readings concerning various features and forest cover types. It was undertaken to verify the various land-cover types identified through satellite image manipulation and by observing exactly available land cover type in the study area and GPS recording on important forest cover boundaries of the study area.

These data are used for designing the final image classification, verifying sample sites and for land cover map validation. At sampling site more than 90 reference points were randomly identified during March 18-30/ 2015 using Garmin76 GPS receiver. In addition, photographs were taken from tea plantation site, settlement around tea plantation, dense forest areas around waterfall and other essential information were generated, which helped to support in the identification and quantifying of forest cover change and also for map making.

Field observation sheet (Appendix I) is designed for storing all information gathered during field survey, i.e., land cover types. These data have been used for designing final image classification and testing sample sites, which are used for land cover map **validation**. This research mainly applies NDVI and Post Classification Comparison using Change detection techniques and on its accuracy assessment in tabulating error matrix.

3.2.2.2. 1.2. **Secondary data**

Secondary data were collected from various published and unpublished sources. Background information of the study area was obtained from previous research works in the study area and annual reports of various departments of **Sheka** zone. Digital maps of kebele, Zone, regional state and Ethiopia boundaries were extracted from CSA, and other sources such as: documents, journals and books were used for this study.

3.2.2.2.2. **Post field work stage**

Based on the final training sample sites, which were generated during field work stage, all the available images were classified into four land-use/cover types by applying supervised classification method and maximum likelihood algorithm with the support of ERDAS Imagine 11.1 software.

To this effect, the year 2015 land-use/land cover classification result was evaluated by employing accuracy assessment technique using ERDAS IMAGIN 11.1 software to investigate how the result reflects the reality on the ground.

Likewise, the years 1973, 1987 and 2015 forest cover maps were also extracted independently from each land use land cover maps. In addition, on the bases of the years 1973, 1987 and 2015 multi-temporal Landsat image data, forest cover change detection analysis were carried out using Post classification change detection comparison and NDVI methods.

Based on 2015 forest cover condition Multi Criteria Evaluation (MCE) analysis was carried out to produce human disturbance risk map. GIS software such as IDRISI Andes and ArcGIS 10.1 using Weighted Overlay in Spatial Analyst tools were used.

3.2.2.2.3. **Creating Geodatabase**

The above mentioned GIS activities produced a series of spatial data. Other data are also organized from field observation and literatures. These tables (See all tables in Chapter 4) needed to be linked with maps in order to observe them in spatio-temporal dimension. Geodatabase was constructed that facilitated analysis, final mapping and proper legend creation. A series of table and maps were finally generated and clearly matched with the results observed on ground.

CHAPTER FOUR

4. Data Analysis, Result and Discussion

4.1. Data Analysis

4.1.1. 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.

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.

4.1.1.1. Unsupervised Image Classification

During unsupervised image classification methods, land cover types were identified. In this study the forest cover and tea plantations played a much more important role than other types of land cover found in the study area. Based on the characteristics of Landsat satellite image of the year 2015, a number of land cover types were determined to run unsupervised classification, which aided the preliminary field visit.

In the year 2015 the major land cover types were classified as, dense forest, tea plantation, rural settlement and wetland. With the support of ERDAS Imagine 11.1 Software the map, of unsupervised Landsat 2015 image classification was produced (fig 6).

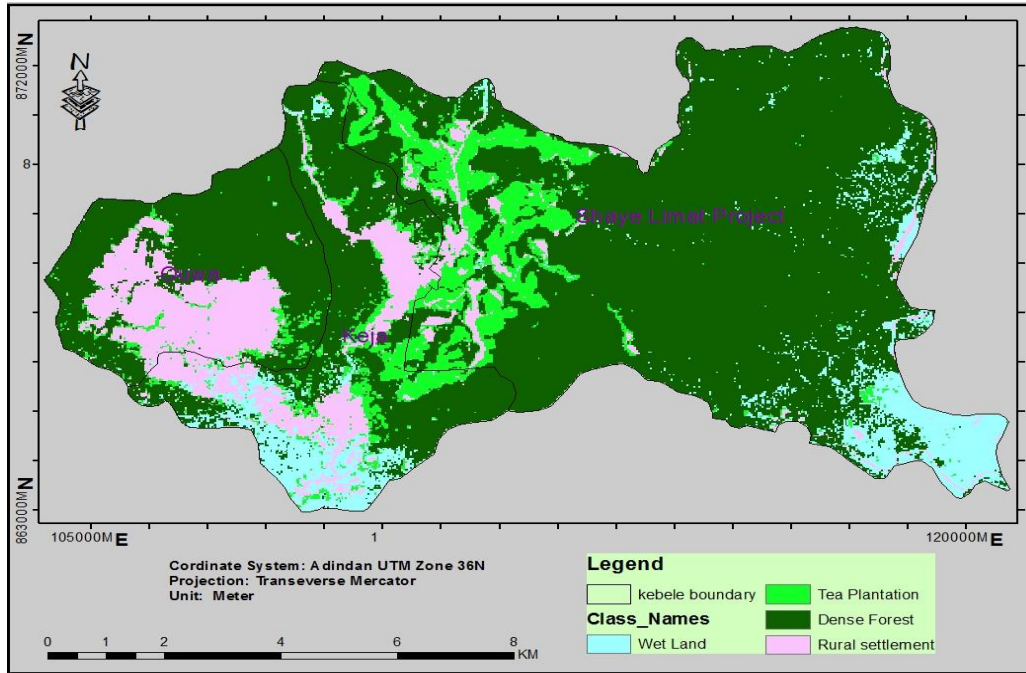


Fig 6: Unsupervised classification of 2015 image

4.1.1.2. Supervised Classification

During the field work various land cover classes were taken and recorded based on systematic sampling using GARMIN 76 GPS device. These samples were used as representative signatures for the various land cover types identified. The MSS 2015 satellite images were classified using the Maximum Likelihood supervised classification based on the sample training signature prepared from the GCPs collected for the MSS 2015 image.

For Landsat MSS 1973 and ETM+ 1987 images, visual observation of the False Color Composite Landsat image, True Color Composite Landsat image and the spectral information of the known land cover categories observed and compared with unsupervised classified Landsat MSS 2015 image (Figure 4). From unsupervised classified Landsat MSS 1973 & ETM+ 1987 image, four classes of land cover were identified as dense forest, moderately dense forest, rural settlement & wetland and for MSS 2015 Landsat image: Dense forest, rural settlement, wetland and tea plantation were produced which provide prior knowledge about land cover types in the past. (See fig 7)

4.1.1.3. Description of Land Covers Types

As there are some differences between the land classes in the historical land-cover maps of 1973, 1987 and 2015 and land-cover classes, which can be discriminated from the satellite image, recoding was needed to create a common classification for change detection purposes.

This section describes the land classes, which are only used for land-cover mapping from satellite images.

Dense Forest: This class represents the evergreen forest and montane forests. The general height of tree was from 18 – 40 m, and the crown coverage is over 60% (IFMP, 1999).

Moderately Dense forest: This class corresponds to forest, which are misused by human activities. It is composed predominantly of regeneration forest from the past disturbance such as, logging. The general heights of trees in this class range between 2m to 25m. The crown coverage was generally less than 60 % (IFMP, 1999).

Crown Coverage: The relative position of the trees or shrubs crown with respect to competing vegetation surrounding the tree or shrub and covers more than 0.5 hactar ([http://forestry\(fao\).about.com/library/glossary/blforglc.htm](http://forestry(fao).about.com/library/glossary/blforglc.htm))

Tea Plantation: a large farm where it found generally between settlement and forest land and also areas mainly tea plants are grown. (<http://www.macmillandictionary.com>)

Rural settlements: are those areas composed of intensive use with much of the land by rural villages, towns and roads. Or areas which are characterized by an artificial cover which replaces the original (semi-) natural cover (FAO, 1997).

Wet land: areas where saturation of land with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et al., 1979).

4.1.2. Accuracy Assessment of procured data

Fieldwork was conducted according with the schedule to collect ground information, gather necessary information through official view of the current land cover change. Sufficient numbers of randomly distributed sample plots was selected for ground observation. Available documents and maps that could shade light on historical dynamics of the *Sheka* Zone forest cover were collected. The error matrix and kappa method was used to assess the mapping accuracy.

The overall accuracy only considers the correction of **diagonal** elements in the matrix, while the kappa method takes the other element in the matrix into account, which can compensate the disadvantage of error matrix method.

Land cover maps derived from remote sensing always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture. In order to wisely use the land cover maps which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy.

Whether the output meets expected accuracy or not is usually determined by the users themselves depending on the types of applications and the map product. Accuracy levels that are acceptable for certain task may be unacceptable for others.

The common means of expressing accuracy of classification is the preparation of classification error matrixes. According to Congalton et, al (1999) an error matrix (confusion matrix) is a square array of numbers organized in rows and columns which express the number of sample units assigned to a particular category relative to the actual category as indicated by reference data. These tables produce many statistical measures of thematic accuracy including overall classification accuracy, percentage and the kappa coefficient, an index that estimates the influence of chance. Error of omission is the percentage of pixels that should have been put into a given class but were not. Error of commission indicates pixels that were placed in a given class when they actually belong to another.

These values are based on a sample of error checking pixels of known land cover that are compared to classifications on the map. Errors of commission and omission can also be expressed in terms of user's accuracy and producer's accuracy (ibid).

User's accuracy represents the probability that a given pixel will appear on the ground as it is classed, while producer's accuracy represents the percentage of a given class that is correctly identified on the map. One of the problems with the confusion matrix and the kappa coefficient is that it does not provide a spatial distribution of the errors (Foody, 2002).

The quality and sufficiency of reference data are important if reliable accuracy assessment is required. A reference data that is not verified thoroughly should not be expected to set accuracy

standard. Insufficient number of verified data also affects the quality of the assessment (Congalton et al., 1999).

In this study, an error matrix was generated based on the year 2015 forest cover classification and area of interest data (Table 5). The accuracy is essentially a measure of how many ground truth pixels were classified correctly.

The kappa value is a measure of the agreement between classification and reference data with the agreement due to chance removed. None of the kappa values in any of the images were very high. The ranked the kappa values, ranging from -1 to 1, into 3 groups: 1) those greater than 0.80 represented as strong agreement between the classification and reference data; 2) those between 0.40 and 0.80 represented as moderate agreement; and 3) those less than 0.40 represented as poor agreement (Landis and Koch, 1977).

The low kappa also was a product of classifying the imagery into just 2 classes. If there had been more classes, the kappa values probably would have been higher.

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. This implies that the Kappa value of 0.84 represents a probable 84% better accuracy than if the classification resulted from a random assignment.

The result obtained in this study fits to the view of (Sharifi, M. 2001) 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.

There were ambiguities in differentiating spectral signature of moderately dense forest from newly growing fresh crops, regrown forest near by rural settlement (open agricultural lands) and limited spatial coverage of study area.

So, because of the above reason moderately dense forests were not considered as land cover class for 2015 image classification. Areas found nearby dense forest and which have nearly equal reflectance value with dense forests were considered as dense forest, so that, areal coverage of moderately dense forests were compensated. The highest user accuracy from the vegetation classes were for rural settlement followed by Tea Plantation. The wet land showed relatively lower users accuracy (78%). The reason was that the spectral signature of wet land was mixing

largely with rural settlement areas (mainly agricultural lands) and dense forest has 80.6 % because signature of dense forest (mainly with moderately dense forest) mixed with newly growing tea plant. Rural settlement and dense forest were having a Producer accuracy of 88.0% and 86.2%.

In general, the overall accuracy of 82% was achieved with a Kappa coefficient of 0.84 (See table 5).

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

$$K = \frac{\sum (O_i - E_i)^2}{\sum (O_i + E_i)} \div 1 - \frac{\sum (O_i - E_i)^2}{\sum (O_i + E_i)} \dots \dots \dots \text{equation 1}$$

K= kappa coefficient

= Summation

r = relative

O_i = Observed value GPS value on the ground

E_i = Expected value during supervised classification

Table 5, Confusion matrix 2015

	Class Name	Supervised Classification				
		Rural settlement	Wet land	Dense forest	Tea Plantation	Row Total
Ground truth	Rural settlement	22	0	1	3	26
	Wet land	0	7	1	1	9
	Dense forest	2	1	25	3	31
	Tea Plantation	1	2	2	23	28
	Column Total	25	10	29	30	94
	Producer Accuracy	88.00%	70.00%	86.20%	76.60%	
	User Accuracy	84.60%	78.00%	80.60%	82.20%	
	Over all accuracy	82.00%				
	kappa coefficient	0.84				

Source: Computed from Erdas imagine software

NB: All the above values in row column represent number of GPS point collected during ground verification

4.1.3. Change Detection procedures

4.1.3.1. Post Classification

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.

Additionally, change detection matrix had been generated to investigate the trends and patterns of land cover change in general and forest cover change in particular.

The rate of forest cover change also computed using equation (2).

$r = \frac{Q2-Q1}{t} \text{ -----Equation (2)}$ $\text{or } r = \frac{q1*100+q2}{t} \text{ -----Equation (3)}$
--

Where, r = Rate of forest Cover Change

$Q2$ = Recent year forest cover in ha

$Q1$ = Initial Year forest cover in ha and

t = Interval year between Initial year and Recent year

100 = initial change in percent

For this study the researcher employs equation (2) because it clearly indicates the changes that occur within each land cover categories in respective with change observed in each year. It will tell the change in areal coverage. Spatial extent of all land cover types are identified and compared with each selected years. Then, Tables and maps for each year are computed based on the result of above formula (equation (2)).

From Land cover maps of the year 1973, 1987 and 2015, three date's polygons representing the forest areas were extracted. This was done by converting the classified forest areas raster data into vector and through masking layers which only represent dense forest (area of interest).

4.1.3.2. NDVI (Normalized Difference Vegetation Index) Comparison

As indicated earlier, spectral band ratio is one of the most common mathematical operations applied to multi-spectral data. Ratio images were calculated as the divisions of digital number values (0-255) in one spectral band by the corresponding pixel value in another band.

Based on the reflectance pattern of vegetation, different models of vegetation indices were developed to explain the healthiness, vegetation cover and biomass condition of vegetation.

Various mathematical combinations of the Landsat channel were used for various analyses; it is depend on the objective of the finding and the type of image available at hand. For instance, MSS image and ETM+ image band 4(NIR band) and3 (Red band) were used and for MSS image which have 5 or 7 band (band 5 and 7) were used. The research result of Norsuzila Ya'acob, et al. (2013) forward that those data calculated based on the above criteria were found to be sensitive indicators of the presence and healthiness of green vegetation.

Among these, NDVI is the most commonly used index for forest vegetation biomass monitoring. The absolute value of NDVI for vegetation change analysis is between 0 and 1.

The NDVI empirical analysis is accomplished using equation (4).

$NDVI = \frac{NIR(\text{band } n) - R(\text{band } n)}{NIR(\text{band } n) + R(\text{band } n)} \dots \dots \dots \text{Equation (4)}$ Where, <i>NIR</i>=Image of Near-Infra Red, <i>R</i>= Image of Red, <i>n</i>=type of band chosen for NDVI calculation, it is based on image type (ETM+ or MSS).
--

As to vegetation conditions, NDVI values vary from 0 to +1. Healthy vegetation yields high positive NDVI values because they have relatively high reflectance in NIR and low in visible wavelength. After conducting NDVI analysis, the mean and standard deviations values were summarized using ERDAS IMAGINE 11.1 software to evaluate the trends of vegetation cover change condition of the area.

4.2. Result

4.2.1. Land use/ Land Cover Map

Land use/land cover unit of the study area were categorized into four types; these are: Dense forest, moderately dense forest, rural settlement (area with predominantly agriculture) and Wet land for 1973 and 1987, and Dense Forest, Tea Plantation, Rural settlement and wet land for 2015. Because of existing ambiguity to differentiate pixels of moderately dense forest with tea plantation and rural settlement (with newly growing crops) no forest areas are categorized as moderately dense forest in 2015.

Rather during supervised classification and ground verification, areas found in center of dense forest and having nearly similar pixel values was categorized as dense forest. The forest in the study area has been divided into dense forest and moderately dense forest based on variation in tone and NDVI values. NDVI values of dense forests (-0.04 - 0.02) are greater than moderately dense forest (-0.05 - -0.04) (i.e. forests disturbed by human action for images of 1973 and 1987. See fig (13)

The intension was to separately identify the natural dense undisturbed forest with disturbed by human forest. Land use/land cover maps of the study area are presented in the figure 7, 8 and 9.

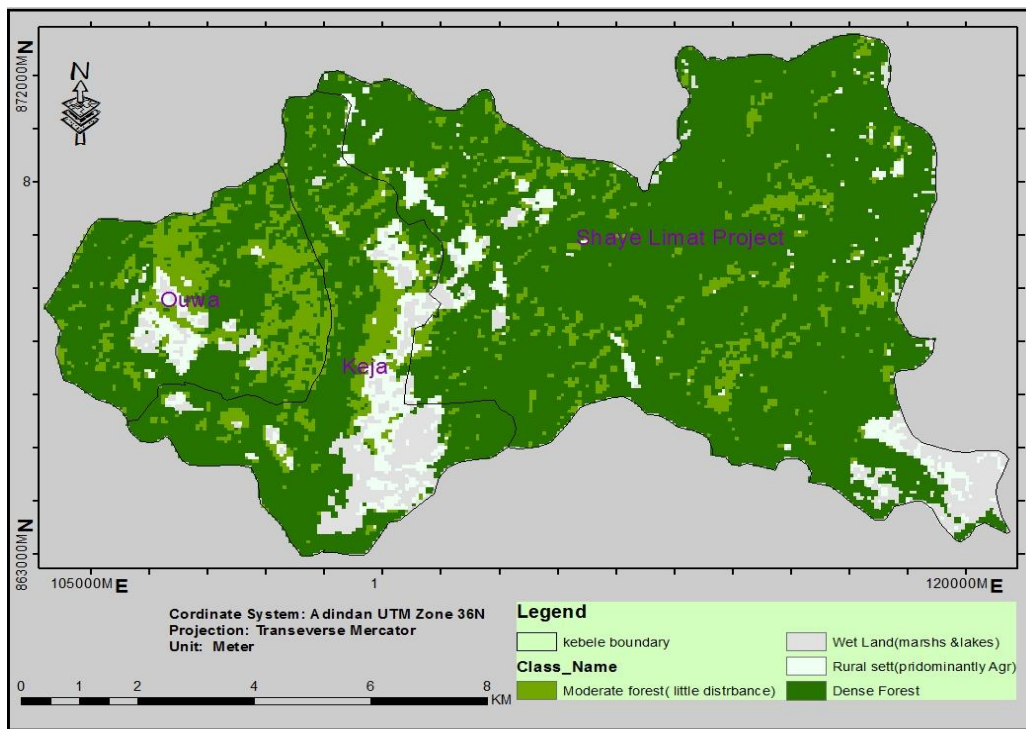


Fig 7: Land use Land cover Map of 1973

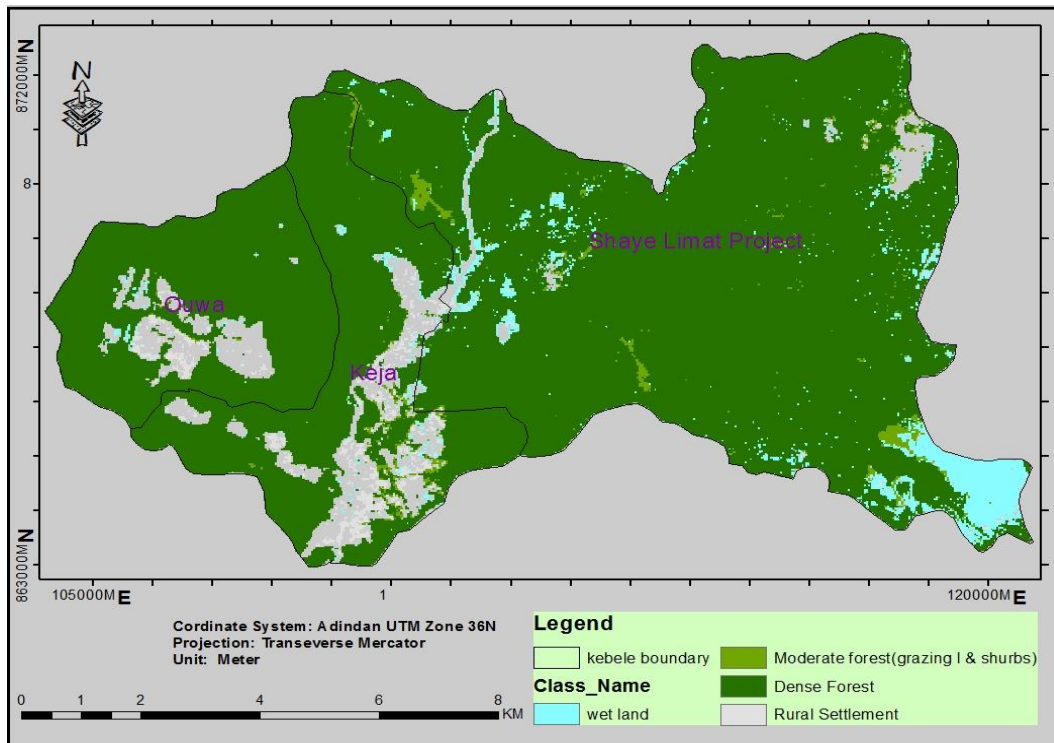


Fig 8: Land use Land cover Map of 1987

Source: CSA and <http://www.Land cover.org> provided by Colombia University

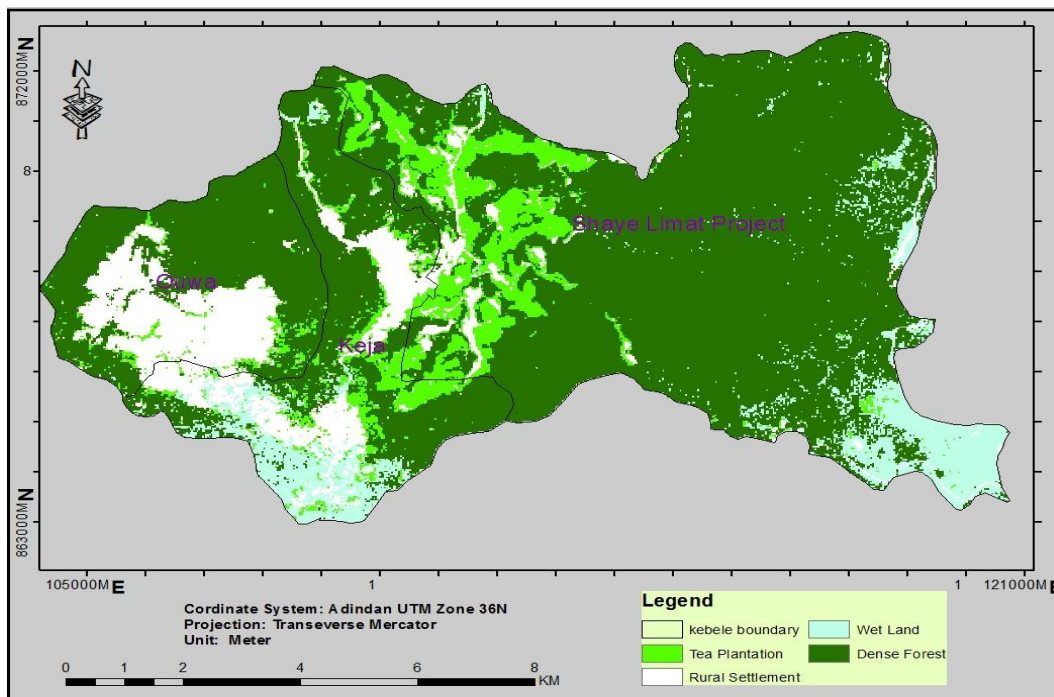


Fig. 9: Land use Land cover Map of 2015

Source: CSA and <http://www.Land cover.org> provided by Colombia University

4.2.2. Detection Result of land cover changes by different methods

4.2.2.1. Change between 1973 and 1987

The major Land cover changes observed during this period had been the reduction in the area of both categories of forests Dense and moderately dense, as well as Wet Land by 80, 67.3 and 28.8 ha respectively. A considerable increase in the overall areas of rural settlements by 175.9 ha has been registered.

Table 6: Land-use/land cover change matrix between 1973 and 1987

	Categories	1973(Initial)									
		Rural settlement		Wet land		Dense forest		Moderately dense forest		Total	
		Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
1987 (final)	Rural settlement	33.9	47.9	52.9	30.3	141	2.2	20	6.3	248	3.6
	Wet land	30	41.8	86	49.2	33.3	0.5	6	1.89	145.2	2.1
	Dense forest	5.4	7.54	20.5	11.7	6074	95.3	183	89.21	6292	92.2
	Moderately dense forest	2.8	2.76	15	8.6	124	2	8	2.6	149.7	2.1
	Total	72.1	100	174	100	6372	100	217	100	6835	100

Source: Computed Arc GIS software

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

4.2.2.2. Change between 1987 and 2015

This period shows decrease huge amount of dense forest than previous period. The major changes observed in this period were decrease in the overall area of dense forest from 6,303 ha in 1987 to 4,635.4 ha (by **1,667.4 ha**) in 2015 and an increase in the areas of the Tea Plantation from 0 ha in 1987 to 1,055.8 ha 2015 (by 1,055.8 ha) and increments on rural settlement from 248 ha in 1987 to 785.6 ha in 2015 (by 537.6 ha) (see table 7). Vast extent of land was transformed to Tea Plantation as a function of huge investment. And the area of tea plantation is expected to increase up to 2,914ha in coming five years (SZARDD, 2014)

Table 7: Land-use/land cover change matrix between 1987 and 2015

	Area (ha)	1987(Initial)/											
		Rural settlement		Wet land		Dense forest		Moderately dense forest		Tea Plantation		Total	
		Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
2015(final)	Rural settlement	94.7	38.7	0.2	0.13	690	11.4	0.7	0.4	0	0	785.6	11.47
	Wet land	24.9	10	46	34	254	0.9	33	16.8	0	0	75.8	5.03
	Dense forest	46.8	19.1	2.2	1.5	4486	74.7	100	50.8	0	0	4635.4	68.42
	Moderately forest	0	0	0	0	0	0	0	0	0	0	0	0
	Tea Plantation	80	32.2	87	64.4	875	13.3	63	32	0	0	1055.8	15.08
	Total	248	100	135	100	6303	100	197	100	0	0	6835	100

Source: Computed from Arc GIS software

4.2.2.3. Change between 1973 and 2015

While considering the whole range of time under consideration, the reduction in the area covered by both forest types (Dense and Moderately dense) were remarkable, despite the Tea Plantation expansion observed in the second time period due to high shift of both type of forest land to Tea Plantation and rural settlement.

Image differencing of the two extreme times, 1973 and 2015 indicated that dense forest cover reduced from 6,372 to 4,635 ha (1,737 ha) and vast decrement on moderately dense forest by 217.2 ha. There were Considerable increment on Tea Plantation and rural settlement by 1,055.8 ha and 785.6 ha respectively.

Table 8: Land-use/land cover change matrix between 1973 and 2015

	Area (ha)	1973(Initial)											
		Rural settlement		Wet land		Dense forest		Moderately dense forest		Tea Plantation		Total	
		Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
2015 (final)	Rural settlement	49	68.3	28.8	20.7	651	10.1	56.79	26.9	0	0	785.6	11.42
	Wet land	4	5.5	46.9	33.8	186.4	2.9	121	56.2	0	0	75.8	5.3
	Dense forest	8.8	11.2	38.5	27.9	4586	71.5	2	0.9	0	0	4635	67.88
	Moderately dense forest	0	0	0	0	0	0	0	0	0	0	0	0
	Tea Plantation	10.9	15	24.5	17.6	987.7	15.5	32.9	16	0	0	1055.8	15.4
	Total	72.7	100	138.7	100	6372	100	217.2	100	0	0	6835	100

Source: Computed from Arc GIS software

4.2.2. Detected changes by post classification

Land cover change analysis by post classification method revealed eleven types of changes in the two periods (Table 9). However, not all of the changes were taken into account, but, forest cover lands for this study are given a consideration. Changes from built up to Tea plantation and vice versa and from wet land to tea plantation and vice versa were not taken into consideration since they were not as such important effect on forest cover land change for this study. Eleven changes, which were analyzed and regrouped in to two land-cover change categories: namely, deforestation and natural forest regrowth.

Table 9: Land covers change detected by post classification techniques

No	Land cover change 1973 – 198	Numerical support in ha	Land cover change 1987-2015	Numerical support in ha	Regrouping
1	From dense forest to moderately dense forest	124	From dense forest to Moderately dense forest	0	Deforestation
2	From dense forest to Rural Settlement area	141	From dense forest to Rural settlement area	690	
3	-	-	From dense forest to tea Plantation	875	
4	From moderate forest to Rural settlement area	20	From moderately dense forest to Rural settlement area	0.7	
5	From Dense to wet land	33	From Dense forest to wet land	254	
6	-	-	From moderately dense forest to Tea Plantation	63	

7	From moderately dense forest to dense forest	183	From moderately dense forest to dense forest	100	Natural Forest regrowth
8	From wet land to Dense forest	20.5	From wet land to Dense forest	2.2	
9	From moderately dense forest to wet land	6	From moderately dense forest to wet land	33	
10	-	-	From Rural settlement to tea Plantation	-	Not considered
11	-	-	From wet land to tea plantation	-	

Source: computed from table 6, 7 & 8.

Table 10: Change Detected by post classification method

Changes	Period(1973-1987) in (ha)	Period(1987-2015) in ha	Total(ha)
Deforestation	318	1,882.7	2,200.7
Natural re-growth	209.5	135.2	344.7
Total	527.5	2,017.9	2,545.4

Source: computed from table 9

From the above table we can understand that vast amount of dense forests were deforested in second time span (1987-2015). From this change was induced by expansion of monoculture tea plantation (about 1,055 ha) from total of 1,882.7 ha took lion share. Whereas natural regrowth took about 209.5 from 1973-1987(14 year interval), but it declines by 74.3 (135.2) in a year 1987-2015 (within 28 year interval). When we minimize deforested from natural regrowth about 1,856 ha of forest is deforested and changed to other land uses.

4.2.3. Changes detected by NDVI differencing

NDVI image differencing cannot provide detailed change information particularly in the study area because there is no NDVI value difference for (the year 1973 & 1987). It can only give overall information about the healthiness of vegetation cover in the study area based on NDVI value. For this study both ETM+ (band 4 and band 3) and MSS Landsat 7(band 5 and 7) were used. The new version erdas imagine 11 automatically calculates based on formulas (equation 4). The negative threshold indicates loss in NDVI and positive threshold indicates area of increased NDVI (restoration or healthy vegetation). The following (Table 11) was generated from Erdas imagine software and it shows that there was minimum change of land cover in general in the three dates of image.

To this effect, the standard value of 2015 image decreased in certain amount, showing that there were decreases of green vegetation or vegetation disturbance. NDVI value of the year 1973 indicates only positive value (0 and 0.5) and poor qualities of image also have significant influence. So, almost all parts of the area were covered by healthy vegetation.

Table 11: NDVI analysis Statistics

Type	Year		
	1973	1987	2015
Minimum	0	0	-0.08
Maximum	0.52	0.61	0.03
Mean	0.46	0.5220	0.020
Median	0.49	0.5	0.025
Mode	0.52	0.6105	0.034
Standard deviation	2.5	2.1	1.63

Source: Computed from Erdas imagine software

From Table 11, it can be seen that the overall NDVI value (mean, median and mode) is not less than 0 which is acceptable for tropical afro-montane rain forest (Norsuzila Ya'acob, et al., 2013). In 1973, the mean, median and mode of the NDVI value are 0.46, 0.49 and 0.52 respectively. In 2013, all of the mean, median and mode value shows little bit increments because MSS image of 1973 have hazes which couldn't be solved during radiometric corrections. Whereas, 2015, all of the mean, median and mode value shows reductions 0.020, 0.025 and 0.034 respectively. So, the difference of statistic data for 1987 and 2015 images shows reduction of mean, median and mode with 0.502, 0.45 and 0.57 respectively. Based on the above statistics most part of study area was relatively disturbed when we compare with previous years.

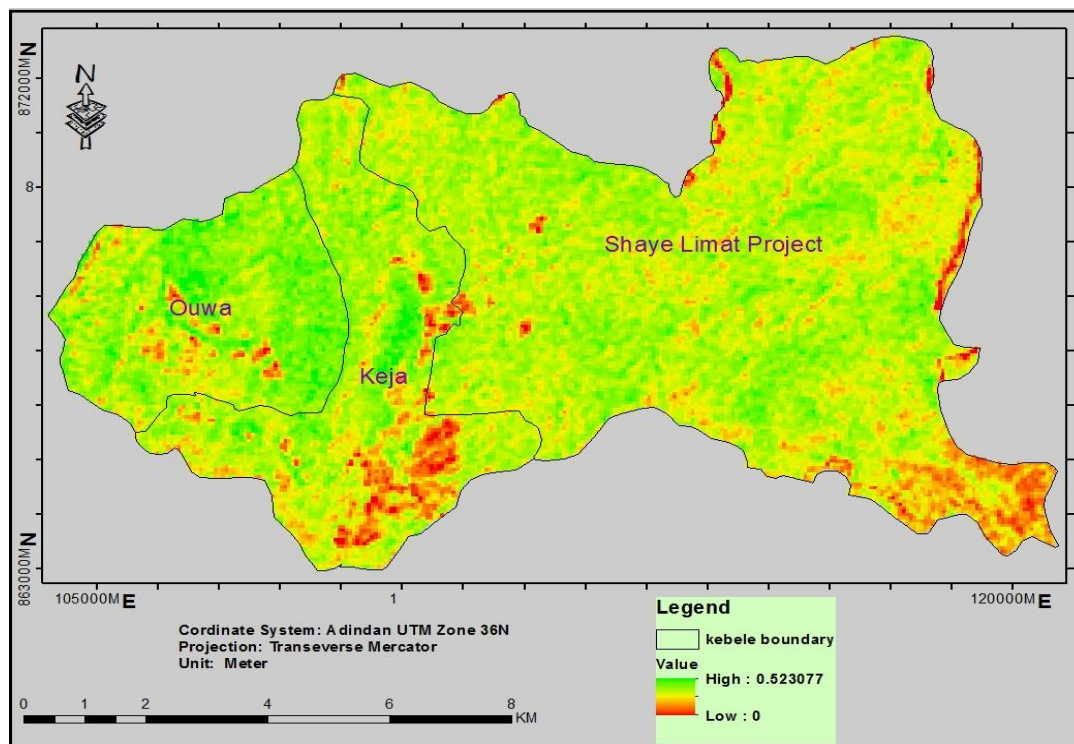


Fig 10: NDVI map of 1973

Source:

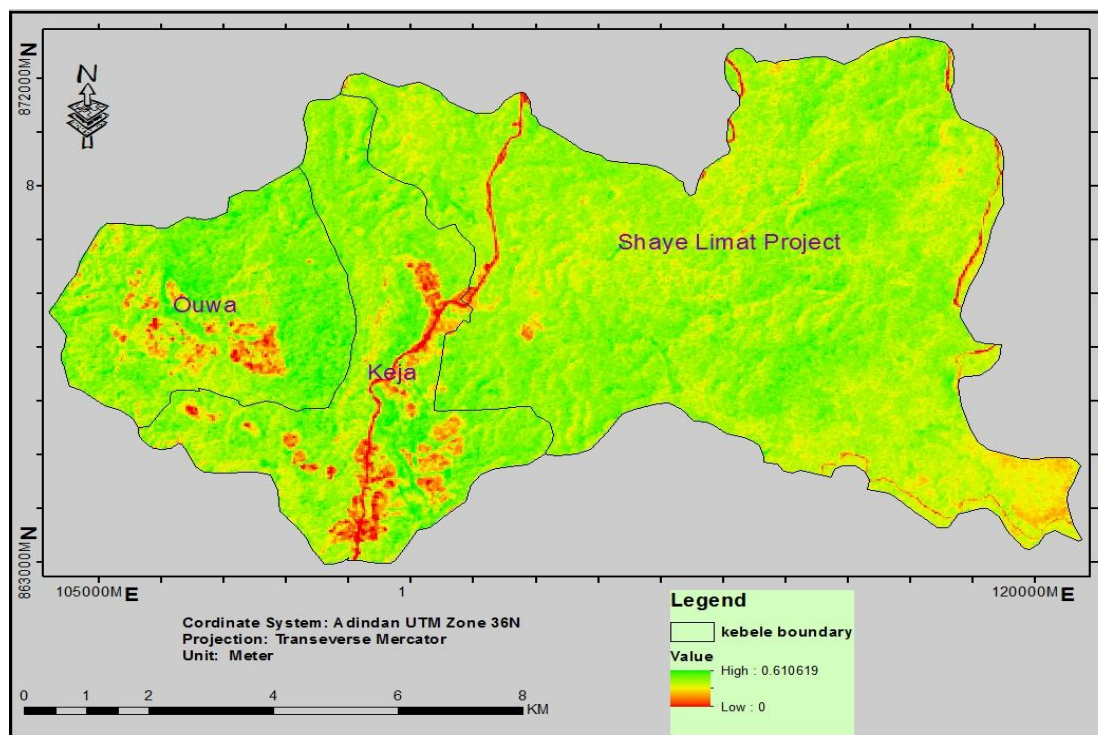


Fig 11: NDVI Map of 1987

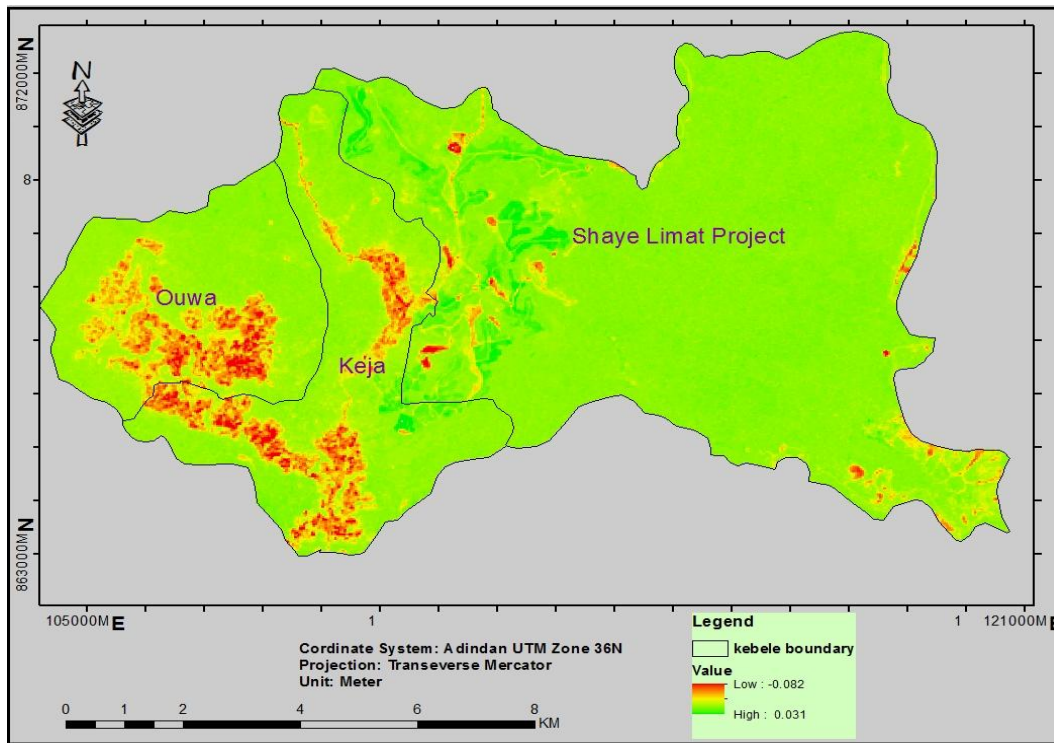


Fig 12: NDVI Map of 2015

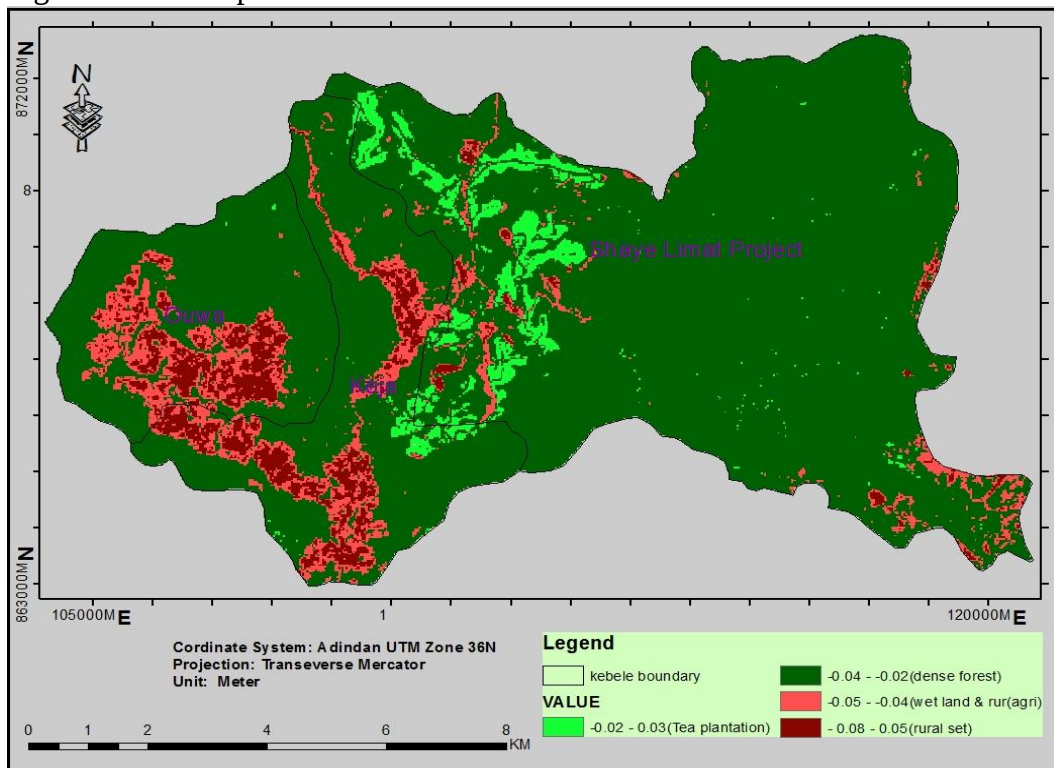


Fig. 13: NDVI map of 2015 image in classified form (including values of each feature on map)

Source: Fig 12

Fig 13 indicates that from all land cover types found in study area tea plantations have greater NDVI (high NIR (near infra-red value) which indicates high restoration followed by dense forest and negative value indicates degradation which approximately found in areas of rural settlement.

4.2.4. Forest cover analysis

In order to determine areas of the forest subjected to different changes were extracted from both types of forest categories (dense and moderately dense forest). Therefore, it requires the extraction of polygons representing the forest areas. On the other hand, reducing the data extent would speed up the subsequent process (for risk map). Accordingly, polygons representing the forest areas have been extracted. This was done by converting the classified forest areas raster data in to vector. Then, finally only layers representing forest was displayed in the following fig (14, 15 & 16) in raster form. The various data layers to be used in the subsequent analysis was therefore be extracted using these polygons.

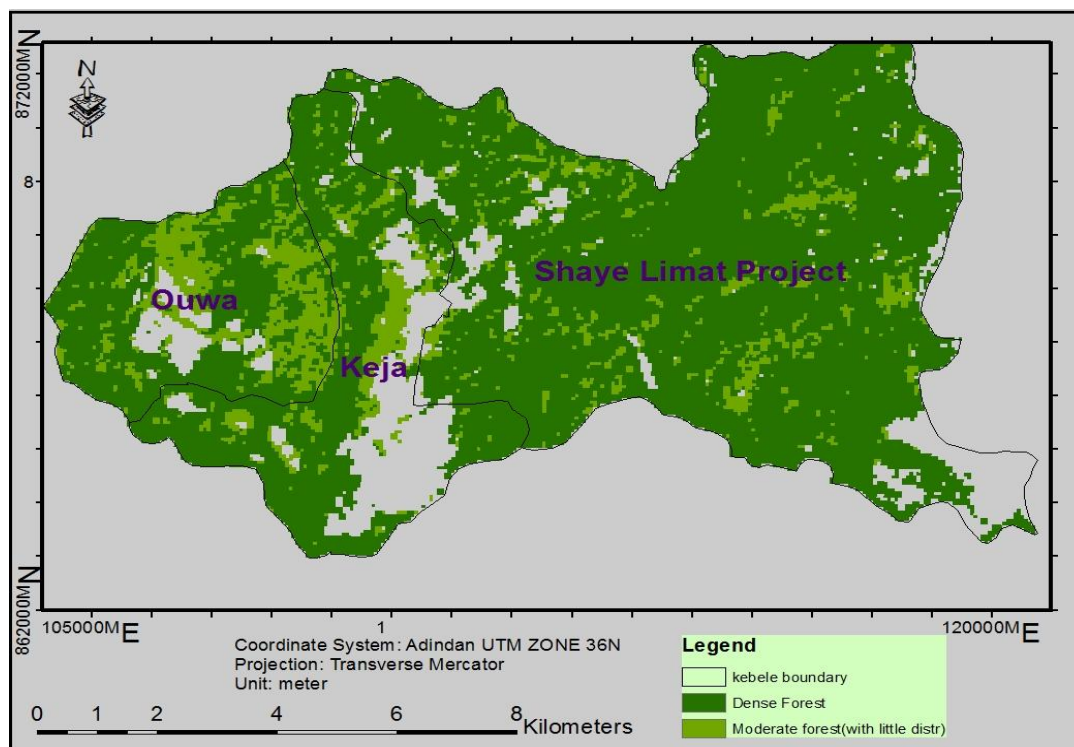


Fig 14: Masked Forest Cover Map of 1973

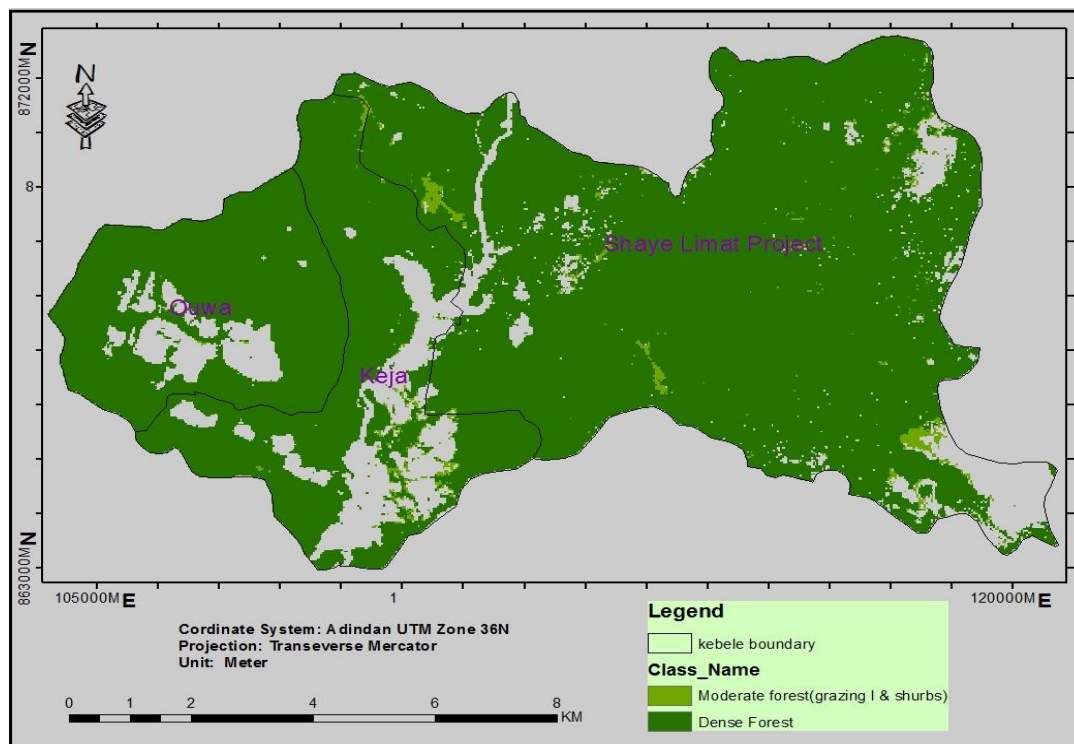


Fig 15: Masked Forest Cover Map of 1987

Source:

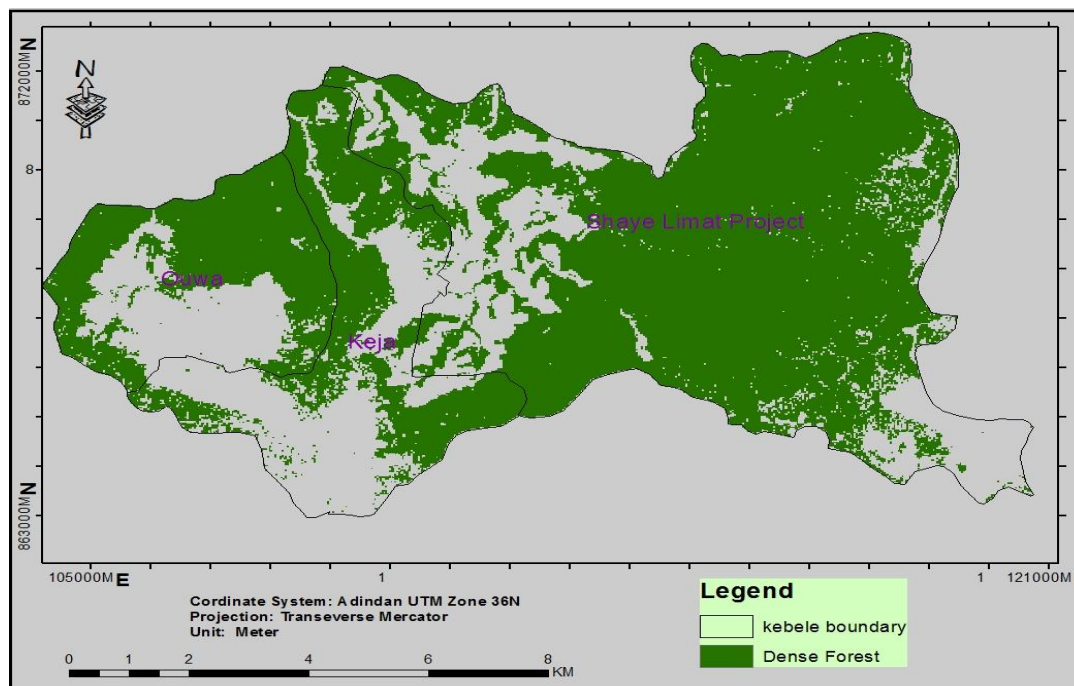


Fig 16: Masked Forest Cover Map of 2015

Source:

Table 12: Summary statistics of land-use/land cover units; 1973, 1987 and 2015

Class Name	Year					
	1973		1987		2015	
	Ha	%	Ha	%	Ha	%
Rural settlement	72.1	1.05	248	3.6	785.8	11.6
Wetland	174	2.55	145.4	2.1	75.8	1.2
Tea plantation	0	0	0	0	1,056	15.4
Dense forest	6,372	93.2	6,292.00	92.2	4,635	67.8
Moderate Forest	217	3.2	149.6	2.1	0	0
Total	6,835	100	6,835	100	6,835	100

Source: computed

4.2.5. Distribution and Rate of Forest Cover Change

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

Second, is that it highlights the seriousness of the forest cover change dynamics which strengthens the need for protected forest cover establishment by 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 with in time series. 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 the following tables.

Table 13: Total Forest Covers Land Area of Keja, Uwa and Chewaqa (Shay limat) kebeles 1973, 1987and 2015.

Year	Forest Cover unit from the total area (in ha)	Forest Cover In %
1973	6,372	93.2
1987	6,292.8	92.05
2015	4,635	67.8

Source: computed

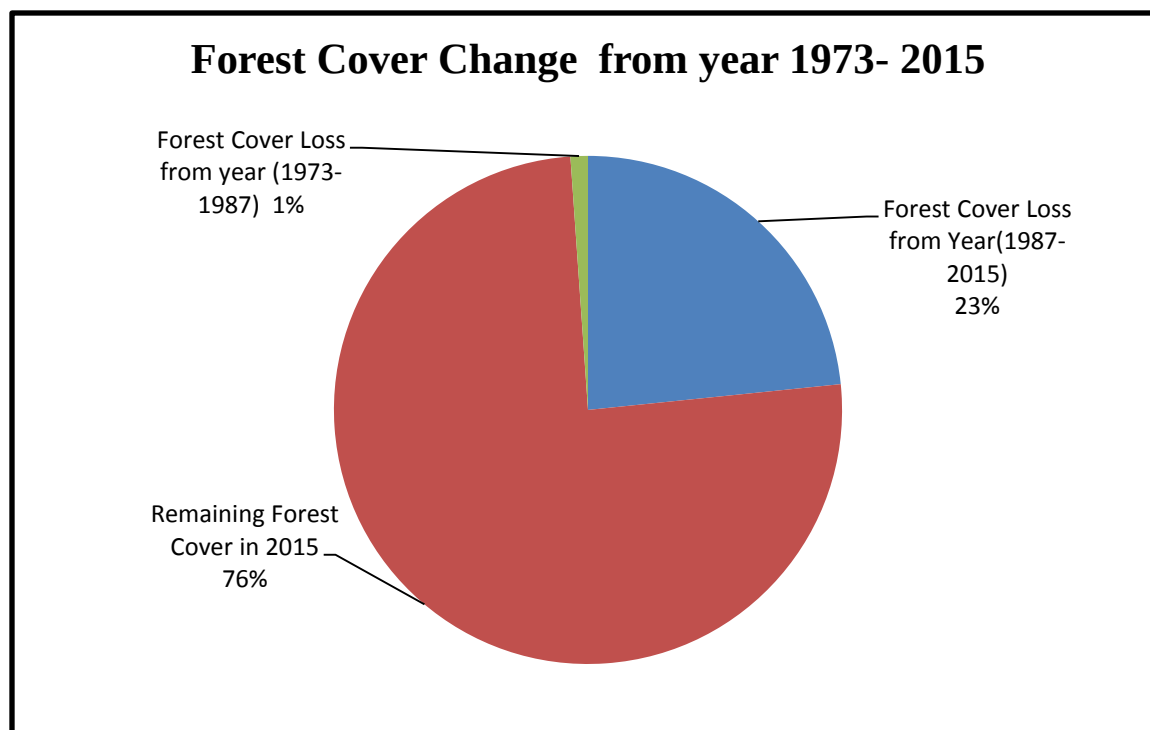


Fig 17: Pie chart of forest covers change.

Source: Table 13

From this result (table, 13) about 6,372 (93.2%) ha of the study area was covered with forest resources in the year 1973. Meanwhile, the forest cover land of the district was accounted for 6,292.8 ha (92.02%) and 4,635 ha (67.8) in the year 1987 and 2015 respectively. From 1973 up to 1987 only 1% from total forest area were deforested whereas from year (1987-2015) about 23% of total forest area were deforested and currently only 76% of dense forests were remaining (above fig 17).

The percentage share (relative to the total of study area) for each year forest cover value and with its trend (table 13) indicates that in the year 1973 and 1987 about 93.2 % and 92.05% of the study area was covered with forest resources respectively. According to the information obtained from woreda agricultural office construction of gravel road between Mettu-Gore (of Illuababora) and Masha-Teppi (of Sheka) in 1986 & 1987 was considered as the main reason for little bit reduction of dense forest in the study area. In 2015 only 76 % of the study area was covered by dense forest. The expansion of rural settlement and mono-culture tea plantation were inducing factor for the declination of dense forest in an alarming rate in the study area.

Table 14: Rate of forest cover change

Forest cover class	Year			Rates of change/ha/		Total/ha/
	1973	1987	2015	1973-1987	1987-2015	1973-2015
Forest cover & loss in ha	6,372	6,292.8	4,635	-79.2	-1,637.2	-1,716.4
Forest cover loss per year in	Ha			5.6	61.2	40.8

Source: computed

The above (table 14) forwards that in the first 14 years variation (1973-1987) about 79.2 ha of forest were deforested, i.e. 5.6 ha per year. But in the second 28 year variation (1987-2015) about 1,637.2 ha of forest was removed (61.2 ha) per year.

4.2.6. Disturbance Risk Map Analysis

In order to examine forest cover change and generate human disturbance risk map of the study area the year 2015 forest cover map was produced, which was extracted from land cover map of 2015 and considered to be the base line for this analysis.

This map was generated from the land cover map of the year 2015 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 research human activities were taken in to 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 cover areas were contributing factors that caused forest disturbance.

4.2.6.1. Setting criteria dataset preparation

To produce the risk of forest disturbance through the analysis of spatial forest cover change pattern in the current study, five factors were identified and evaluated. These are: altitude, proximity to rural settlement, proximity to the major road, proximity to river and proximity to tea plantation. All these factors were rasterized, reclassified and evaluated to understand the level of disturbance in the area.

Finally MCE using ArcGIS 10.2 and ERDAS 11.1 software were applied to develop disturbance risk map which was helpful to develop conservation of forest land for the future. Below each reclassified maps of considered factors were presented.

I. 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 (World Bank, 2011). 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 agriculture based investment, high altitudes part of the study area was more important.

The spatial extent of forest cover change pattern indicates that complete forest clearance occurred on the relatively higher altitudes (1890-2205masl) of the study area, which are more convenient for both human settlement and crop cultivation. On the other hand, the disturbance of the natural forest for the purpose of income generation, fuel wood, charcoal production, agricultural land and vast expansion of tea plantation mainly occurred in relatively medium to low altitude parts of the study area.

Hence, high altitude was convenient for crop production and settlements were more prone to disturbance than the moderately low altitude within the current context of the study area. Therefore, higher disturbance value was assigned to the high altitudes, followed by the medium ones.

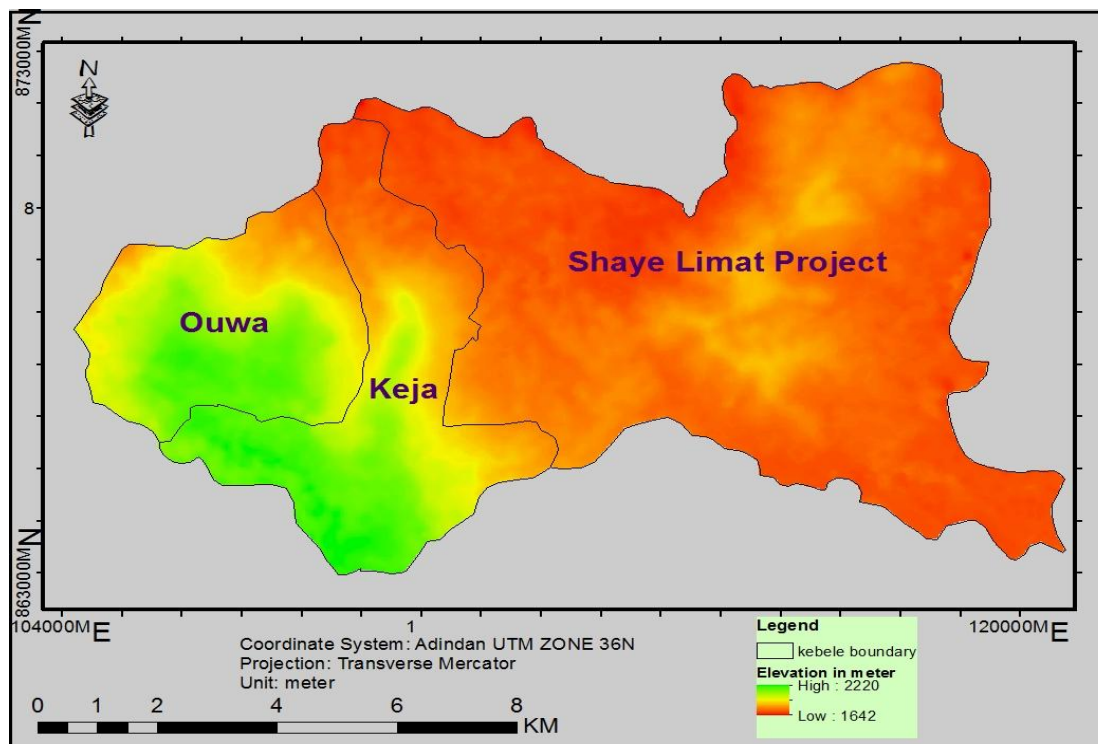


Fig. 18: Elevation Map of study area
Source: Prepared from Digital elevation model (DEM)
Table 15: Reclassified elevation

Altitude(meter)	Disturbance rate	Area in /ha/
2025-2220	High	157.2
1870-2025	moderate risk	741
1770-1870	low risk	2,988.4
1642-1770	No risk	748.4
Total		4,635

Source: computed from attribute table of Reclassified elevation map

According with the above table areas that found 1870-2025 meter elevation intervals encompass about 898.2 ha land are more prone to human disturbance risk. Because, researcher witnessed that majority of rural settlement and agricultural activity practiced elevated areas of the study this also supported by World Bank (2011). So, it was more preferable for settlement and agricultural activity.

After settling and standardizing altitude dataset, the output reclassified altitude dataset map (Figure 19) was prepared based on MCE (multi criteria evaluation) techniques. The forest cover areas shaded with red and deep blue colors were more prone to disturbance than forest cover areas shaded with green and light blue colors respectively.

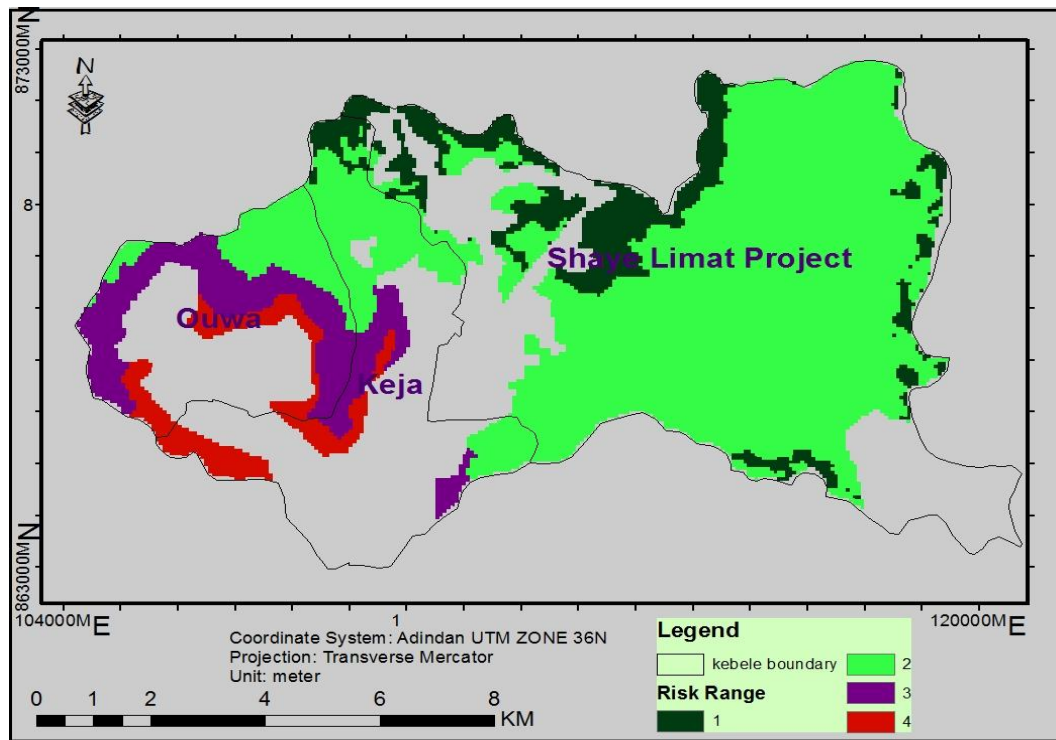


Fig 19, Reclassified elevation factor data set map

Source: prepared from elevation map

III. Proximity to River

It was essential to characterize the forest cover condition of the area and its future disturbance in relation to river proximity. Then, river distance raster dataset was derived. The river raster data layer was reclassified to analyze and determine the degree of forest disturbance in relation with river proximity.

From the reclassified river proximity (Figure 22) dataset forest cover areas having low distance value from river location have less susceptible to disturbance than those located to high distance.

Because, areas near the major rivers were steep and rugged and hence less workable and therefore less preferred by people. As stated above, this independent study shows that areas found following river basin and wet land were culturally protected from any human interference what native people called **Guudo** and it must be far from human settlement and other related activity. This view was also supported by the finding of (Bedru Sherefa, 2011) which states that this area (*Guddo*) must far from any human related disturbance at to the minimum of 1-1.5 km. So, based on this research report buffer distance was determined.

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 22) red color indicate areas which found in high risk whereas green color shows forest areas which found in moderate risk.

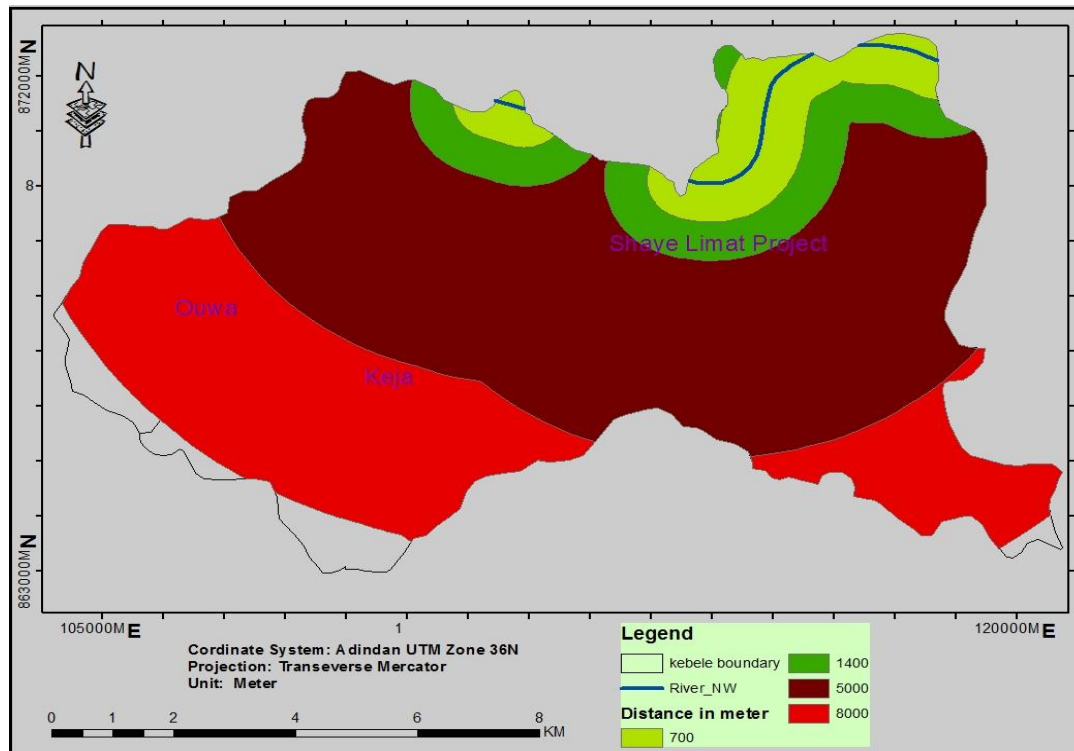


Fig 20, buffer map of river
Source: Arc map software

Table 18: Classification of river proximity masked forest

Distance in meter	Risk range	Value	Area in hectare
Above 5000	High	4	576.3
3000-5000	Moderate	3	810.2
1000-3000	Low	2	2,511
Below 1000	No	1	739.5
Total			4,635

Source: computed from Reclassified river buffer map.

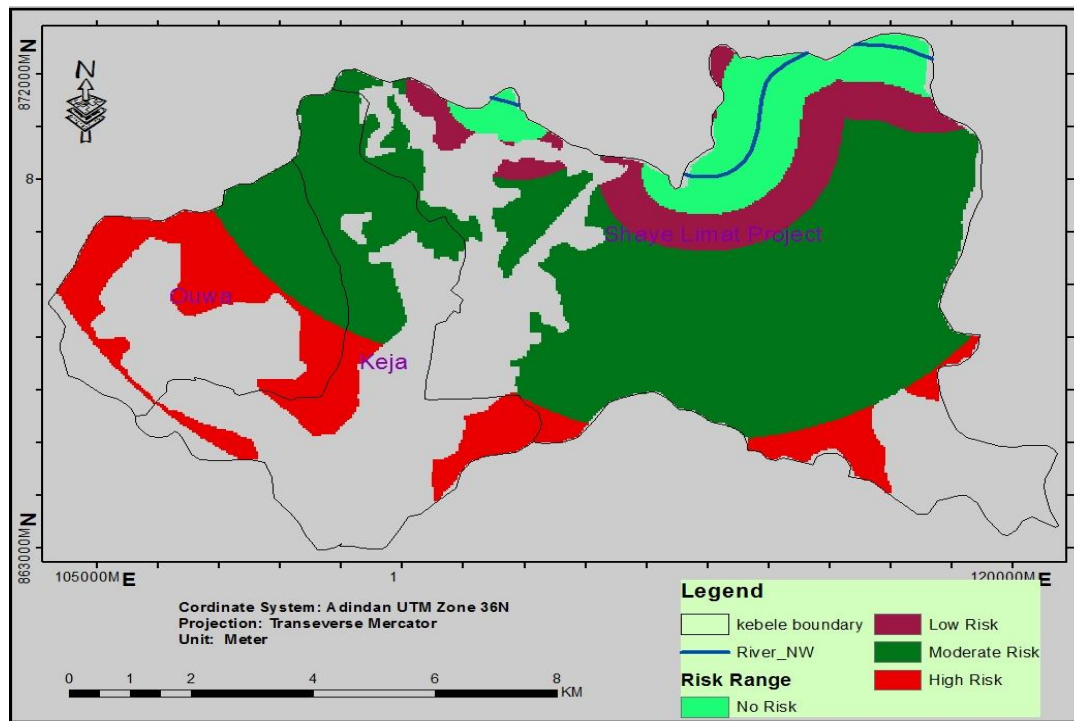


Figure 21: Reclassified River Proximity Factor Dataset map

Source: River buffer map

IV. Proximity to Main Road

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 Desanker, P. and Magadza, C. (2001) 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 strong co-correlation 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 analysis. The reclassified road proximity raster map with respect to forest cover was presented in (Figure 24). The forest cover land shaded with red color is highly prone to disturbance than the forest cover found far away from road.

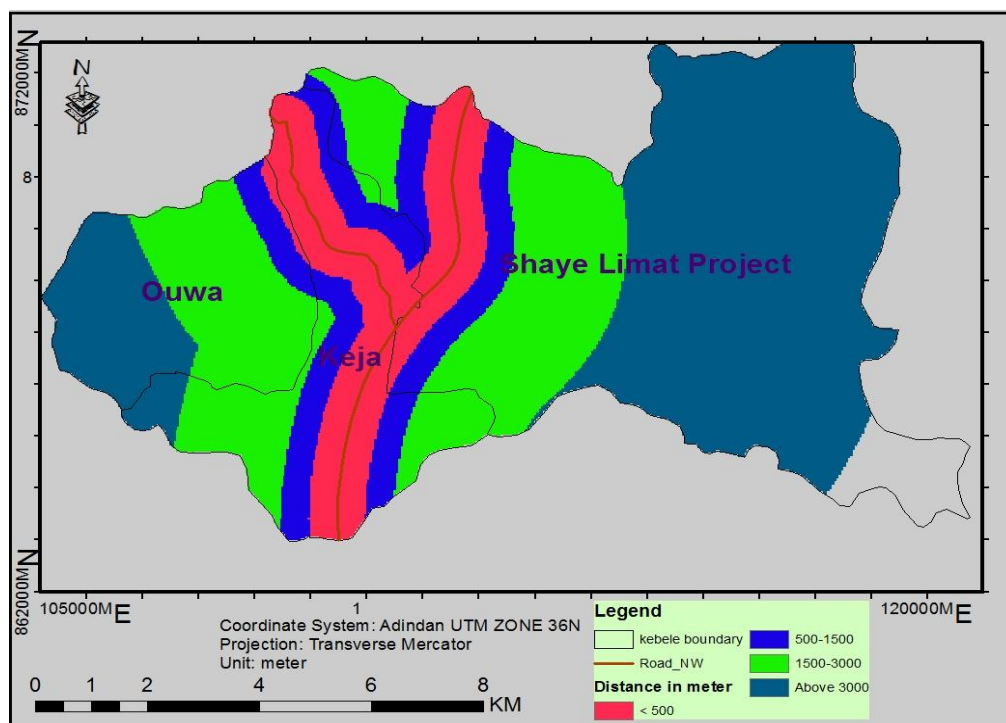


Fig 22: Road proximity factor dataset map

Source: computed

Table 19: Road proximity for masked dense forest

Distance in meter	Risk range	Value	Areal coverage in ha
Below 500	High	4	286.39
500-1000	Moderate	3	364.11
1000-3000	Low	2	1,412.5
3000-6000	No	1	2,571
Total			4,635

Source: Computed from attribute table of reclassified road map

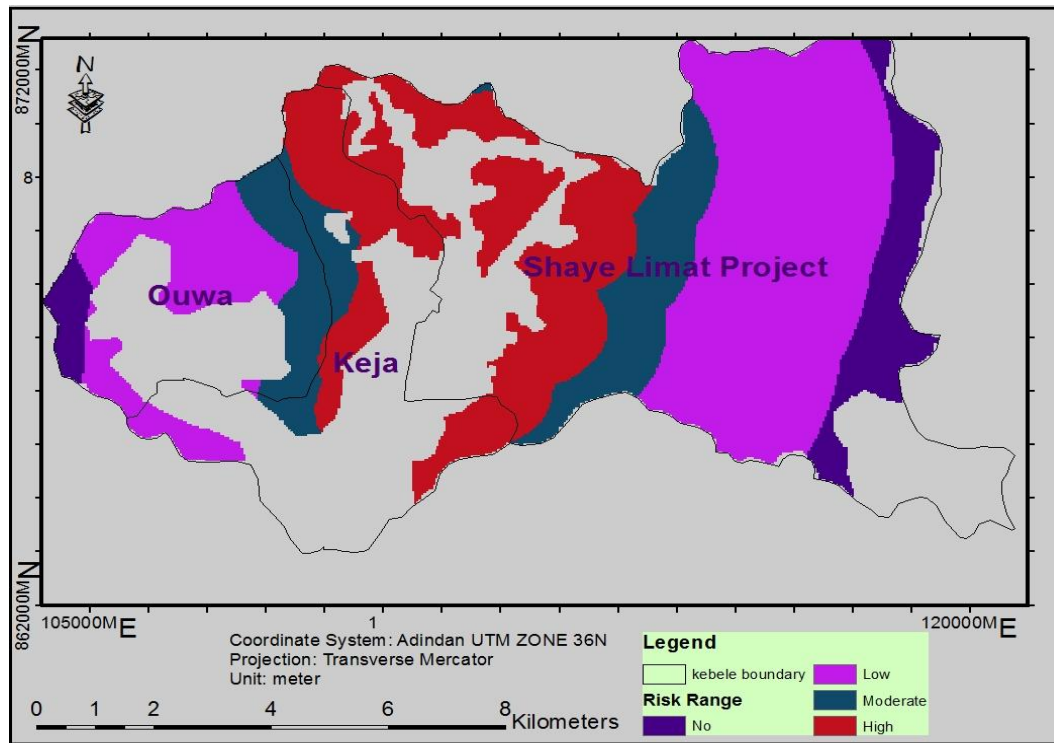


Fig 23: Reclassified Main Road factor data set using forest covers as masking layer
Source: Buffer map road

V. Proximity to Tea Plantation

Proximity to tea Plantation also rasterized and standardized in order to reclassify and to distinguish the future forest disturbance problem in the study area. People prefer to settle around Tea plantation for various reasons, mainly it is relatively gentle topography in nature in comparison with rural settlement and it is also in short distance from main road.

So, currently the researcher witnessed that majority of population were settled around tea plantation and dense forest are converted in to new rural settlements. People also started cultivating tea in addition to cereal crops and *enset*. Because of this, tea plantation data set was considered as major factor in forest degradation. And rural settlements were expanding at the expense of natural forest following boundaries of tea plantation.

The above reason was also supported by (SZARDO, 2014) annual report, currently peoples prefer to reside along the border of tea plantation, because the area found in relatively gentle topography and start to cultivate cash crops (tea).

A successfully growing tea plantation is known to reduce erosion significantly (Othieno, 1975). However, establishment of the plantation entails a huge soil work that facilitates severe soil erosion (Thomas and Bekele, 2004). Moreover, there is a periodical complete clear cutting as some part of the tea plant block gets old or produces low quantity and quality.

However, since it was not possible to determine the duration of time the land was exposed bare, it was possible to determine the severity of erosion induced by activities of tea plantation establishment. But, we can forecast that the study areas are known by its all year rain fall, if areas vegetation cover was cleared, so, there was great possibility for occurrence of severe erosion which might affect the regular flow and volume of huge river called **Baro** by creating huge Sedimentation.⁵

The researcher witnessed a vast block of land was cleared and any vegetation after such tea plantation management. The reclassification criteria for making tea plantation proximity raster map with respect to forest cover was based on the research result of Desanker, P. and Magadza, C. (2001) presented in (Figure 25). The forest cover land shaded with red color is highly prone to disturbance than the forest cover found far away from tea plantation.

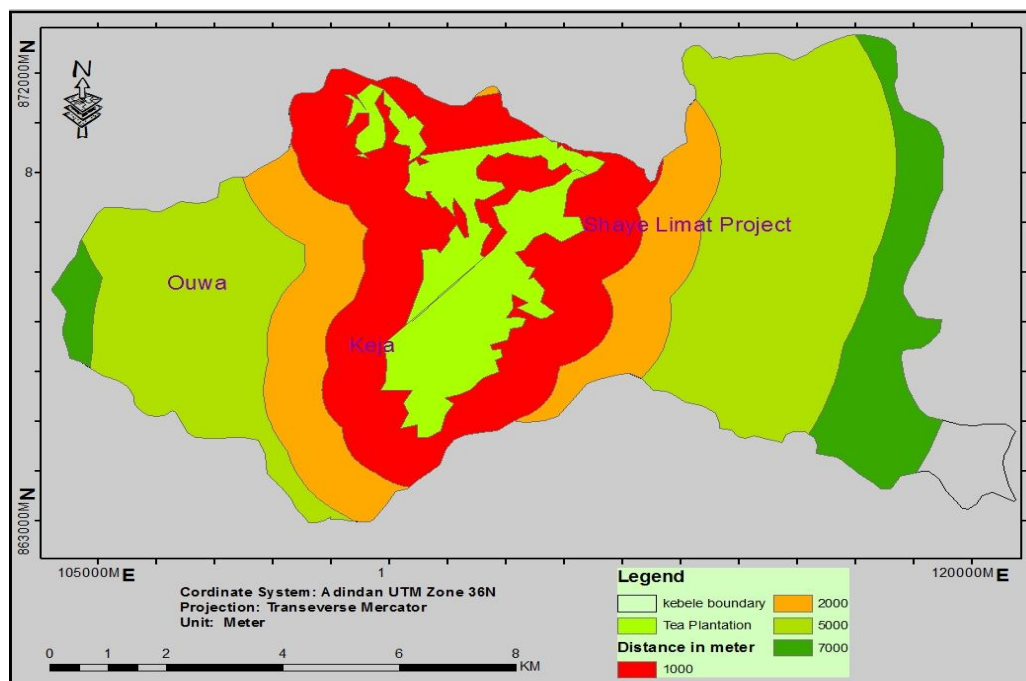


Fig 24: buffer map of tea plantation

Source: Computed

⁵ Baro: Name of the river

Table 20: Tea plantation factor data set using forest cover as masking layer

No,	Distance in meter	Risk range	Value	Area in ha
1	Below 1000	High	4	522.75
2	1000-3000	Moderate	3	680
3	3000-5000	Low	2	2,601.35
4	Above 5000	No	1	831
Total				4635

Source: Computed from reclassified tea plantation data set

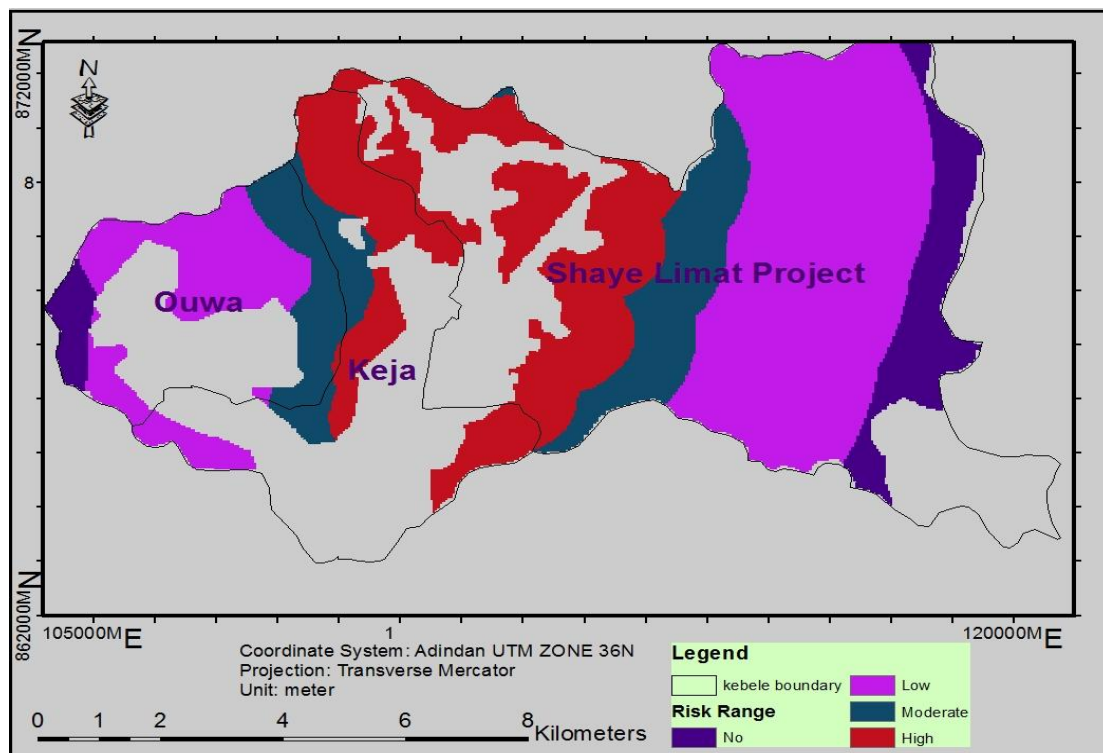


Fig 25: Reclassified Tea plantation factor data set map using forest cover as masking layer

Source: Tea plantation buffer map and masked forest cover

VI. Proximity to Rural settlement

Proximity to rural settlement dataset also rasterized and standardized in order to reclassify and to distinguish the future forest disturbance problem in the study area. Around the major settlement centers crop lands were expanding at the expense of natural forest. The above idea was also supported by (USEPA, 2004) forwards that the forests nearer to rural settlement or residential sites (to the minimum 2-2.5 Km) 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 was presented in (Figure 26). The forest cover land shaded with red colour is highly prone to disturbance than the forest cover found far away from rural settlement.

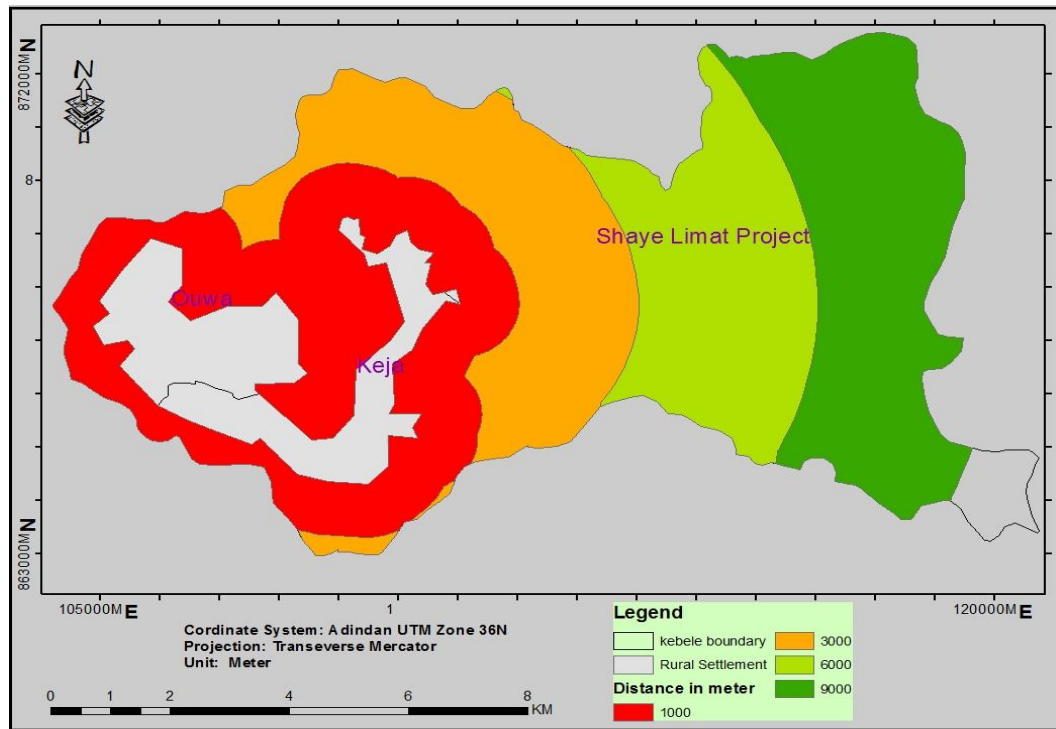


Fig 26: Buffer map of rural settlement

Source: Prepared Arc Map software

Table 21: Proximity to Rural settlement

Distance in meter	Risk ranges	Value	Areal coverage in ha
Below 2500	High risk	4	1,012.15
2500-3500	Moderate risk	3	879.25
3500-5500	Low risk	2	1,224.91
Above 5500	No risk	1	1,518.87
Total			4635

Source: Reclassified proximity to rural settlement

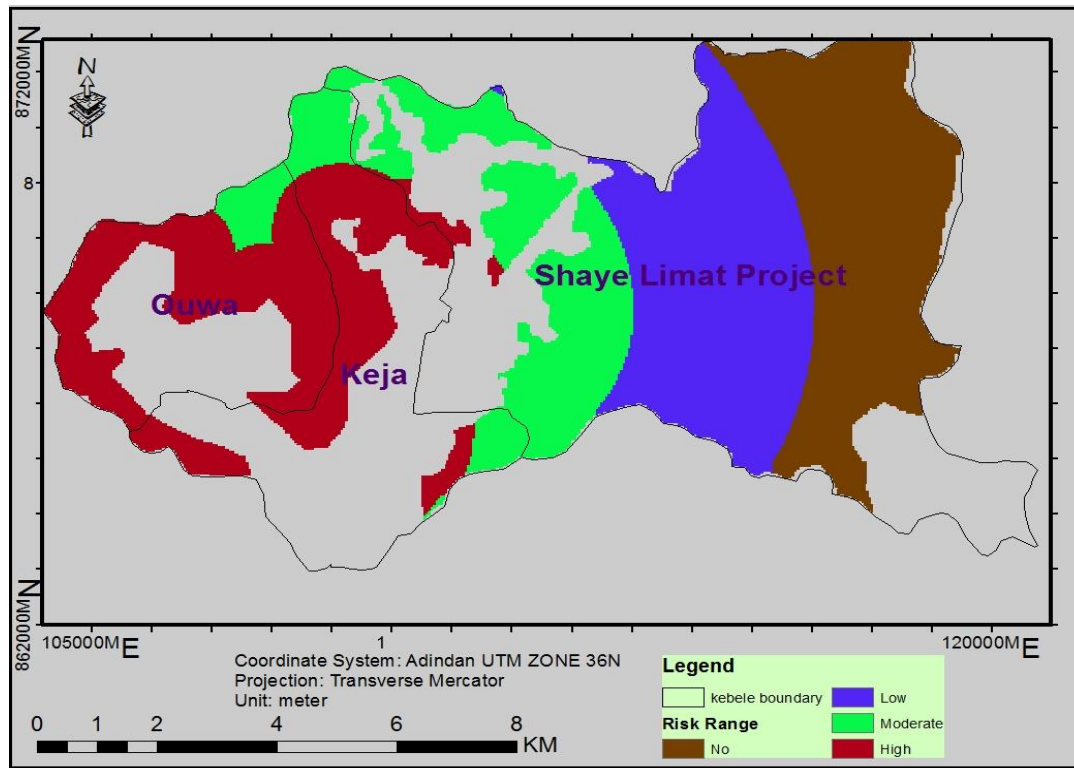


Fig 27: Reclassified Map of rural settlement using forest cover as masking layer

Source: buffer rural settlement map

4.2.7. Weighting 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.

Standardization of each data set to a common scale of 1 to 4 was done in IDRISI Software. Prior to combining the factors, weights have to be given based on Satty' s Analytic Hierarchy Process (AHP), where a pair-wise comparison matrix are prepared for each map using a nine point importance scale (Table 22). 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 utility. Based on the given pair-wise comparison, IDRISI calculates hierarchical weights for all layers. It also calculates consistency ratio that shows if the given pair-wise weights are accepted or if another arrangement is necessary.

Before using Pairwise Comparison Matrix on Edrisi software, factor maps were converted from raster and shape file in to Idrisi compatible format such as: Imagine, Edrisi grid and tiff format using Arc GIS 10 software. Each factor weights are calculated by comparing two factors at a time using a scale with values from 7 to 1/7 or from 9 to 1/9 introduced by Saaty (1980). A rating of 7 or 9 indicates that in relation to the column factor, the row factor is more important. The comparison conducted indicated that highest weighting for the rural settlement layer followed by the proximity to road layer, elevation data layer, proximity to tea plantation and proximity to river (Table 25).

Table 22: Pair wise comparison: 9 points of continuous rating scale (adapted from saaty, 1989 as cited in malczwsk, 1999)

1/9	1/7	1/5	1/3	1	1/3	1/5	1/7	1/9
Extremel y	Very strongly	Strongl y	Moderatel y	Equally important	Moderate ly	Strongl y	Very strongly	Extremely

Table 23: Weight of factors in the study area the pair-wise ratio matrix

Data Sets	Proximity to Rural settlement	Proximity to road	Elevation	Slope	Proximity to tea plantation	Proximity to river
Proximity to Rural settlement	1	3	3	5	5	7
Proximity road	1/3	1	3	3	5	5
Elevation	1/3	1/3	1	3	3	5
Proximity tea plantation	1/5	1/5	1/3	1/3	1	3
Proximity river	1/7	1/5	1/5	1/5	1/3	1

Table 24: The weight of each factor map obtained from pair wise comparison

<i>Data Sets</i>	<i>Eigenvector weight</i>	<i>In %</i>
Proximity to Rural settlement	0.392	39.2
Proximity road	0.24	24
Elevation	0.27	27.1
Proximity tea plantation	0.064	6.4
Proximity river	0.033	3.3
Total	0.099	100

CR=0.08 it is within acceptable limit because it is less than 0.1(saaty's standard)

The complete pair-wise comparison matrix contains multiple paths by which the relative importance of criteria can be assessed. The consistency ratio (CR) indicates the probability that

the matrix ratings were randomly generated, so that matrices with CR ratings greater than 0.10 should be re-evaluated.

In this study, the consistency ratio calculated as **0.08**, which is acceptable. Therefore, each of the parameters can be assigned by these weights.

Table 25: Reclassified values for factor maps

No	Data set	Range	Rank	Area in ha	Value	Reference
1	Elevation(altitude)	2025-2205	High risk	157.2	4	Researcher(Arc GIS :Natural jerk)
		1890-2025	Moderate risk	741	3	
		1770-1870	Low risk	3,988.4	2	
		1650-1770	No risk	748.4	1	
2	Proximity to Main road(km)	< 1	High risk	286.39	4	Desanker, P. and Magadza, C. (2001)
		1 - 2.5	Moderate risk	374.11	3	
		2.5 - 3.5	Low risk	1,425.5	2	
		> 3.5	No risk	2,591	1	
3	Proximity to River(km)	<1.5	No risk	576.3	1	<i>Bediru sharefa (2011)</i>
		1.5 – 3	Low risk	820.2	2	
		3 – 5	Moderate risk	2,521	3	
		>5	High risk	759.5	4	
4	Proximity to Tea Plantation(km)	<0.7	High risk	525	4	Desanker, P. and Magadza, C. (2001)
		0.7 – 1.5	Moderate risk	690	2	
		1.5 – 3	Low risk	2,631.35	1	
		>3	No risk	831	4	
5	Proximity to rural settlement(km)	<2.5	High risk	1,012.15	4	USEPA (2004)
		2.5-3.5	Moderate risk	879.25	3	
		3.5-5.5	Low risk	1,254.91	2	
		Above 5.5	No risk	1,529.89	1	

Source: computed

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 and then fed in to the spatial analyst raster calculator of the ArcGIS 10.1 software.

$$\textbf{Disturbance Risk} = \textit{Altitude} * 0.27 + \textit{Distance from river} * 0.033 + \textit{Proximity to Road} * 0.24 + \textit{Proximity to Tea plantation} * 0.064 + \textit{proximity to Rural settlement} * 0.392 \dots (3)$$

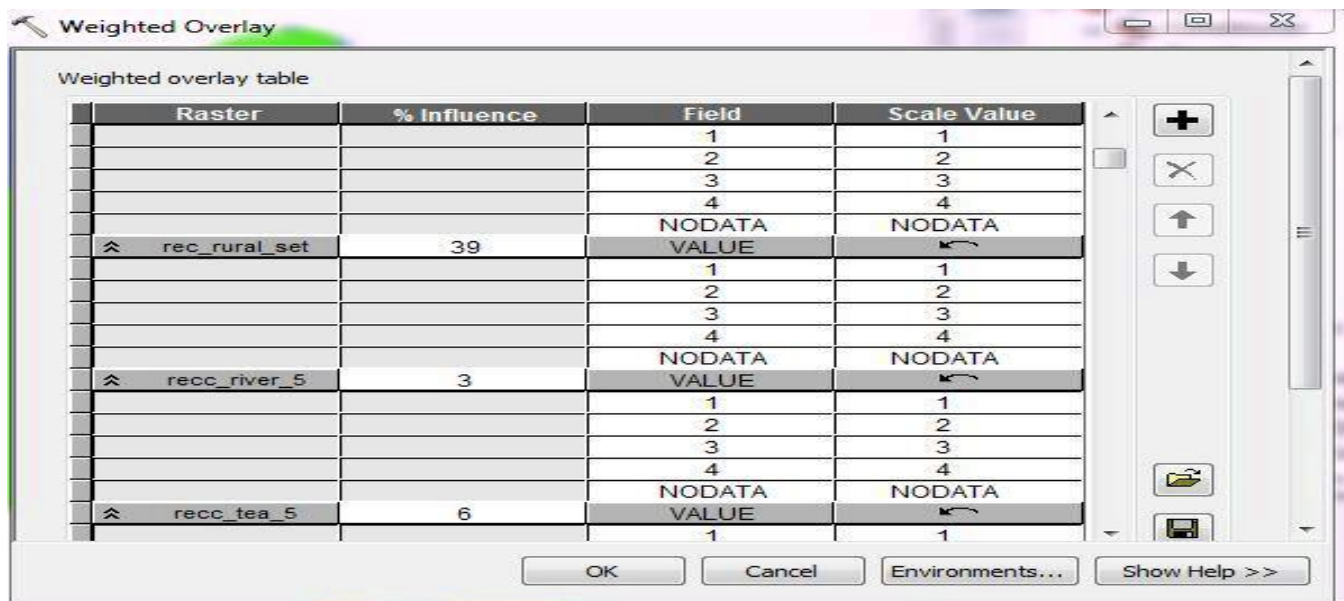


Fig 28: weighted overlay table

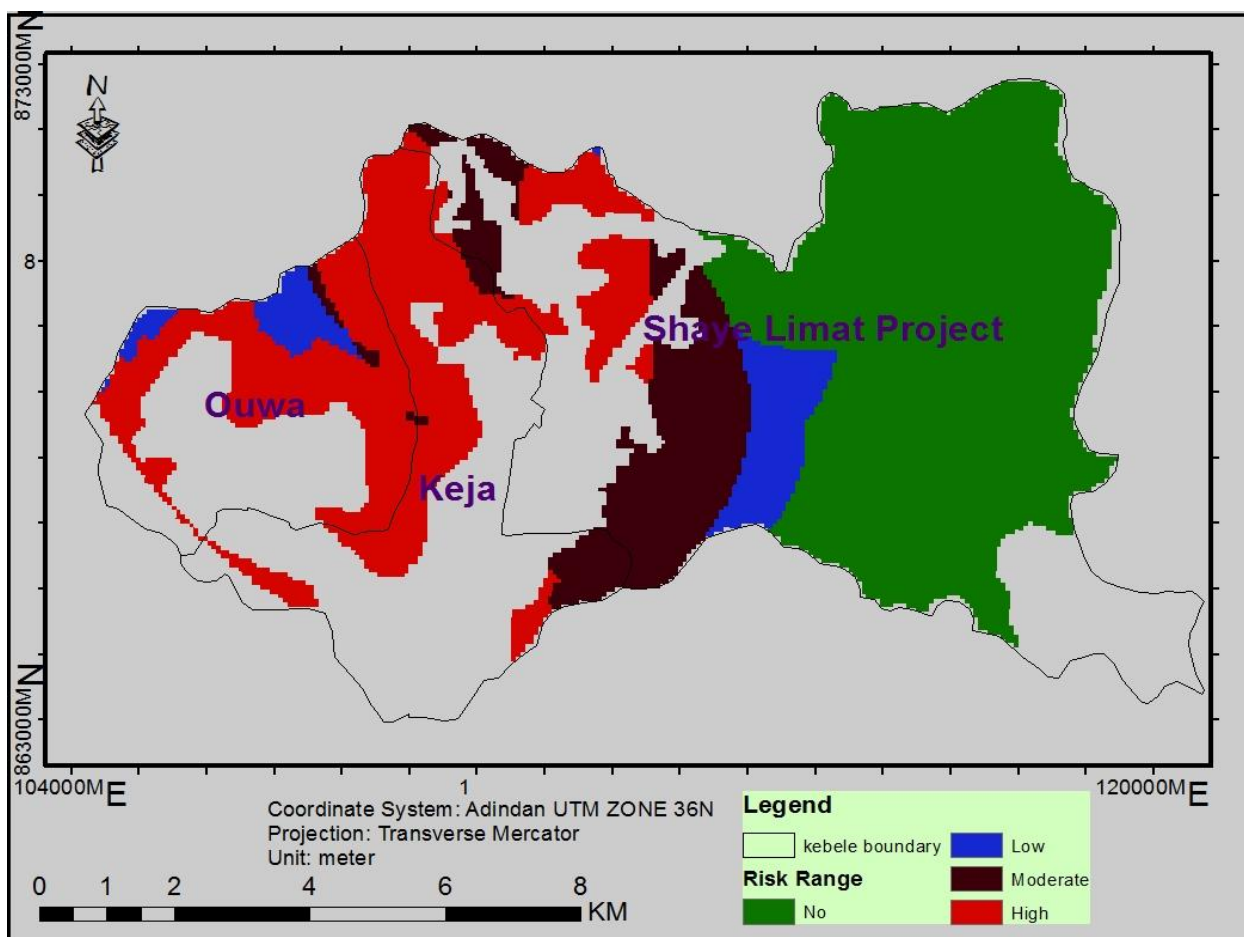


Fig 29: Risk map of the study area

Source: Factor data sets maps

Table 26: Risk ranges and areal extent

No,	Risk range	Areal coverage in ha	Kebeles that found in Risk	Areal coverage in %
1	High	844.25	Uwa & Keja	18.2
2	Moderate	587.4	Uwa, Keja & Chewaqa_utto (Shay Limat)	12.6
3	Low	310.59	Chewaqa_Utto (Shay Limat)	6.6
4	No	2,892.76	Chewaqa_Utto (Shay Limat)	62.4

Source: Computed from attribute table of Weighted Overlay result

According to the above table about 844.25 ha (18.2%) and 587 ha (12.6%) of forest land was found in high risk area and moderate risk area respectively. Both Uwa and Keja kebeles found in high risk (comprises about 844.25 ha) of forest cover, whereas Keja, Chewaqa_Utto(Shay Limat) found in moderate risk(took 587 ha ,12.6%) of total forest cover of study area and finally Chewaqa-utto(Shay limat) kebele found in Low and No risk with 2,892.76 ha (62.4%) and 310.59ha (6.6%) respectively.

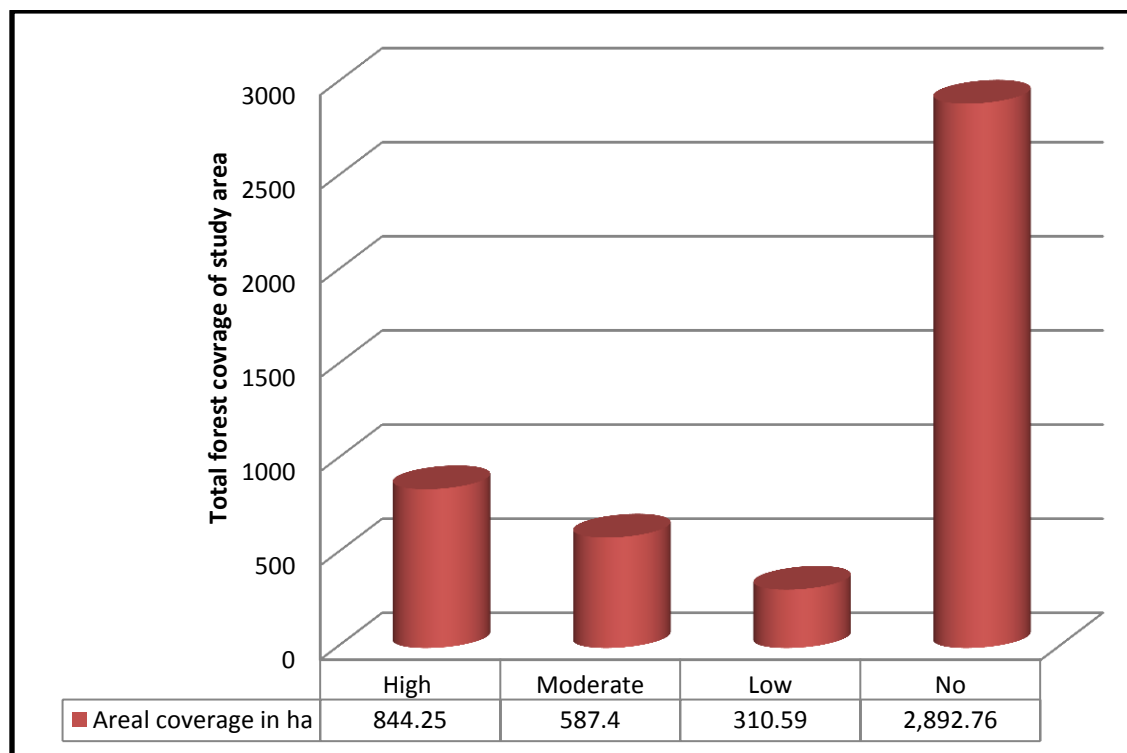


Fig 30: Forest covers at risk

Source: Table 26

4.7. Discussion

Spatio-temporal forest cover deals about rate of forest cover change in space and time in a particular area. Based on the above basic concept the researcher tries to forwards spatial extent and timely variation of forest cover change of Keja,Uwa and Chewaqa_Utto (Shay Limat) kebeles for the year 1973,1987 & 2015.

As stated in problem identification part the pertaining clues or initiating factor for this research report was vast clearance of forest resource in past 40 years for investment purpose without considering Indigenous and environmentally feasible nature protection of local community and another reason was Lack of reliable data(map) which indicate spatial extent forest cover in the study area.

Therefore, this research study emphasized on mapping forest cover change due various man made natural factors using the integrated techniques of remote sensing and GIS technology in SNNPRS, Sheka Zone, Masha woreda, Keja,Uwa and chewaqa_Utto(Shay Limat) kebeles forested but high investment priority area.

In this work, general objective was to “Identifying the Spatio_temporal forest cover change process using GIS and Remote sensing techniques, SNNPR, Sheka zone, Masha woreda, Keja,Uwa and Chewaqa_Utto(Shay Limat) kebeles.” Specifically: the study emphasizing on: Making maps of 1973.1987 & 2015 by using various GIS tools & analyzing difference, quantifying rate of deforestation, producing disturbance risk map, forwarding clues pertaining to the restoration potential of degraded and deforested lands.

The above mentioned targeted objective was fulfilled through various methods and software's such as Erdas imagine, Arc GIS and EDRISI 2 software in combination for various purposes. Then, finally rate of forest cover change was indicated in a number of tables and maps, and future risk map was identified by using five significant factor maps (Elevation, Proximity to Rural Settlement, Proximity to main road, Proximity to Tea Plantation and Proximity to river). Finally, the research result leads to conclusion and recommendation.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This finding tries to give emphasis on using integrated techniques of GIS and Remote sensing for forest change detection start from data extraction up to risk map generation. In order to quantitatively explain forest cover change both NDVI and post classification techniques was used. The weakness of NDVI was solved by post classification techniques and vice versa. And for risk map generation multi-criteria comparison and weighted overlay method were used.

The present study area is composed of five major land use/land cover types; dense forest, open forest, Rural settlement, wetland and Tea plantation. From the analyzed results, the magnitude of land-use/ land-cover in general and forest cover change in particular was observed between the year 1973 and 2015 in the study area. Particularly, expansion of Tea plantation and rural settlement and decline of both dense forest land and moderately dense forest (open forest) land were observed. In relation to this, currently, from overall condition of the forest cover land approximately half of the study area is strongly disturbed. Besides, the areal extent of forest cover is reduced from time to time.

The findings indicated that from the total area of the forest land (both dense and open forest) about 6,372 ha of land were covered with forest in 1973. But, this figure declined to 4,635 ha in the year 2015 (by 1,737 ha) and above 844.25, 587.4 ha of forest lands were at high and moderate risk respectively.

Yet, the rate of forest cover change between 1987 and 2015 show declining as compared with the first period due to construction of New road which joins two zones of different region (Sheka of SNNPRS and Illuababora of Oromia) and the practice of Chewaqa_utto tea plantation(owned by East Africa agri-business company).

The spatial forest cover change pattern indicated that complete forest clearance occurred on the relatively higher altitudes (1800-2205masl) of the study area which are more convenient for both human settlement and crop cultivation. The East African Agri-business company has concession of 2,914 ha to establish tea plantations (SZARDD, 2014).

EAA has cleared and established tea and eucalyptus plantation on 1056 ha up to 2015. (Table 12) The impact of such conversion can be seen from two aspects: loss of biodiversity and loss of sustainable traditional farming practices (particularly beekeeping).

5.2. Recommendation

From the whole study, GIS and Remote sensing tools are important tools for forest cover change detection. It had been recognized that the forest cover land of Keja, Uwa and Chewaqa area has declined though; the rate was different in different period. For future application of this tools for multi-purpose including forest cover change detection in general and to protect the forest resources of the study area from further depletion in particular, and to use these precious resources in a sustainable basis, the following feasible suggestions are forwarded based on the findings and the conclusions drawn.

- In-depth application of GIS and Remote sensing tools in integration which will minimize error, so more project will be carried out.
- Classification and delineation of all areas into different land use categories using GIS and Remote sensing tools based on their ecological sustainability, potential for economic uses and social justice.
- To protect the forest resources from further destruction, to realize the impact of deforestation as well as how to use this precious resource with a sustainable manner, awareness creation campaigns especially for the farmers who are dwelling along the margin and inside the forest areas should be an indispensable phenomenon.
- Recognition of the customary rights of the local community over their lands, their life style that strongly depends on forest, and the crucial contribution of their knowledge for sustainable use, incorporation of such issues in relevant federal and regional laws.
- Investment projects already licensed should be assessed, their impacts on biodiversity and local livelihood evaluated, and corrective measures taken to avoid further damages.
- Give priority to investments that are environmental friendly and socially acceptable such as ecotourism, honey and spices production.

5.2.1. Mapping:

- GPS based simple mapping techniques for Zonal and *woreda* officers. There is a possibility to use normal desktop computer facilities in Masha town. These facilities can be upgraded for use in GPS based mapping. Timely mapping forested areas.
- *Sheka* zone forest potential is considered as one of remaining afro-montane forest in Ethiopia. More research should be carried out on forest cover change and forest degradation mapping using remote sensing and GIS techniques.
- So, this kind of research will benefit the forest cover change detection efficiently as well as in order to provide sound information to take appropriate measures to combat the problem of forest cover change.

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Appendix I: Image Interpretation and Classification Ground Control Points

Ground control points which were Generated During Filled survey, Unit: meter			
No,	X	Y	Land Use Land Cover
1	771403	869476	tea plantation
2	771329	869441	tea plantation
3	771159	869411	tea plantation
4	771189	869388	tea plantation
5	771113	869334	tea plantation
6	771074	869396	tea plantation
7	771073	869424	tea plantation
8	771067	869455	tea plantation
9	771048	869493	tea plantation
10	771033	869512	tea plantation
11	771094	869573	tea plantation
12	771101	869628	tea plantation
13	771100	869675	tea plantation
14	771079	869701	tea plantation
15	771109	869743	tea plantation
16	771111	869782	tea plantation
17	771148	869847	tea plantation
18	771163	869851	tea plantation
19	771202	869852	tea plantation
20	771228	869887	tea plantation
21	771260	869904	tea plantation
22	771310	869928	tea plantation
23	771370	869982	tea plantation
24	771384	870027	wet land
25	771389	870073	wet land
26	771344	870168	wet land
27	771313	870195	dense forest
28	771220	870302	dense forest
29	771168	870713	dense forest
30	771218	870732	dense forest
31	771374	870712	dense forest
32	771520	870595	dense forest
33	771558	870588	dense forest
34	771752	870355	rural settlement

35	771919	870084	rural settlement
36	772202	869963	rural settlement
37	772378	869493	rural settlement
38	772975	869915	border of dense forest
39	773598	869735	border of dense forest
40	773690	869731	border of dense forest
41	773651	869783	wet land
42	773991	869721	wet land
43	774356	869724	wet land
44	775082	869368	utto road
45	774821	868949	utto road
46	774958	867860	reserved forest
47	774469	867495	reserved forest
48	774535	867123	dense forest
49	774723	866800	dense forest
50	774127	869707	dense forest
51	774532	869506	dense forest
52	775260	869282	dense forest
53	773626	865329	wet land
54	773170	864725	project road
55	773130	864725	tea plantation
56	772838	864266	getahun border
57	772693	863965	reserved forest
58	772590	863250	border of keja kebele
59	772705	862818	wet land
60	772255	863099	border of keja kebele
61	771694	864276	rural settlement
62	771331	865073	rural settlement(agri)
63	771764	865580	rural settlement(agri)
64	771816	865644	rural settlement(agri)
65	772254	866528	rural settlement (agri)
66	772291	866506	rural settlement (agri)
67	772331	866510	rural settlement(agri)
68	772441	866579	federal road
69	772663	866842	rural settlement(agri)
70	772652	866961	rural settlement(agri)
71	772549	867035	tea plantation
72	772783	867515	tea plantation
73	772783	868535	tea plantation
74	772547	867680	wet land
75	772197	869129	keja kebele

76	772118	862806	wollo kebele
77	772821	863025	dense forest
78	772689	863143	dnse forest
79	777625	867679	dense forest
80	779554	864037	dense forest(wl)
81	781180	863300	dense forest (WL)
82	783781	865316	dense forest (wl)
83	783781	869522	dense forest (yepo_border)
84	780124	874594	dense forest
85	773626	864530	dense forest
86	770146	865733	dense forest
87	771122	869088	dense forest
88	770819	870822	dense forest
89	767372	866985	rural settlement
90	769952	866660	rural settlement (df border)
91	766679	866248	rural settlement (df border)
92	771859	867939	rural settlement (df border)
93	772011	866032	rural settlement(tp border)
94	770537	863495	rural settlement(WL border)

Photos



Plate 1: Tea Plantation



Plate 2: Researcher at field work (Collecting GPS Points)



Plate 4: Farmers' home stead around tea plantation
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Plate 5: Dense Forest around Shekiskeko Cave and waterfall