ANALYZING BELETE-GERA FOREST COVER CHANGES, IT'S DRIVING FORCES AND SOCIO-ECONOMIC INFLUENCES ON LOCAL HOUSEHOLDS

MSc Thesis

Ababu Adam Abelti

Jimma University,

College of Agriculture and Veterinary Medicine,

Department of Natural Resource Management

June, 2016

Jimma, Ethiopia

ANALYZING BELETE-GERA FOREST COVER CHANGES, IT'S DRIVING FORCES AND SOCIO-ECONOMIC INFLUENCES ON LOCAL HOUSEHOLDS

By

Ababu Adam Abelti

Thesis Submitted to the
The School of Graduate studies,
College of Agriculture & Veterinary Medicine,
Jimma University

In Partial fulfilment of the Requirements for the Degree of Master of Science in Natural Resource Management
(Specialization: Forest & Nature Conservation)

June, 2016
Jimma, Ethiopia

List of Acronyms

CBD: Conservation of Biological Diversity
CBO: Community Based Organization
CF: Coffee Forest
CRGE: Climate Resilience Green Economy
CSE:Conservation Strategy of Ethiopia
CSA: Central Statistics Agency
EPA: Environmental Protection Agency
EFAP: Ethiopian Forestry Action Programme
ERDAS: Earth Resource Data Analyse System
ETM: Enhanced Thematic Mapper
FGDs: Focused Group Discussions
FAO: Food and Agriculture Organization
FMA: Forest Management Agreement
GT: Ground Truth
GDP: Growth Domestic Product
GPS: Ground Positioning System
JICA: Japan International Cooperation Agency
KBA: Key Biodiversity Area
LU/LC: Land Use Land Cover
MLC: Maximum Likelihood Classifier
MSS: Multi Spectral Scanner
NF: Natural Forest
NTFPs: Non Timber Forest Products
OFWE: Oromia Forest and Wildlife Enterprise
PCA: Principal Component Analysis
PFM: Participatory Forest Management
RFPA: Regional Forest Priority Areas.
SPSS: Statistical Package for the Social Sciences
TM: Thematic Mapper
USGS: Unite State Geology Survey
UTM: Universal Transverse Mercator.
WaBuB: Waldaa Bulchiinsa Bosona in Oromiffaa (Forest Management Association)
WBISPP: Woody Biomass Inventory and Strategic Planning Project
WRI: World Resources Institute

Acknowledgment

First of all, I would like to thank the almighty GOD for HIS inestimable help for all my accomplishments. I would also like to express my gratitude to my advisors Dr. Debela Hunde and Dr. Gudina Legese Feyisa for valuable comments and constructive advice they gave to my research proposal, data collection, and thesis writing and closely supervising me at all stages of this work. I also thank Jimma University College of Agriculture and Veterinary Medicine, Department of Natural Resource Management, Postgraduate and Research Coordination office for the financial assistance and facilitations of the fund I received from International Foundation of Science through Dr.Gudina. I will not leave unmentioned that Dr. Debela Hunde has discussed on the funding of my MSc thesis with Dr. Gudina.

I would also like to thank Mr Zerihun Kebebew and Hirko Dibaba for their constructive comments on the proposal and research paper in sharing their experiences and materials as well as encouragement is sincerely acknowledged.

I would like to acknowledge OFWE Jimma Branch office workers Mr Mohamad Seid PFM experts and Tamirat Magarsa Ecologist who supported me in giving secondary data and sharing their experiences. Special thanks also go to Belete-Gera District office workers Mr Tamiru Negas, Mr Isubale Messele , Mr Abdella Nuna and Mr Bahire for their kind cooperation during socio economic survey questionnaires field data collection. Also I would like to acknowledge all individuals or my friends who assisted me during the study time.

Finally, I would like to acknowledge and appreciate the encouragement and patience of my wife, Nechitu Dilalessa during the whole study period.

Table of contents

Figures

List of Appendices

ABSTRACT

Rapid population growth and various anthropogenic factors like agricultural expansion, woody forest product extraction and illegal settlement have caused the conversion of natural forest land cover to other land use types which have a great implication on environment and socio-economy of local households. The objective of the study is to analyze Belete-Gera forest cover changes, its major drivers and socio economic implication of forest cover changes on local households. To accomplish the objective of the study, Landsat images from 1985 TM, 2001 ETM^+, and 2015 ETM^+, and ERDAS and GIS technologies in combination with ground verification and socio-economic survey were used. The five major land use land cover types of the study area are closed forest, open forest, agriculture, settlement and wetland. Even though, closed forest is the dominant land cover type in the study area, it decreased from time to time. In the first (1985-2001) and second (2001-2015) 15 years, it decreased by 11.4% and 5.6%, respectively. Wetland also decreased by 17.6% and 39.1%, respectively. In contrary, agricultural land was increased by 53.9% and 11.5%, and settlement increased by 19.5% and 10.9% in the first and second 15 years, respectively. Open forest showed a very little change. Belete-Gera forest cover change was driven mainly by anthropogenic factors like agricultural expansion, illegal settlement, woody forest product extraction, free grazing, population growth, poor governance, law awareness and accessibility. Agricultural land expansion is the main driving force of Belete-Gera forest which accounted for 81-100%. Because of anthropogenic driving forces, in the past 30 years ago, 19,898.9ha (16.7%) of Belete-Gera forest was deforested and converted to other land use types. Belete-Gera forest cover change affects the main land dependent incomes of the households like cereal crops, pulse crops, NTFPs, livestock and others .Even though land dependent income of the households increased , annual income per family size was decreased from time to time. Therefore, in the past 30 years ago, great Belete-Gera forest cover changes were occurred, and the forest is disappearing annually at the rate of 0.48%. The changes are driven by interlinked direct (65%) and indirect (35%) anthropogenic factors. Belete-Gera forest cover change influences agricultural crop productivity, agricultural inputs, woody and non woody uses of forest products for subsistence purposes.

Key words: Belete-Gera, Forest cover change, driving forces and socio-economy

1. INTRODUCTION

1.1. Background information

Forests provide a wide variety of ecological, economic and social services, including the conservation of biological diversity, carbon storage, soil and water conservation, provision of employment and enhanced livelihood, enhancement of agricultural productivity and improvement of urban and per urban living conditions (FAO, 1999). Obviously, these services differ widely in nature and therefore tend to be valued in different manners by different society and different social groups. However, these forest functions and services are being continuously affected by forest degradation and deforestation.

Unprecedented rates of human population growth and other factors (e.g., timber harvest, cropland cultivation, infra structure development) have caused the conversion of natural forests to other land use across the world (Carr, 2004). Conversion of forest lands into other land uses often results in degradation of environmental conditions (Foley et al., 2005). With increasing demand for forest products and land for food production, pressure on forest reserves is increasing (Geist and Lambin , 2002) and this is of particular environmental concern in many tropical countries (Gibbs et al., 2010).

Ethiopia has already experienced drastic deforestation and consequent land degradation and other undesirable environmental problems (Tadesse et al., 2001). Forest cover changes in tropical areas are often small-scale complex in patterns (Fisher, 2010). While forest land conversion is a local process, it may result in global scale environmental changes such as enhanced greenhouse emissions (Foley et al., 2005), and at the same time local households who are heavily dependent on natural resources are likely to be impacted by immediate local consequences such as soil and water degradation (Banerjee and Madhurima, 2013).

According to FAO (2010) report, Ethiopia’s forest cover is 12.2million ha (11%). It further indicated that the forest cover shows a decline from 15.11 million ha in 1990 to12.2 million ha in

2010, during which 2.65% of forest cover was deforested. Today, little of natural vegetation of the high land remains, except for the southern and south western part of the country.
Belete-Gera Regional Forest Priority Area(RFPA), where the study was conducted is a forest fragment in the Jimma zone, Oromo Regional State, in the South Western parts of the country, and is recognized as a Key Biodiversity Area (KBA) within the eastern afromontane biodiversity hotspot (Mittermeier et al., 2004). Furthermore, the forest is inhabited by people from different ethnic groups, who extract coffee, honey, spices, bush meat, wood and medicines from the forest. The increasing population growth in and around the Belete-Gera forest increases pressure on forest resources (Hylander et al., 2013).

Farmers are stimulated to convert NF to CF deeper inside Belete-Gera forest. On the forest edges, trees are being cut to increase agricultural fields while rising human population and live stock results in an overexploitation of the remaining forest. As a result, large areas, which were under dense forest cover, are now exposed to deforestation, which leads into environmental degradation and serious threat to wildlife habitat loss. Furthermore; the loss of the vegetative cover could result in biodiversity loss, which could lead to species extinction even though the rate differs with type of species due to its geographic distribution and abundance (De Beenhouwer et al., 2015).

This study is conducted to understand Belete-Gera forest cover change using remote sensing data of 1985, 2001 and 2015, and its driving forces which have a great implication on socio economy of local households. Even if, different studies were undertaken on forest cover change detection in the southern forest of Ethiopia, there is still a gap on clearly addressing the drivers of the forest cover change and its socio economic implication on the local households .Also the research finding helps in identifying the problems on similar ecosystems and setting recommended solutions for it. Hence, the current forest cover change of the country in general and areas with natural forest like Belete-Gera forest with rich biodiversity should be studied in order to identify the specific problems and to recommend and suggest appropriate solutions.

Therefore, this research addresses relevant issues on forest cover changes in relation to the natural resources and the socio-economic set up of the study area and try to provide recommendations which may contribute to the sustainability of Belete- Gera forest and hence the improvement of the livelihoods of farming households in the study area and beyond.

1.2. Objective of the study

1.2.1. Overall Objective

- To contribute to better understanding of Ethiopian forest resources cover changes, its major drivers and discourse socio economic implication of forest cover changes on local households.

1.2.2. Specific Objectives

- To analyze Belete- Gera forest cover changes over three temporal period of 1985, 2001 and 2015 using landsat image.
- To identify the driving forces of Belete-Gera forest cover change in the study area.
- To assess the influences of Belete–Gera forest cover changes on the socio economy of local households.

1.3. Research questions

- What is the magnitude of the changes in Belete- Gera forest from 1985-2015?
- What driving forces are contributing to changes in Belete–Gera forest cover?
- What influences Belete–Gera forest cover changes would have on the socio economy of local households?

2. LITERATURE REVIEW

2.1 Forest covers change in Ethiopian context

Historically, deforestation in Ethiopia, particularly in the long-inhabited highland areas, has been a severe and persistent process (Dessie and Christiansson 2008). However, the prevailing narrative of once densely forested highlands that have become denuded of their forest cover through a linear and continuous deforestation process was questioned by McCann (1997). The suitability and potential productivity of the highlands have made them attractive for settlement for a long period of time (Place et al. 2006). This long-term occupation and exposure of these areas to ox-plough agriculture (McCann 1997) are the most widely given explanations of the heavy deforestation. The absence of regular forest assessments at national level has limited the availability of up-to-date information on the dynamics and extent of forest cover change. The most current and relatively thorough assessments of deforestation and degradation are therefore limited to specific forest areas connected to development projects on forest management and conservation, or those forests considered for academic or other studies. Therefore, countrywide information on deforestation can only be found in the form of projections made from the WBISPP assessment.

Declining standard of livelihood of the farming households and their close dependence on forests and woodlands have led to clearing / burning for subsistent farming, cutting of trees/shrubs for fuel wood and charcoal production (both for consumption and sale), construction material, over-grazing, burning associated with traditional apiculture, etc. Population growth and its pressure resulted in the concentration of the largest proportion of the population in the highlands leading to heavy load on the forests for cultivating crops, fuel wood, and construction material and grazing. Poor economic performance was demonstrated through declining rates of economic growth between 1974 and 1990 (EFAP, 1993). With population increasing faster than the economy, the per capita income declined. These had adverse effect on natural resources, particularly forests and woodlands.

According to the FAO estimates, the average annual rate of deforestation from 1990 to 2010 is 0.93%. However, most of the more location-specific studies conducted across the country give higher estimates (see Table 1). FAO estimates and the findings of the individual studies, the forecast forest and woodland cover change indicate that the average annual rate of deforestation is greater than 0.25%. This is the threshold value used by Hosonuma et al. (2012) for what is known as the early forest transition stage, a period when the deforestation rate is relatively high but the remaining forest cover is still above 50% of the forest cover from 20 years earlier.

Table 1. Annual deforestation rate estimates of studies in different areas of Ethiopia.

Study	Time period	Location	Forest type	Av. annual deforestation rate	Method
Mulugeta (2011)	1984–2002 2002–07	Central highlands	High forest	3.5% 8.8%	Unsupervised classification of satellite images with field verification
Assefa (2010)	1987–2006	South west Ethiopia	High forest	0.92%–0.98%	Unsupervised classification of satellite images with field verification
Garedew (2009)	1973–2006	Central Rift Valley	Woodlands	1.1%–1.2%	Participatory field point sampling and remote sensing
Dessie and Christiansson (2008)	1972–2000	South-central Rift Valley	High forest	2.9%	Satellite images with supervised maximum likelihood classification method
FARM Africa & SOS Sahel (2008)	1986–2006	Bale eco-region	High forest	0.25%	Remote sensing and GIS
Zeleke and Hurni (2001)	1957–95	Northern highlands	High forest	2.6%	GIS and remote sensing with field verification
Reusing (2000)	1971–97	South west Ethiopia	High forest	2.3-5%	Satellite images with detailed forest monitoring using black and white aerial photographs

Source: Bekele et al., 2015

2.2. The main drivers of forest cover changes

The main drivers of forest land cover change were established in the 1990s and forecasts have been made on the assumption that the same processes would continue in the near future (WBISPP 2004). Forest land cover driving forces are direct/proximate driving forces and indirect /underlying driving forces.

2.2.1. Direct and proximate drivers of forest cover change

Direct causes of deforestation include the motivational factors and decisions of agents of deforestation that immediately impinge upon forests (Contreras, 2000), and proximal causes include the human activities (i.e. land use) that directly affect the environment (Geist and Lambin, 2001). Table 2, lists five major drivers of deforestation and the extent of their impact on forest cover in Ethiopia according to the country's R-PP report (FDRE, 2011c).

Table 2. The major direct drivers of deforestation in Ethiopia and their level of impact.

No	Major drivers of deforestation	Their level of impacts
1	Expansion of traditional smallholder agriculture in forest areas driven by population growth of households around forest	Large impact
2	Expansion of large-scale commercial agriculture and other development activities including road networks and mega development projects such as hydroelectric dams	Large impact
3	Population growth due to government settlement programs relocating people to forest areas	Large impact
4	Increased extraction of wood and other forest products following massive population growth and the resultant high domestic energy demand	Medium impact
5	Forest fires related to raising livestock (pasture improvement activities) and making charcoal, due to poor incentives to local households for sustainable forest use and weak forest protection	Medium impact

Source: FDRE, 2011c

According to the WBISPP (2004), forest clearance for agricultural expansion is the main direct cause of deforestation. Consistent with this, several case studies have also identified agriculture as the major deforestation driver. For example, in parts of the south-central Rift Valley, agricultural land expansion accounts for 82% of the high forest lost (Dessie and Christiansson 2008). Similarly, in the central and southern Rift Valley, agricultural activity accounted for 80% of the observed change in land cover and degradation from 1973 to2000 (Sherefa ,2006). In the same time period, Garedew (2009) estimates that in the semi-arid areas of the central Rift Valley, which have low agricultural potential, 30–33% of woodlands were converted for crop production. As for the relatively severely deforested northern highlands, forest clearance for agricultural expansion has resulted in the loss of nearly all of its existing forests until no land is left for cultivation including the "very last marginal areas and steep slopes with gradients >30%" (99%) (Zeleke and Hurni 2001, 184). On the other hand, in the relatively less populated forests of the Bale eco-region, the annual deforestation rate due to agricultural expansion is estimated at only 0.25% for the years 1986–2006 (FARM Africa and SOS Sahel, 2008).

2.2.2. Indirect/underlying causes of forest cover change

Indirect causes of deforestation and forest degradation refers to the broader economic, political, cultural, demographic and technological forces that influence the decisions of agents involved in deforestation (Kaimowitz and Angelsen 1998), or the forces that are far removed in the causation chains from the deforestation agents and their immediate actions (Contreras, 2000).

The underlying causes of forest cover change in Ethiopia include demographic, economic, social and institutional factors. Population growth is the most dominant underlying cause with its resulting increase in demand for agricultural land (impacting deforestation) and fuel wood (impacting forest degradation) (WBISPP, 2004). Both the gradual, slow process of natural population growth and the rapid, drastic population increase following internal migration and settlement around forest areas are important underlying forces (Dessie and Christiansson, 2008; Mulugeta 2011; Stellmacher and Eguavoenare, 2011). Such continued population pressure on forest resources reflects the fast population growth unmatched by growth in agricultural productivity. This is amidst a highly agrarian rural economy with a low level of agricultural technology and prevalent poverty.

However, population growth and demand for land and forest products also operate within institutional and political contexts that are conducive to the deforestation process. In the past few decades, the institutional environment for the use of forest resources was characterized by the interplay of customary institutions and protective and exclusionary state control. This has often resulted in conflicting interests between the State and local people who traditionally are dependent on forests for their livelihood security (Bekele, 2003; Stellmacher, 2007). Similarly, the R-PP lists implementation of an unworkable regulatory approach, insufficient/unclear user rights for forests, lack of a benefit-sharing scheme, lack of empowerment of local households and lack of law enforcement as the major institutional factors underlying the deforestation process in the country.

In addition, political vacuums during government transition periods, such as the recent crisis in 1991, are occasional events with pervasive and extreme impacts on deforestation. These periods are typically when massive resettlement and deforestation takes place, drastically changing the forest frontier and setting the stage for ensuing deforestation processes (Bekele, 2003). For example, 71% of the forestlands of a state-owned forest enterprise were converted to farmlands during the 1991 government change, resulting in settlements and agricultural activities deep inside the forest proper (Dessie, 2007).Another important underlying deforestation driver is the country's development strategy. In the past decade, the agriculture sector has been given a central role as an engine of economic growth (PASDEP, 2006). Given the dominant role of agricultural expansion in the deforestation process, this development strategy has undoubtedly had significant impacts on the dynamics of forest cover change (FDRE, 2010).

2.3. Land covers changes and its consequences in Ethiopia

2.3.1. Crop production and land degradation

Cereals occupy two thirds of the cultivated land in the Ethiopian highlands. Some reports even indicate that grain crops to occupy about 90% of the area cultivated under all crops in Ethiopia (CSA, 2003). Soil degradation in Ethiopia can be seen as a direct result of the past and present agricultural practices on the highlands. The dissected terrain, the extensive areas with slopes above 16 percent, and the high intensity of rainfall lead to accelerated soil erosion once removal of vegetation occurs. Also some of the farming practices within the highlands encourage erosion. These include cultivation of cereal crops such as teff (Eragrotis tef) and wheat(Triticum spp.) which require the preparation of a fine seedbed, single cropping of fields, and the down slope final ploughing to facilitate drainage. Furthermore, it is also assumed that insecurity of land and tree tenure has discouraged farmers from investing in soil conservation practices.

Research has shown that soil erosion is greatest on cultivated lands where almost half of the loss of soil comes from, even though they cover only 13 percent of the country (Hurni, 1990). The highest average rates of soil loss are from currently unproductive but formerly cultivated lands with less vegetative cover. Deforestation and forest degradation leads to excessive land degradation, along with other climatic factors such unreliability and high intensity of rainfall could lead to reduced average crop yields per unit area (FAO, 2000). As a result of continuous low crop yields, the total produce of most farming families is not sufficient to cover their annual consumptions.

2.3.2. Forest Resource degradation

The Ethiopian Forestry Action Programme (EFAP, 1993) estimates the annual rate of deforestation in the range of 150,000and 200,000 hectares. However, Conservation Strategy of Ethiopia (CSE, 1997b) reported that it ranges from 80,000 to 200,000 hectares. In fact, information on forest area considered by FAO, reflects the area actually covered with forests, assessed through field survey or remote sensing as opposed to forestland that some opt to use. Something that cannot be ruled out, though, is the inability to clearly estimate the change due to technical difficulties or organizational inconveniencies. Hence, calls for a nationwide assessment in order to stop these inconsistencies of the Ethiopian forestry reports, be it from regional, national or international point of view.

Generally, deforestation can result in the loss of biodiversity; which in turn results in declines in ecosystem integrity, and also genetic losses that may impede future scientific advances in agriculture and pharmaceutics. The consequences of deforestation will therefore be felt by the many poor because of lack of cash to buy modern medicine. In addition, deforestation can also impact hydrological processes, leading to localized declines in rainfall, and more rapid runoff of precipitation, causing flooding and soil erosion, a common phenomenon in the study area and areas close to it (Legesse et al., 2003).

2.3.3. Desertification

Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variation and human activities. Furthermore, UNCCD defines land degradation as a reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation (WMO, 2005).

2.3.4. Biodiversity Loss

The CBD defines biodiversity as the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. It is the variety of life on earth at all levels, from genes to worldwide populations of the same species; from households of species sharing the same small area of habitat to worldwide ecosystems (IAIA 2005).

Biodiversity plays an important role in the way ecosystems function and in the many services they provide. Services include nutrient and water cycling, soil formation and retention, resistance against invasive species, pollination of plants, regulation of climate, as well as pest and pollution control by ecosystems. For ecosystem services it matters which species are abundant as well as how many species are present (Facts on Biodiversity, 2005).

2.4. Applications of remote sensing and GIS to monitor forest cover change

"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 and Kiefer, 2000). It is a powerful technique for surveying, mapping and monitoring earth resources. This technology combined with GIS which outshine 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.

Several scientific researches indicated that remote sensing and GIS are used in various fields like, watershed management, flooding, road network analysis, urban and rural development, mining, hydrology, irrigation, hydropower, monitoring of forest resources and so on. Especially, 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. Larsson and Stromquist (1991) described that the interpretation of Landsat imagery was found to be the most convenient rapid appraisal technique for assessing and estimating dynamic environmental changes and trends. Image interpretation and analysis will provide accurate information on forest cover, forest type, forest condition and biomass and land potential for afforestaion program.

The application of satellite remote sensing in forest cover change detection has developed rapidly in association with the digital image analysis of earth resource satellite data. With rapid changes in land cover occurring over large areas, Remote sensing technology is an essential tool especially in monitoring tropical forest conditions. The remote and inaccessible nature of many tropical forest regions limits the feasibility of ground based inventory and monitoring methods for extensive land areas. Initiatives to monitor land cover and land use change are increasingly dependent on information derived from remotely sensed data. An array of techniques is available to detect forest cover changes from multi-temporal Remote sensing data (Hayes and Sader, 2001).

Furthermore, Howard’s (1991) argument revealed that satellite remote sensing can be used to provide quick information about forest cover land and for monitoring of forest cover change over a long period of time at the continental and regional level. The assessment of forest cover change into other land cover and land use systems on country basis using Landsat data has contributed to the world wide appreciation of the problem of the diminishing forest cover land. In this regard, Howard (1991) had been quoted several examples to indicate the usefulness of Remote sensing techniques to apply on forest cover change:

Hence, from this analysis we can generalize that satellite Remote sensing data were very useful in deriving quantitative data on forest cover change and presenting the results in an understandable form. Besides, digital image analysis applied to forest cover monitoring has the advantage of being fast and able to handle large quantity of data and, is increasingly being used

2.5 Change detection methods

According to Lillesand and Kiefer (2000) change detection involves the use of multi temporal datasets to discriminate areas of land cover change between dates of imaging. In addition Jonsen etal (1997) indicated that change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. For example, information about change in the landscape provides valuable data on the processes at work and the information may be obtained from remotely sensed data and/or by visiting the specific sites on the ground. Therefore, the goal of change detection is to determine those areas on digital images that depict change features of interest (e.g. forest cover change) between two or more image dates. 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 (Bottomley, 1998). The basic premise in using satellite data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing flexibility in manipulating digital data and increasing computing power.

3. MATERIALS AND METHODS

3.1. Description of the study area

The study was conducted in Belete-Gera forest which is situated in Jimma zone, Oromiya National Regional State, at about 390 km South West of Addis Ababa (Fig. 1). It was found in the concession area of Oromia Forest and wildlife Enterprise, Jimma Branch of Belete-Gera District.

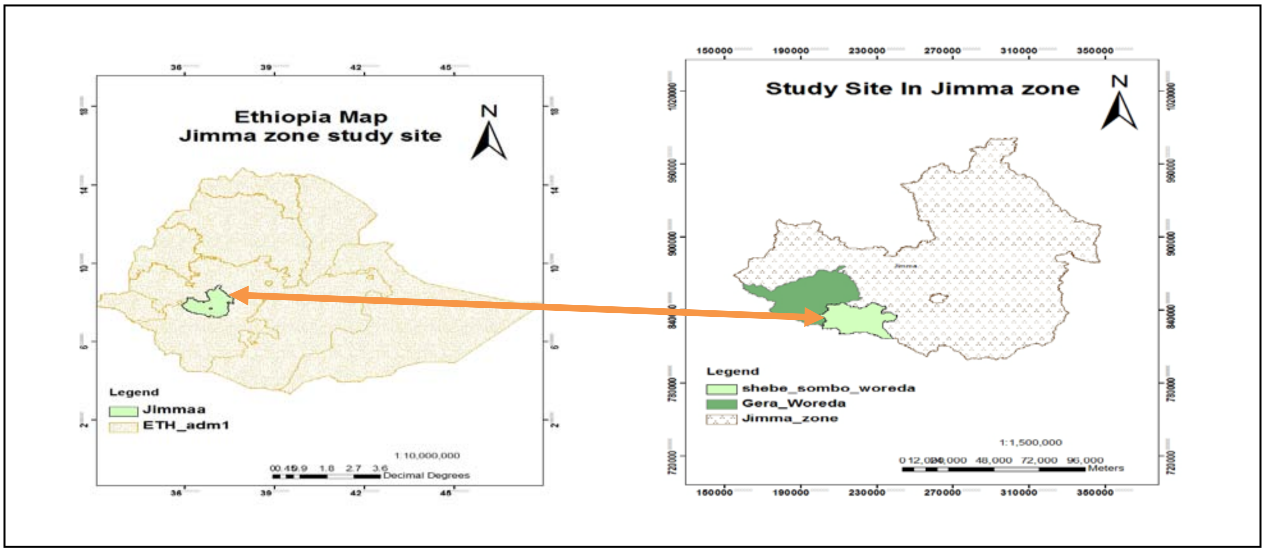

Fig. 1: Map of the study area

Source: Processed from Ethiopia and Oromia shape file

3.1.1. Bio-physical characteristics

a. Climate

The area is characterized mostly by hot moist tropical agro-climatic zone. The rainfall of the area is bimodal, with unpredictable short rains from March to April and the main season ranging over June to September. The maximum and minimum annual temperatures are also about 27^0c and 9 ^{0}c, respectively. The area receives annual rainfall that ranges from 1200 – 2001 mm (JICA, 1998)

b. Topography

The area is characterized by variable topography with the altitude ranging from 1500 -2800 m as. With the concentration of many headstreams, these high lands consists of moderately undulating hills for the most parts, while in some areas steep-sloped mountains with deep valleys prevail. Steep mountains terrain can be found in some areas. In the low land area of the forest site is mainly dominated by coffee forest, but in the high land area of the forest site is dominated mainly by high land forest species and agricultural crops.

c. Soil

Soils of the study area are largely volcanic in origin and relatively fertile and the dominant soil types are nito soils. Major soil types of the study area are Hapllice Nitosoil, Humic Nitosoil, and Dystric Calmbisols (JICA, 1998).

d. Hydrology

The study area situated in the basin of Gojeb and Gibe Rivers. Belete Forest is located to the north of Gojeb River. The southern portion of the forest descends sharply toward Gojeb River. Belete Forest contains a network of streams, most of which flow in to Gojeb River. Gera forest is also situated to the north of Gojeb River. Naso River runs from north to south through the central part of the forest, delivering tributary water from the high land to Gojeb River .In the northern part of Gera Forest a small river flows in to Gojeb River. Another river which leads to Didesa River, tributary of Abay River is located in to the north western part of the forest.

There are also many seasonal rivers which are originated from Belete-Gera Forest, and drains in to Gojeb and Naso Rivers. Therefore, Belete-Gera forest also occupies the headwater of several rivers that are tributaries or main sources of some major rivers.

e. Vegetation

The Belete-Gera forest is one of the 58 National (Regional) Forest Priority Areas (N/RFPA). The forest is situated in Gera and Shabe-Sombo districts of Jimma zone, Oromia National Regional State in the southwestern part of Ethiopia. It is characterized as an Afromontane evergreen forest, dominated by trees like *Syzigium guineense*, *Olea welwitchii*, *Prunus africana and Pouteria adolfi-friederici* (Demissew et al., 2004).

According to Oromia Forest and Wildlife Enterprise Jimma branch office forest demarcation data (2015), the forest cover of the study area is estimated at **121, 026.6ha**, of which **1,728.42ha (1.4%)** is plantation forest and the rest **98.6%** is natural forest.

Forest in the study area is characterized by high land rain forest of broad leave tree species. The most dominant tree species found in the study area are *Polyscias fuluva (Araliaceae family), Mankilara butji (Sapotaceae family), Olea capensis (Oleaceae), Syzygium guineenses (Myrtaceae), Milttettia ferruginea, Albizzia gummifera ,Cordia africana, Hagenia abyssinica ,Crorton machrostachyas, Aningeria adolfi-frienderici and Podocarpus gracilior*. The five important and endangered tree species which is prohibited to cut are *Juniperus procera (Cupressaceae), Podocarpus gracilor (podocarpceae), Hagenia abyssinica (Rosaceae), Aningeria adolfi-frienderici, and Cordia africana (Boraginacea)*

Within the study area, pure Bamboo (*Arundinaria alpine*) thickest exist in humid areas at high altitude .Forest plantation in the study area contain many dense stands, which are virtually free of damages from disease and pests. Man made plantation dominated in the study area are *Eucalyptus (Eucalyptus camandulensis and E. Saligina), Cuprsuss lustanica (Cupressaceae), Pinus patula(Pinaceae) and Geravilla robusta*

Belete-Gera forest is one of the few forests in the country where wild coffee is naturally grown. Wild forest coffee grows naturally in the local forest and is genetically distinct from commercial or garden coffee varieties. In Belete forest there is huge plantation of exotic tree species such as *Eucalyptus, Cupressus, Pinus and Cassuarina* spp. with different age and size

f. Wildlife resources

Belete–Gera forest is the home of many wildlife resources. Accordingly, there are many wild animals in the area, including endemic species. It is also common to see several bird species of different habitats (forest and water bodies). The major wild animals are *Black and White Colobus, Grivet Monkey, Giant Forest Hog, Warthog, Buffalo, Civet Cat, Anubis Baboon, Black Leopard, Lion and Hayne.*

g. Livelihood strategies

The main livelihood of people living in and surround Belete-Gera forest is mainly mixed farming system. They produce coffee, maize, wheat, sorghum, barley, pea and beans. Forest coffee is the dominant non forest product income of the area. Coffee and spice from the forest is the main source of income for the households. In addition, Livestock play a major role in the mixed farming system, providing to cultivate the lands, cash as well as food for domestic consumption.

Livestock husbandry supports crop production mainly through providing traction power, while crop residue is used as a major livestock feed. Consequently, farmers keep wide variety and high livestock population. The livestock include cattle, sheep, goat, equines, poultry and bees. Small ruminants and cattle are the dominant animals

g. Demography

The forest area encompasses 44 villages or Peasant Associations (30 in Gera and 14 in Shabe-Sombo). It is estimated that there are around 17,500 households with approximately 119,709 populations found within these villages (CSA, 2007).

3.1.2. Local institutions

a. Belete–Gera District

Belete-Gera District is one of the largest Districts from five Districts found in Jimma Branch Forest and Wildlife Enterprise. It is the legal governmental entity responsible for the management of Belete-Gera natural and plantation forest.

Prior to June 2008, Belete–Gera forest was managed as Natural Forest Priority area of the project. In this case the forest management activities mainly focused on forest development and protection by hiring forest guards. But since July 2008, the forest has been managed as forest Enterprise. In this case, forest management activities are mainly focused on forest development, forest utilization on sustainable base, and also forest protection by participation of local people through implementing PFM.

b. Belete-Gera PFM

The goal of PFM is to build effective local institution that fill the gap of former institutional vacuum that puts forest in a condition of *de facto open access* situation. Concomitantly, it aims to enhance the role of forests and related sectors in rural development as an incentive to sustain community's engagement in forest management practices. The Belete-Gera PFM project approach to address these goals by designing the project to encompass three complementary strategies called herein 'the triple project strategy'. These are i) the WaBuB institution, ii) Forest Coffee Certification Program, and iii) Farmers Field School. These three components of the project stand for one core aim: conserving Belete-Gera forest for sustained ecosystem services and goods that benefit the local community in and around the forest and those far beyond.

c. The WaBuB institution

Successful communal forest management is possible only when effective and strong institutions that mediate collective actions are developed. Institutions are core elements to mediate forest human interactions. Absence of vibrant institution was one of the major underlying drivers for the excessive deforestation of Belete-Gera forest.

Community based organization (CBO) called WaBuB takes over the responsibility and accountability of managing Belete-Gera forest. WaBuB is abbreviation for "Walda Bulchiinsa Bosonaa" in Afaan Oromoo, meaning "Forest Management Association." WaBuB is an association of voluntary 'households' that are interested to participant in the management of forests in their locality. The name was originally given by a community which established the first WaBuB. WaBuB is established at sub-village level, equivalent of a 'Goti' in local administrative term. Consequently two or more WaBuBs can be established in a PA1 depending on its size (Goti number) and settlement pattern. This arrangement has kept the size of each WaBuB at a relatively manageable size of 90-120 member households.

A WaBuB becomes legally accountable for forest management upon signing Forest Management Agreement (FMA) with government representative Oromia Forest and Wildlife Enterprise (OFWE). So far a total of 124 WaBuBs have been established to cover all villages across the Belete-Gera forest.

3.2. Methodology

3.2.1. LU/LC change data collection

Imagery acquired by sensors of Landsat Thematic Mapper and Enhanced Thematic Mapper Plus satellites (path 170 and row 55) were used. The imagery were downloaded free of chargefrom United States Geological Survey (USGS) data portal.Medium resolution images (e.g. Land sat) are most commonly used in LU/LC classification even though they have low time frequency, and rarely have cloud-free images (Henry et al., 2011). All the imagery used was acquired during dry seasons of the years between 1985 and 2015, at 15 years intervals. The selected months of the year were not only suitable for obtaining cloud free images, but also assumed that confusion in spectral signatures of forest and non-forest green vegetation could be minimized and the contrast between forest and non-forest land uses is maximized during dry seasons(January).

Table 3. Three periods of Satellite images for the study

Land sat types	Date of Acquisition	Spatial resolution(m)
Land sat 5 – TM	**January 1985**	**30mx30m**
Land sat 7 – ETM+	**January 2001**	**30mx30m**
Land sat 7 – ETM+	**January 2015**	**30mx30m**

Source: (USGS download site http://earthexplorer.usgs.gov/

3.2.2. Land Use/ LU/LC classification

Major LU/LC of the area were characterized through discussion with local people and visual observation. Forest canopy cover was also estimated visually and with a densitometer. The time difference between image acquisition and ground surveying was about one month and no major LU/LC change was assumed to have occurred within this time difference. Based on the satellite images, local knowledge and reconnaissance survey during ground truth taking, five LU/LC categories were identified (Table 4).

Table 4. Description of land use LU/LCs categories

Land use/cover type	Land use/cover description
Closed forest land	The forest area which has closed tree canopy cover > 40%
Open forest land	the forest area which has open tree canopy cover 10-40%
Agricultural land	Areas of land ploughed/prepared for crops and fallow land. This category includes areas currently under crop, fallow and land under preparation. The class may include small inter field cover types (e.g. hedges, grass strips, small windbreaks, etc.) as well as farm infrastructure.
Settlement	Areas of land occupied by houses and homestead
Wetland	Marshy area and /or natural areas where water level is shallow and when it recede, some of the land could be used for crop production

According to FAO (2000), open forests as having a canopy cover of between 10% and 40%, butclosed forest have canopy cover > 40%. Similarly, according to Europe Forest Resource Assessment, (2000) open forest is formation with discontinues tree layer but with a crown coverage of at least 10% but less than 40%, but closed forest is multi stories with crown interlocking of > 40% . Therefore, based on this open and closed forest was identified.

3.2.3. Ground truth data collection

In order to support image classification, ground verification was done in the field. First, reconnaissance assessment was done for site identification. The reconnaissance survey was aimed to gain general information of the study area and existing biophysical conditions as the vegetation cover of the study area. During field survey, the coordinates of the Ground Truth (GT) of the past and actual forest cover types were collected using a global positioning system (GPS). In the inaccessible site, GT was taken from Google Earth Pro. The GT of LU/LC of year 1985 and 2001 were collected based on information from elderly people, zonal and woreda agriculture offices, Top Map of the study area, Google Earth Pro, known and/or fixed ground feature of the study area. 30-50 GT per class were collected depending on the size of the land classes. For small area class (wetland) 30 GT, but for larger area (Closed forest) 50 GT per class was collected. For supervised classification and accuracy assessment totally 400 GT per study year were collected. The LU/LC classification was done by maximum likelihood supervised classification using the training areas identified during the field survey. Distribution of Ground Truth data taken from the whole site of study area for accuracy assessment and supervised classification is given in Figure 2.

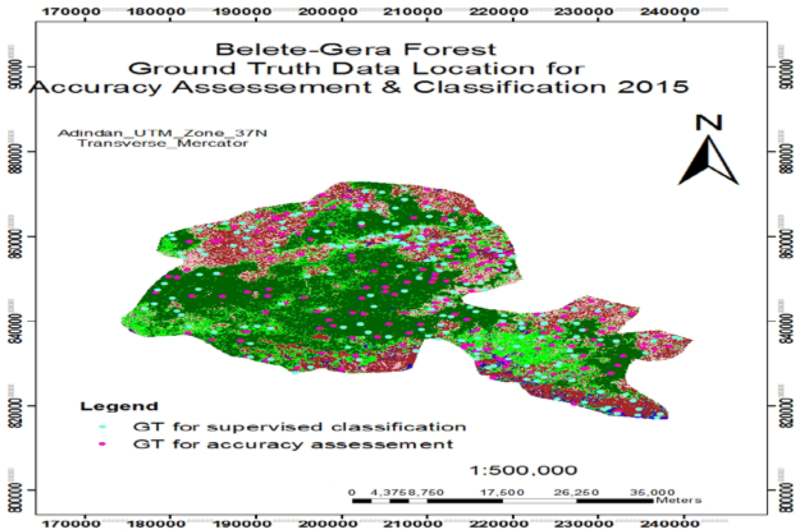

Fig. 2: Location of GT data in the study site

3.2.4. Socio-economic survey

a. Sample household selection

Sample households were selected based on **"Rule of thumb"** .According to Manly (2004), 10% of sample intensity is recommended for population size 101 up to 1000, and 1% of sample intensity is recommended for population size greater than 10,000. Accordingly, 176 households from all kebeles (4 households per kebele) were selected out of the 17500 households in the study area. Based on discussion with development agents, four households per kebele were selected. The selected households have well aware of the status of Belete-Gera forest and socio economic condition of the study area since 1985. Because of this, the age of all selected sample household was greater than 40 years.

b. Socio-economic data collection

Data were collected based on a questionnaire as well as group discussions. Data were gathered from both primary and secondary sources. Primary data were collected by using survey questionnaires. But, secondary data was obtained from different literature review, from annual reports of Jimma zone, Gera and Shebe Sombo woreda governmental office, and also from JICA office found in Jimma zone. Furthermore, relevant secondary socio economic data such as total population and agricultural income was collected from the statistical year books provided by the statistical offices at Jimma zone.

To every interviewee, the purpose of the research and its importance was explained by the interviewer in order to build confidence in the participants to respond to all questions. In all the interviews, heads of the selected household, who are implicit decision-makers in the household and responsible for the whole farm management, was interviewed.

Focused Group Discussions (FGDs) were conducted by forming small groups (members of 5–8 persons) with members sharing similar background and experience of the issues under study. Detail information was generated from FGDs was insight into various political, social, and environmental factors that influence decisions on land use and LU/LC at the household and landscape level. Focused Groups are individuals who had lived in the area for a long time (greater than 50 years) and had good experience in Belete-Gera forest change and socio economy of the study area .A socio-economic survey was conducted from February 2015 to May 2015 and mainly focused on family size, landholding, education background, land dependent income, non cash use of woody forest products for subsistence purpose and driving forces of Belete-Gera forest LU/LC changes.

Socio-economic data collection time duration:-

- The 1985 socio-economic data collection time duration includes 1985-1995 years
- The 2001 socio-economic data collection time duration includes 1995-2005 years
- The 2015 socio-economic data collection time duration includes 2005-2015 years

Socio-economic survey of land dependent income was conducted based on the quantity of the products produced in each study years, and then multiplied by year 2015 market price of the products. This helps to avoid the effect of inflation.

Fig. 3: Socio-economic survey data collection field photo

3.2.5. Data Analysis

a. Image pre-processing

Image pre-processing like atmospheric correction, hazard reduction, de-striping (removing of stripe especially from Landsat 7 ETM^{+} 2015), and image enhancement was `done using ERDAS software. Because ERDAS imagine software allowed spectral clusters to be identified with a high degree of objectivity (Mundia and Aniya, 2006). This has allowed the extraction of information on LU/LC condition and quantification of changes and its rate over the past 30 years using multi temporal analysis. Images acquired by Landsat 7 have stripes of data gaps.

b. Image classification

For this study, the Maximum Likelihood (ML) supervised image classification algorithm was used. This is one of the most widely used LU/LC classification algorithms (Campbell and Wynne, 2011). The system is a reasonable and enduring classification scheme which allows interpretation of features from remotely sensed images (Lillesand et al, 2008). It is parametric classification algorithm (Jensen, 2005b; Currit, 2005), which is based on the probability that a pixel belongs to a particular class. The basic theory assumes that these probabilities are equal for all classes, and that the input bands have normal distributions.

All image processing was carried out using software called ERDAS imagine 9.1 and Arc GIS 10 .The forest cover maps obtained from three different satellite images was compared to generate necessary information.All images were rectified to Universal Transverse Mercator (UTM) zone 37 N, datum WGS-84)

c. Classification categories

Land Use /LU/LC classification categories;

- ❖ Plantation forest is classified as closed forest. Because the plantations forest found in the study area are unevenly distributed in the forest, and also they have closed canopy coverage as closed forest.
- ❖ Forests which have wide canopy coverage (10-40%) classified as open forest.
- ❖ Grazing land classified as agricultural land. Because in the study area, farmers widely practiced shifting cultivation by interchanging grazing land and agriculture in every season. Rural roads are also classified as agricultural land.
- ❖ Homestead land, rural settlement and built-up found in the small towns are classified as Settlement.
- ❖ All season water logged areas are classified as wetland.

d. Post classification Change detection

Images of different reference years were first independently classified. The classified images were compared in three periods, i.e., 1985–2001, 2001–2015 and 1985-2015. Change statistics was computed by comparing image values of one data set with the corresponding value of the second data set in each period. The gain and losses by each category, and the net change experienced by each category was investigated using the change analysis tab.

The magnitude and rate of forest cover change for the three periods would be computed using the following simple formula and statistics and change maps were compiled to express the specific nature of the changes between the dates of imagery (Lamichhane, 2008).

$$R = (Q2-Q1)/t$$ ---------------- Annual rate of change

Where, R = rate of change

Q2 = recent year land use/ LU/LC in ha

Q1 = initial year land use/ LU/LC in ha and

t = interval year between initial and recent year

e. Accuracy assessment

The accuracy assessment was performed for classified images of 1985, 2001, and 2015.User accuracy, producer accuracy, overall accuracy and Kappa statistics of each year classified image was calculated by Jensen and Cowen Kappa statistics using the following equation

$$\text{Kappa statics} = \frac{N\sum^{r}_{i=1} X_{ij} - \sum^{r}_{i=1}(X_{i+} * X_{+j})}{N^2 - \sum^{r}_{i=1}(X_{i+} * X_{+i})}$$

- r is the number of rows in the matrix,
- xii is the number in row i and column i,
- $x{+}i$ is the total for row i, and
- $xi{+}$ is the total for column.

Kappa can be used as a measure of agreement between model predictions and reality (Congalton, 2008) or to determine if the values contained in an error matrix represent a result significantly better than random (Jensen and Cowen, 1999). It is stated that Kappa values of more than 0.80 indicate good classification performance. Kappa values between 0.40 and 0.80 indicate moderate classification performance and Kappa values of less than 0.40 indicate poor classification performance (Jensen, 2005; Kiefer and Lillesand , 2004).

f. Socio-economic Data analysis

The socio-economic data obtained from the survey was entered to excel spread sheet checked for consistency and cleaned and was made ready for analysis. Statistical mean, frequency and t-test analyzing was done using Statistical Package for the Social Sciences (SPSS) version 20 (SPSS Inc. 2008) software. And also analyzed by the following equation;

- ❖ Family size, land holding and education level was analyzed by taking mean of each variables of the households. In this context illiterate means not able to read and write.

- Land dependent income was analyzed by taking the mean of each land dependent income of sampled household in the study area.
- Non cash value of woody forest products and NTFPs was analyzed using simple weighted mean equation. The forest products local households have benefited from forest were categorized into five levels of benefit.

$$\sum ((5*n/176) + (4*n/176) + (3*n/176) + (2*n/176) + (1*n/176))$$

Where;

n is number of respondents

176 is total number sample of household

5 is very high benefited value **2** is low benefited value

4 is high benefited value **1** is very low benefited value

3 is medium benefited value

- Driving forces of Belete-Gera forest cover change was analyzed by similar to that of benefit of forest products.

$$\sum((5*n/176) +(4*n/176) +(3*n/176)+(2*n/176)+(1*n/176))$$

Where, **n** is number of respondents

176 is total number of sample households

5 is very high level of impact **2** is low level of impact

4 is high level of impact **1** is very low level of impact

3 is medium level of impact

The whole procedure of analysis followed is summarized in the chart as follow

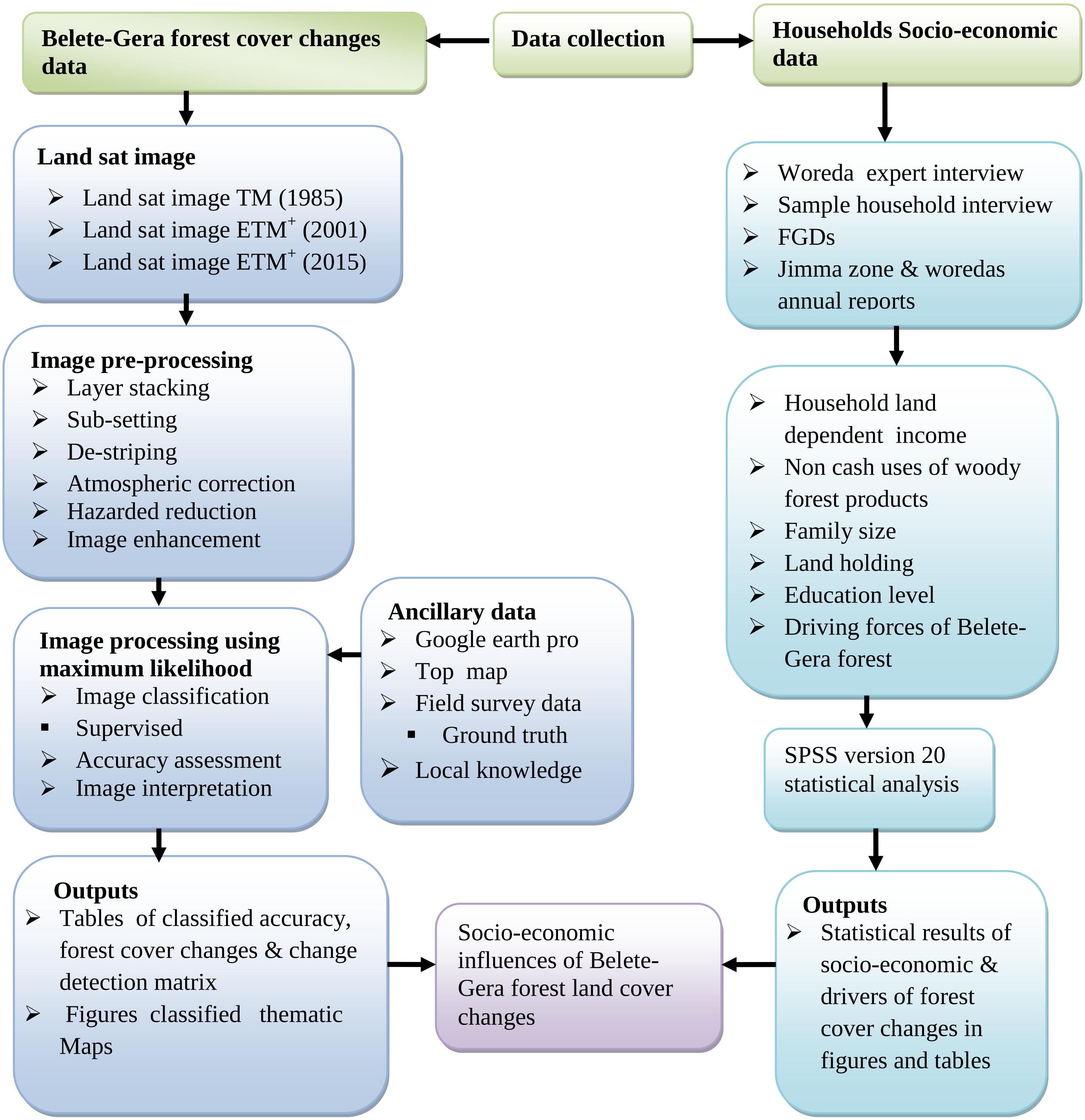

Fig. 4: Forest covers change and socio-economic analyzes procedures

4. RESULT AND DISCUSSION

4.1. Belete-Gera forest cover classification

Based on the reults assessement of the Landsat image of 1985, 2001 and 2015, the map of the five major land use types of the study area (closed forest, open forest, agriculture, settlement and wetland) were given on Figure 5, 6 and 7 .

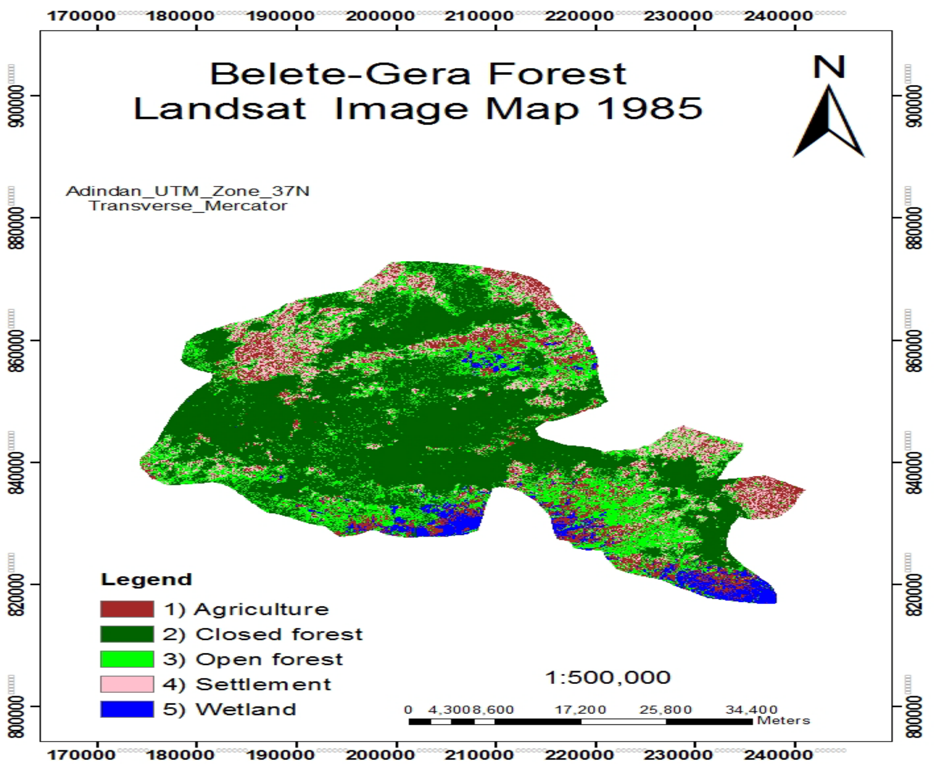

Fig.5: Landsat image Map of Belete-Gera Forest 1985

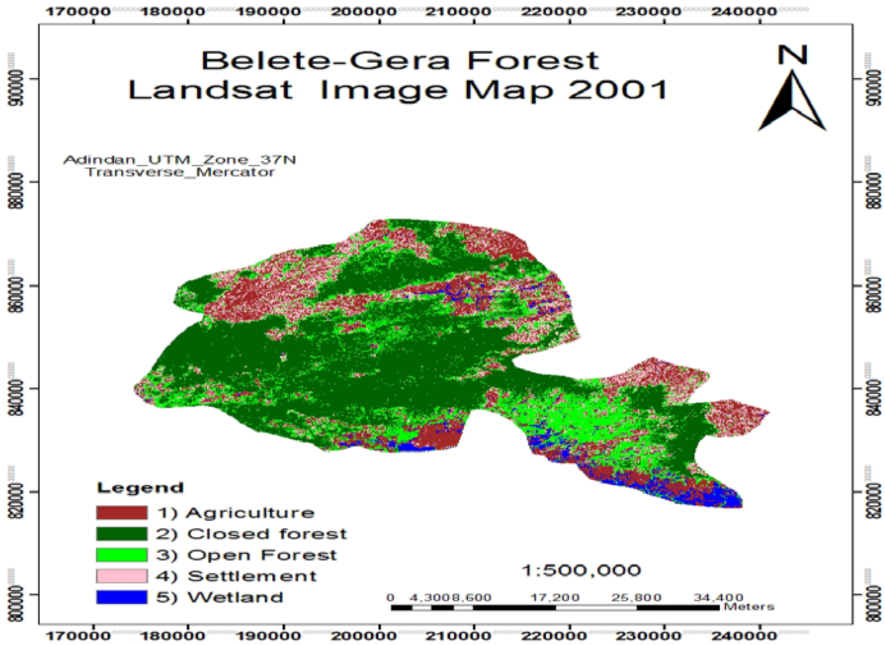

Fig.6: Landsat image Map of Belete-Gera Forest 2001

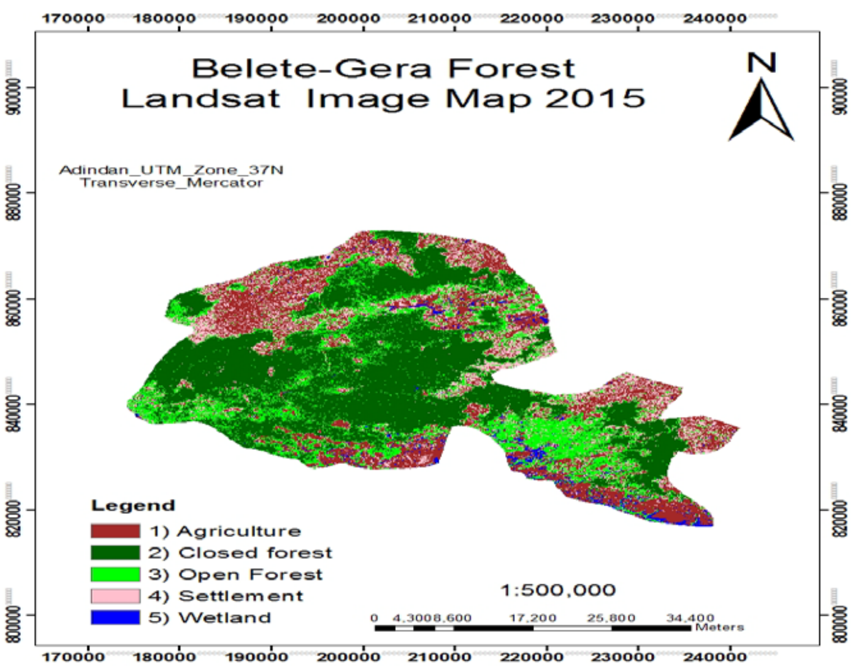

Fig.7: Landsat image Map of Belete-Gera Forest 2015

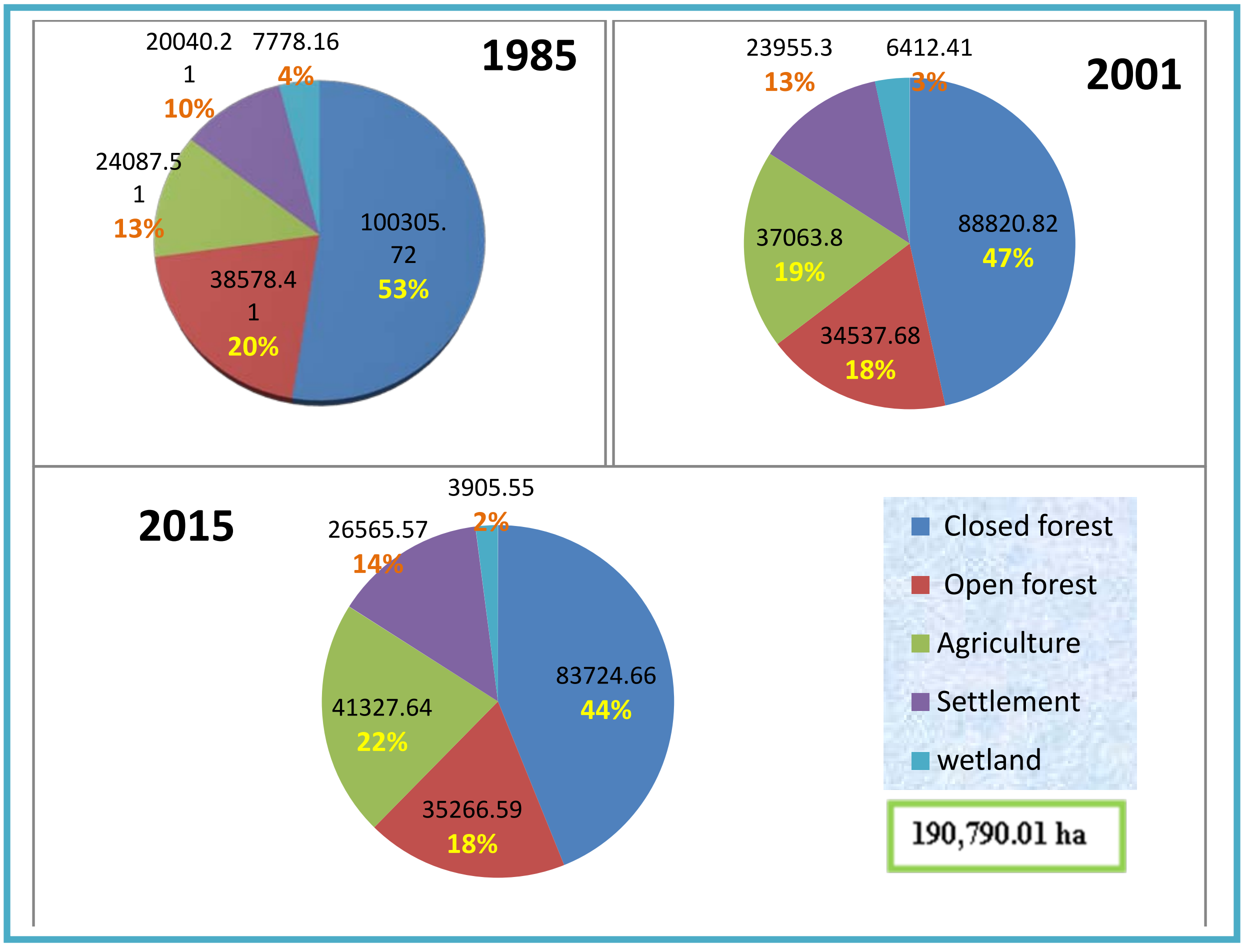

Figure 8: Belete-Gera forest LU/LC classification results of 1985, 2001 & 2015

The above Figure depicited that in 1985 majority of the study area was under closed forest and open forest accounted for 100,305.72ha (53%) and 38,578.41ha (20%), respectively. While, agriculture, setttlement and wetland accounted for 24087.51 ha (13%), 20,040.21ha (10%), and 7778.16ha (4%), respectively.

In 2001, closed forest and agriculture were the first and the second LU/LC types which amounted to 88,820.82ha (47%) and 37,063.8ha (19%), respectively. The rest LU/LC types open forest, setttlement and wetland accounted for 34,537.68ha (18%), 23,955.3ha (13%), and 6,412.41ha (3%), respectively. Meanwhile, in 2015, closed forest and agriculture were still the dominant LU/LC types which accounted for 83,724.66ha (44%) and 41,327.64ha (22%), respectively. The rest LU/LC types open forest , settlement and wetland accounted for 35,266.59

ha (18%), 26,565.57 ha (14%), and 3,905.55 ha (2%) , respectively. As previous periods, most portion of the study area was under closed forest.

4.2. Classification accuracy

Based on the rsult assessement of the Landsat image of TM 1985, ETM^+ 2001 and ETM^+ 2015 the Producer accurecy, user accuracy, overalla accuracy and kappa statistics of the study area is given in Table 5 .

Table 5:-Classification accuracy of land sat image of 1985, 2001 and 2015

No	Land Class Type	year					
		1985		2001		2015	
		Producer accuracy	**User accuracy**	**Producer accuracy**	**User accuracy**	**Producer accuracy**	**User accuracy**
1	Agriculture	87.5	71.4	70	82.4	87.5	83.3
2	Closed Forest	94	92.2	88	86.3	98	92.5
3	Open Forest	75	85.7	72.5	70.7	95	92.7
4	Settlement	72.5	78.4	90	75.0	95	92.7
5	Wet land	93.3	100	80	92.3	76.7	100
Overall accuracy		***84.5%***		***80.5%***		***91.5%***	
Kappa coefficient		***0.81***		***0.75***		***0.89***	

The above table showed that overall classification accuracy and Kappa coefficient of Landsat image TM of year 1985 was 84.5% and 0.81, respectively. The Kappa coefficient indicated that the classified image showed good classification performance or good agreement (> 0.80). Kappa values of more than 0.80 indicate good classification performance; between 0.40 and 0.80 indicate moderate classification performance and Kappa values of less than 0.40 indicate poor classification performance (Jensen, 2005; Kiefer and Lillesand, 2004). Except agriculture, Producer accuracy of the all land use classes is greater than or equal to 75 % (Annex 1, accuracy assessment of 1985).

The overall classification accuracy and Kappa coefficient of landsat image ETM^+ of year 2001 was 80.5% and 0.75, respectively. The Kappa coefficient indicated that the classified images showed moderate classification performance or moderate agreement. Except agriculture and open forest, the rest land use classes have high producer accuracy which was greater than 80% (Annex 2, accuracy assessment of 2001).

The overall classification accuracy and Kappa coefficient (Statistics) of Landsat image ETM^+ of year 2015 is 91.5% and 0.89, respectively. The Kappa coefficient indicated that the classified image showed good classification performance or good agreement. All land use classless has produce accuracy of greater than 75%, and user accuracy greater than 80% (Annex 3, accuracy assessment of 2015).

4.3. Forest covers change detection

Table 6: LU/LCs change detection in three periods

Land Class type	Change detection								
	1985-2001			2001-2015			1985-2015		
	Area (ha)	%	Change rate /year	Area(ha)	%	Change rate /year	Area(ha)	%	Change rate /year
1) Closed forest	-11485	-11.5	-765.67	-5096.2	-5.71	-339.75	-16581.1	-16.5	-552.70
2) Open forest	-4040.7	-10.5	-269.38	728.91	2.1	48.59	-3311.82	-8.6	-110.39
3) Agriculture	12976.3	53.9	865.09	4263.84	11.5	284.26	17240.1	71.6	574.67
4) Settlement	3915.09	19.5	261.01	2610.27	10.9	174.02	6525.36	32.6	217.51
5) wetland	-1365.8	-17.6	-91.05	-2506.9	-39.1	-167.13	-3872.61	-49.8	-129.09

Negative loss, but positive gain in area coverage

The above table shows that when the 2001 classification compared with 1985, agriculture and settlement were increased by 12976.3ha (53.9%) and 3915.09(19.5%), respectively. On the other hand, closed forest, open forest and wetland were decreased by 11485ha (11.5%), 4040.7ha (10.5%) and 1365.8ha (17.6%), respectively.

When the 2015 classification compared with 2001, open forest, agriculture and settlement were increased by 728.91ha (2.1%), 4263.84ha (11.5%) and 2610.27ha (19.5%), respectively. On the other hand, closed forest and wetland were decreased by 5096.2ha (5.7%) and 2506.9ha (39.1%), respectively.

Finally, when the 2015 classification compared with 1985, agriculture and settlement LU/LC was increased by 17240.13ha (71.6%) and 6525.36ha (32.6%), respectively. Whereas, closed forest, open forest and wetland was decreased by 16581.06ha (16.5%), 3311.82ha (8.6%), and 3872.61ha (49.8%), respectively. The detail analysis of the conversion of one land use type to other land use type was described on change detection matrices which depict the changes in extent and directions in land use classes (Table 7, 8 and 9).

Table 7:Change detection matrix of 1985 to 2001

	Final state (2001)												
Initial state (1985)	Class type	Agriculture		Closed Forest		Open Forest		Settlement		Wet land		Class total	
		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
	1) Agriculture	**20299.06**	**84.3**	234.09	1.0	133.27	0.6	2466.88	10.2	954.26	4.0	24087.56	100
	2) Closed Forest	1457.41	1.5	**86121.12**	**85.9**	12337.3	12.3	389.85	0.4	0	0.0	100305.7	100
	3) Open Forest	11186.55	29.0	2457.91	6.4	**21650.59**	**56.1**	2645.68	6.9	637.65	1.7	38578.38	100
	4) Settlement	1242.01	6.2	0	0.0	416.5	2.1	**18381.7**	**91.7**	0	0.0	20040.21	100
	5) Wet land	2878.82	37.0	7.65	0.1	0	0.0	71.19	0.9	**4820.5**	**62.0**	7778.16	100
	Class total	37063.85		88820.77		34537.66		23955.3		6412.41		190790	100

Table 8 change detection matrix 2001-2015

	Final state (2015)												
Initial state (2001)	Class type	Agriculture		Closed Forest		Open Forest		Settlement		Wet land		Class total	
		Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
	1) Agriculture	**31876**	**86.0**	39.6	0.1	245.87	0.7	4587.34	12.4	315.09	0.9	37063.85	100
	2) Closed Forest	16.74	0.0	**81272.3**	**91.5**	6966	7.8	510.52	0.6	55.26	0.1	88820.77	100
	3) Open Forest	6482.19	18.8	2409.7	7.0	**24652**	**71.4**	910.67	2.6	83.11	0.2	34537.66	100
	4) Settlement	0	0.0	3.11	0.0	3395.15	14.2	**20557.1**	**85.8**	0	0.0	23955.33	100
	5) Wet land	2952.81	46.0	0		7.51	0.1	0	0.0	**3452.09**	**53.8**	6412.41	100
	Class total	41327.69		83724.66		35266.52		26565.60		3905.55		190790.02	

Table 9: Change detection matrix of 1985-2015

		Final state (2015)											
Initial state (1985)	Class type	Agriculture		Closed Forest		Open Forest		Settlement		Wet land		Class total	
		Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
	1) Agriculture	**20554.4**	**85.3**	279.9	1.2	2737.89	11.4	477.85	2.0	37.52	0.2	24087.56	100
	2) Closed Forest	2249.8	**3.2**	**82213.43**	82.0	14456.9	14.4	1189.49	1.2	196.11	0.2	100305.7	100
	3) Open Forest	11453.61	29.7	1213.69	3.1	**17956.82**	**46.5**	7499.79	19.4	454.5	1.2	38578.41	100
	4) Settlement	3132.93	15.6	0	0.0	114.99	0.6	**16792.29**	**83.8**	0	0.0	20040.21	100
	5) Wet land	3936.95	50.6	17.64	0.2	0	0.0	606.15	7.8	**3217.42**	**41.4**	7778.16	100
	Class total	**41327.69**	**102.4**	**83724.66**		**35266.6**		**26565.57**		**3905.55**		**191790.1**	**100**

4.4. Change detection comparisons

4.4.1. Closed forest

In the first 15 years (1985-2015), closed forest decreased by 11,485ha (11%) (Table 6). The change detection matrix analysis showed that 12,337.3ha (12.3%) of closed forest was converted to open forest (Table 7). The average rate of change was 822.49 ha/year. The change was induced by anthropogenic factors like extraction of woody forest products (illegal logging, commercial logging, pit sawing, fuel wood, agricultural tools and construction materials), and free grazing in Belete-Gera forest (FGDs).

In the second 15 years (2001-2015), closed forest further decreased by 5096.2ha (5.7%) and converted to other land use types (Table 6). The change detection matrix analysis depicted that as first 15 years, most of the closed forest was converted to open forest than other land use types amounted to 6,966ha (7.8%) (Table 8). Its average rate of change was 464.4ha/year. When this rate of change compared with the first 15 periods, it was decreased by 358.09 ha/year.

Meanwhile, in 30 years period of comparison (1985 to 2015), Belete-Gera closed forest decreased by 16581.1ha (16.5 %). The 30 years change detection matrix analysis showed that as the first and second 15 years, most of the closed forest was converted to open forest amounted to 14,456.9 ha (14.4%) (Table 9). Its average rate of change was 481.9 ha/year.

Fig. 9: Belete-Gera closed natural forest

4.4.2. Open forest

In the first 15 years, open forest decreased by 4040.73ha (11.5%) (Table 6). Based on change detection matrix of the first 15 years, 11,186.55ha (29%) and 2,645.68ha (6.9%) of open forest was converted to agriculture and settlement, respectively (Table 7). Their average rate of change was 745.77ha/year and 176.38 ha/year, respectively. This indicated that agricultural expansion and illegal settlement was mostly undergoing within open forest than closed forest land.

Whereas, in the second 15 years, open forest increased in small amount by 728.91ha (2%) (Table 6). This is because of the amount of closed forest converted to open forest was greater than the amount of open forest converted to agriculture or other land use types (Table 8). Based on the change detection matrix analysis, 6482.19ha (18.8%) and 910.67ha (2.6%) of open forest was converted to agriculture and settlement, respectively (Table 8). Its average rate of change was 432.15ha/year and 60.71 ha/year, respectively. This indicated that agricultural expansion and illegal settlement was mostly undergoing in open forest rather than other land uses categories.

The third comparison made during 1985 to 2015 showed 3,311.82ha (8.6%) of open forest reduced and converted to other land use types (Table 6). The change detection matrix analysis showed that within 30 years, 11,453.61ha (29.7%) and 7499.79ha (19.4%) of open forest was converted to agriculture and settlement, respectively (Table 9). The average rate of change of open forest to agriculture and settlement was 381.79ha/year and 250 ha/year respectively.

Fig. 10: Belete-Gera opens natural forest

4.4.3. Agriculture

In the first 15 years, agricultural land increased by 12976.3ha (53.9 %) (Table 6). The change detection matrix analysis depicted that there is high agricultural land expansion to open forest, closed forest and wetland amounted to 11,186.55ha, 1457.41ha and 2,878.82ha, respectively (Table 7). On the other hand, in this period, 2,466.88ha (10.6%) of agricultural land was converted to settlement.

In the second 15 years, agricultural land further increased by 4263.84ha (11.5 %) (Table 6). Based on change detection matrix analysis in this period as the first 15 years, high agricultural land expansion was occurred to open forest and wetland amounted to 6,482.19ha and 2952.81ha, respectively (Table 8). On the other hand, 4587.34ha (12.4%) of agricultural land was converted to settlement.

The third comparison made during 1985 to 2015 described that within 30 years agricultural land was increased by 17,240.1ha (71.6%) (Table 6). The change detection matrix analysis showed that in this periods, agricultural land was highly expanded to open forest, wetland and closed forest amounted to 11453.61ha, 393695ha and 3249.8ha respectively (Table 9).

Fig. 11: Agricultural lands in & around Belete-Gera forest

4.4.4. Settlement.

In the first 15 years, settlement increased by 19.5% (Table 6). The change detection matrix analysis showed that in this period high settlement was undergoing with in open forest and agricultural land amounted to 2645.68ha and 2466.88ha, respectively (Table 7).

The second comparison, in the second 15 years, settlement further increased by 10.9% (Table 6). The change detection matrix analysis showed that settlement was mostly expanded to agriculture land rather than other land use types amounted to 4587.34ha (Table 8).

Meanwhile, within 30 years, settlement increased by32.6 % (Table 6). In this period 7499.79ha of open forest, 1189.49 ha of closed forest and 477.85ha of agricultural land were converted to settlement (Table 9).

Fig. 12: Settlement in and around Belete-Gera forest.

4.4.5. Wetland

In the first 15 years, wetland decreased by 17.6 %(Table 6). The change detection matrix analysis illustrated that in this period 2,878.82ha or 37 % of wetland was converted to agricultural land (Table 7). Annually, 91.07 ha of wetland converted to agriculture (Table 7). As discussed in open forest, the main cause of shrinkage of wetland was expansion of agricultural land to wetland.

In the second 15 years, wetland further decreased by 39.1% (Table 6). Based on the change detection matrix analysis described that 2952.81ha or 46 % of the wetland was converted to agriculture (Table 8). When compared to the first 15, the rate of change increased by 105.75ha/year. This indicated that high population growth and scarcity of agricultural land resulted in high expansion of agricultural land to wetland.

The third comparison from 1985 to 2015 within 30 years 3,872.61ha (49.8%) wetland was converted to other land use system (Table 6). The change detection matrix analysis showed that in 30 years study period 3,936.95ha or 50.6 % of wetland was converted to agriculture (Table 9)

Fig. 13: Wetland converting to agricultural land

4.5. Deforestation rate of Belete-Gera forest

Both closed and open forests are categorized under forest LU/LC, but agriculture, settlement and wetland are categorized under non forest LU/LC.

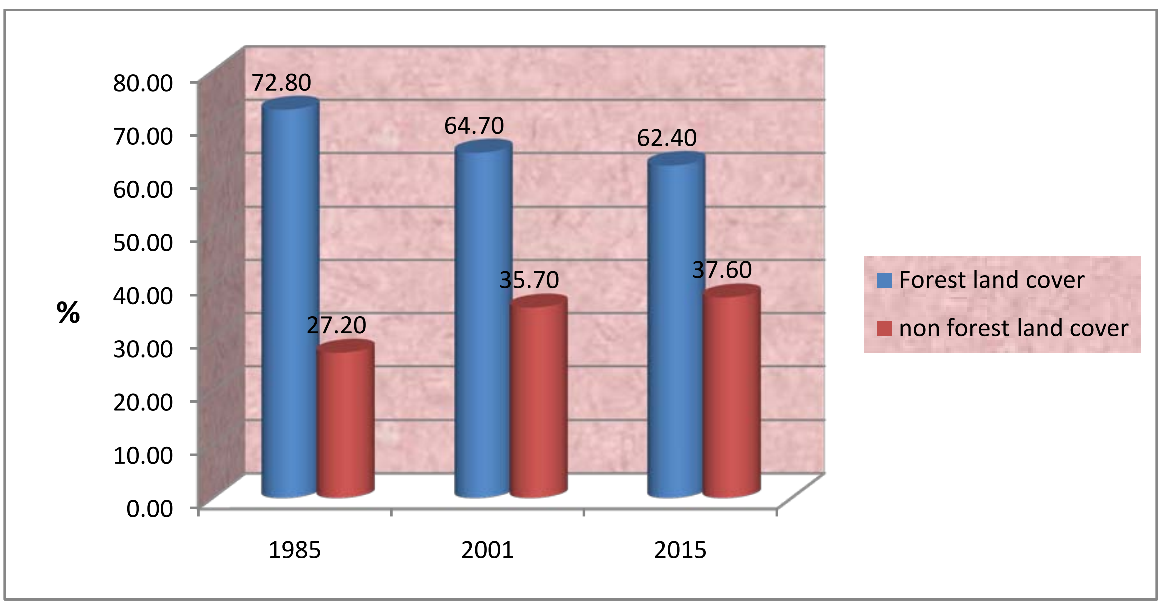

Fig. 14: Belete-Gera forest & non forest LU/LC in 1985, 2001 and 2015

The above figure depicted in 1985, 72.8% of the study area was covered by forest. Whereas, 27.2% of the study area was occupied by non forest land categories like agriculture, settlement and wetland. After 15 years, in 2001 the forest LU/LC of the study area was further decreased to 64.7%. In this period about 6.9% of Belete-Gera forest was deforested and converted to other land use types.

Meanwhile, after the second 15 years, in 2015, forest LU/LC of the study area was declined to 62.4%. In this period 2.3% of forest land was converted to other land use types. When compared to the first 15 years, deforestation rate of Belete-Gera forest was decreased by 71.9%. Assessment of annual deforestation rate of Belete-Gera forest is given on Fig. 15.

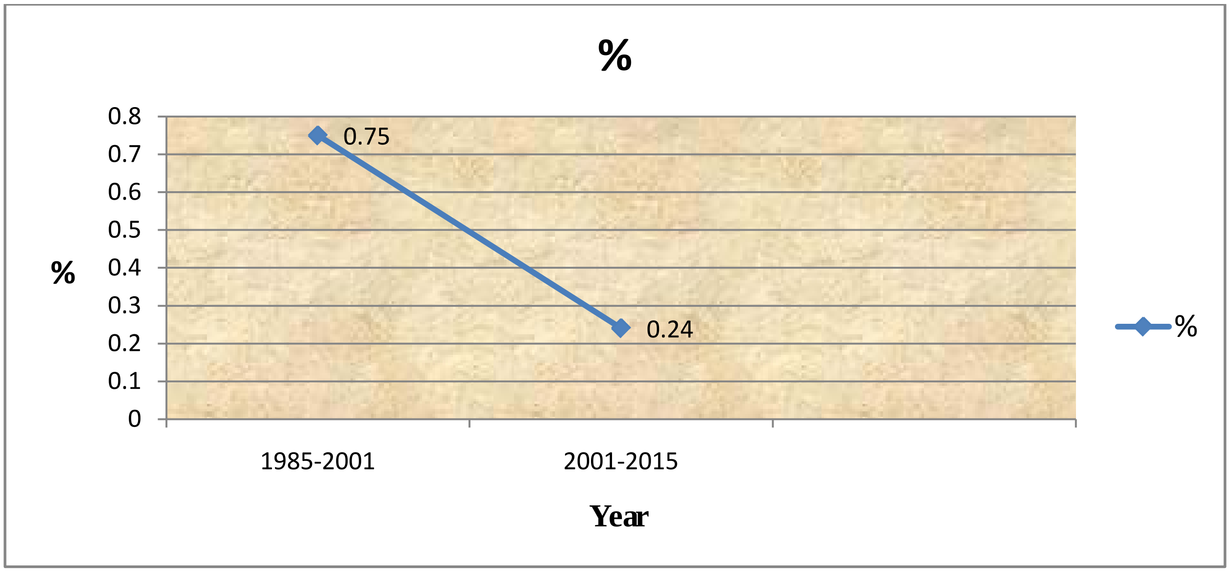

Fig. 15; percent of annual deforestation rate of Belete-Gera forest

The above figure illustrated that, percent of annual deforestation rate of Belete-Gera forest in the first (1985-2001) and second 15 year (2001-2015) is 0.75% and 0.24%, respectively. In the second 15 years annual deforestation rate of Belete-Gera forest decreased from 0.75% to 0.24%. Whereas, 30 years annual deforestation rate of Belete-Gera forest is 0.48%, which is lower than the deforestation rate assessment done by World Bank (2005), Ethiopia‘s annual deforestation rate of 0.8% is similar to low income countries as a whole. Similarly, according to FAO (2010), annual deforestation rate of Ethiopian forest is 0.96%. But the WBISPP (2005) indicated the actual deforestation rate of Ethiopia forest may be close to 2%. Therefore, in Ethiopia, different authors outlined different rate of annual deforestation. Hence, Belete-Gera forest annual deforestation rate is the least of all.

The causes of high deforestation rate of Belete-Gera forest in the first 15 year is the political vacuums occurred during government transition periods in 1991 are occasional events with pervasive and extreme impacts on deforestation. During Ethiopian government transition period (1991-1995) Belete-Gera forest was highly deforested by agricultural expansion, illegal settlement and extraction of woody forest products (FGD). This is in line with Bekele (2003), Ethiopia transition periods are typically when massive resettlement and deforestation takes place, drastically changing the forest frontier and setting the stage for ensuing deforestation processes. For example, 71% of the forestlands of a state owned forest enterprise were converted to farmlands during the 1991 government change, resulting in settlements and agricultural activities deep inside the forest proper (Dessie, 2007)

However, in the second 15 period annual deforestation rate of Belete-Gere forest was decreased by 71.9%. This is due to forest policy formulation and implementation, PFM implemented in Belete-Gera forest and establishment of Oromia Forest and Wildlife Enterprise.

Even if Oromia Forest Proclamation 72/2003 is not fully implemented, it has positive impact on reducing deforestation by giving great impasses on;

- Provides for three types of forest ownership, state, communal and private forest
- List down endangered species of indigenous tree species(*Juniperus procera (Cupressaceae), Podocarpus gracilor (podocarpceae), Hagenia abyssinica (Rosaceae), Aningeria adolfi-frienderici, and Cordia Africana (Boraginacea)*
- Explicitly provide that anyone who develops forests on his\her holding shall have full rights of using such forests.
- Provide the prohibition of clearing forest in order to plant coffee and practicing agricultural activities.

Since 2003, Participatory Forest Management (PFM) has been implementing in Belete-Gera forest. The community based organization (CBO) called WaBuB that takes over the responsibility and accountability of managing Belete-Gera forest. WaBuB is abbreviation for "Walda Bulchiinsa Bosonaa" in afaan oromoo, meaning "Forest Management Association. According to Mulugeta Lemenih & Alemayehu Negassa (2012), after PFM was implemented in

Belete-Gera forest illegal logging from the forest, agricultural expansion in to forest boundary, incidence of forest fire, overgrazing in the forest and pressure on wildlife was decreased. In contrary tree planting in homestead, regeneration status, forest protection and management of Belete-Gera forest was highly increased.

Oromia Forest and Wildlife Enterprise (OFWE) which was recognized by Regulation No 122/2009 has defined state forest as "any protection or production forest, high-forest or woodland, demarcated or non-demarcated forest, and includes lowland and highland bamboo, incense and gum, and all owned by the Regional Government of Oromia. Since, OFWE has been established both plantation and natural forest boundary of Belte-Gera forest was demarcated and secured from illegal activities. Belete-Gera forest development and management activities also improved since OFWE has been well-known. Therefore, OFWE Jimma Brach office which has been working on Belete-Gera forest has made great contribution in reducing Belete-Gera forest deforestation

4.6. Driving forces of Belete-Gera forest LU/LC change

After making the series of interviews and discussions conducted with the households, respondents pointed out that four direct and four indirect interlinked major driving forces Belete-Gera forest cover change appear to explain a large part of the study area. These driving forces are in agreement with those identified by Ethiopia Woody Biomass Inventory and Strategic Planning Project (1990) estimated that up to 15% of Ethiopia was forested. Since then more than 2 million hectares have been lost. These forest losses are driven by household needs for fuel wood, construction materials, agricultural land and livestock grazing. Combined with rapid population growth, the pressure on Ethiopia's forests are high and intensifying. Summary of drivers of Belete-Gera forest cover changes is given in Table 10.

Table 10: Drivers of Belete-Gera forest LU/LC change

No	Driving forces	Respondents & Values	Level of impacts					total
			5	4	3	2	1	
1.	Agricultural expansion	Respondents	133	30	9	4	0	**176**
		%	0.76	0.17	0.05	0.02	0	**1**
		Value	3.78	0.68	0.15	0.05	0	**5**
2.	Illegal settlement	Respondents	19	120	21	11	5	**176**
		%	0.11	0.68	0.12	0.06	0.03	**1**
		Value	0.54	2.73	0.36	0.13	0.03	**4**
3.	Woody forest product extraction	Respondents	0	23	137	11	5	**176**
		%	0	0.13	0.78	0.06	0.03	**1**
		Value	0	0.52	2.34	0.13	0.03	**3**
4.	Free grazing	Respondents	0	4	7	15	150	**176**
		%	0	0.02	0.04	0.09	0.85	**1**
		Value	0	0.09	0.12	0.17	0.85	**1**
5.	Population growth*	Respondents	9	21	109	32	5	**176**
		%	0.05	0.12	0.62	0.18	0.03	**1**
		Value	0.26	0.48	1.86	0.36	0.03	**3**
6.	Poor governance and/or institution*	Respondents	0	10	11	127	28	**176**
		%	0	0.06	0.06	0.72	0.16	**1**
		Value	0	0.23	0.19	1.44	0.16	**2**
7.	Accessibility*	Respondents	0	2	6	18	150	**176**
		%	0	0.01	0.03	0.10	0.85	**1**
		Value	0	0.05	0.10	0.20	0.85	**1**
8.	Low awareness *	Respondents	0	5	8	18	145	**176**
		%	0	0.03	0.05	0.10	0.82	**1**
		Value	0	0.11	0.14	0.20	0.82	**1**

*Indirect driving forces

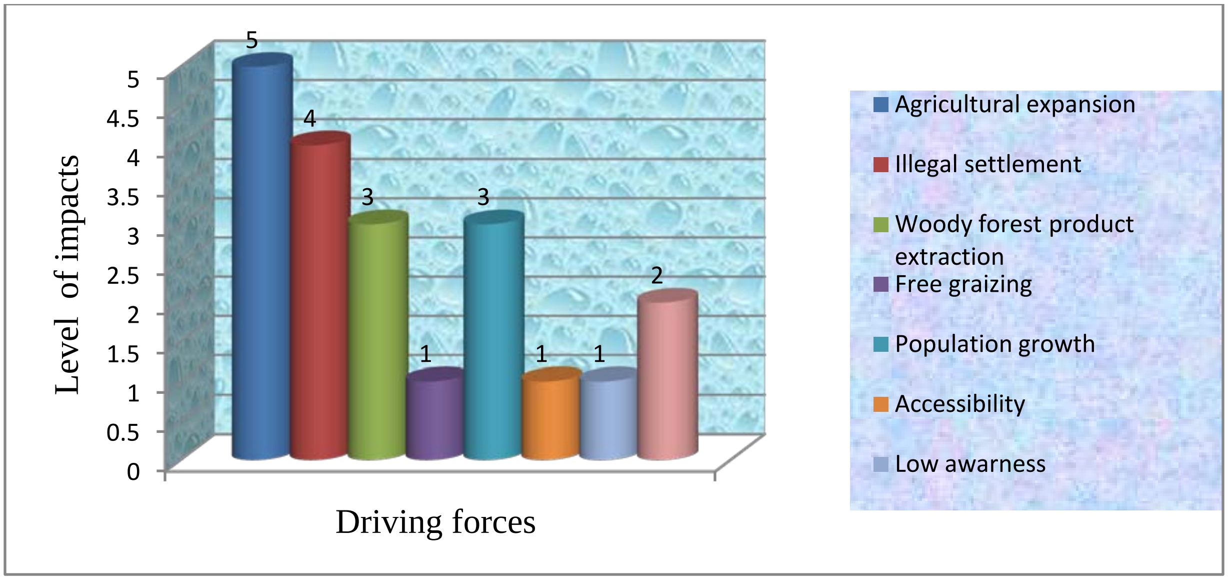

Fig. 16: Driving forces of Belete-Gera forest cover change

Note; *5 = Very level high impact (81-100%),* *2 = Low level impact (21-40%),*

4 = High level of impact (61-80%), *1 = Very level low impact (1-20%)*

3 = Medium level of impact (41-60%),

4.6.1. Direct drivers

The direct drivers of Belete-Gera forest cover change which accounted for 65 % the total driving forces are agricultural expansion, illegal settlement, and extraction of woody forest product and free grazing in natural forest.

a. Agricultural expansion

Figure 16 illustrated agricultural expansions is the first and the main driving force which has very high level impact (81-100%) on reducing Belete-Gera forest cover changes. The 30 years (1985-2015) change detection matrix analysis showed that 11,453.61ha of open forest and 3,249.8ha of closed Belete-Gera forest was converted to agricultural land (Table 9). The expansion of croplands to forest and marginal lands, including continuous and over cultivation, has resulted in shrinking Belete-Gera forest cover. This is in line with driving forces of tropical deforestation reported by Geist and Lambin (2001) the expansion of cropped land and pasture is, by far, the leading proximate cause of tropical deforestation. It was found to lead to deforestation (96%). Similar, the WBISPP (2004), forest clearance for agricultural expansion is the main direct cause of deforestation. De Sherbinin (2002) also reported that even though; agricultural expansion is the dominant proximate cause for LU/LC change, the tropical deforestation caused by multiple factors rather than single variables. Therefore, humans habitual abuse of the precious forest resource knowingly or unknowingly for immediate economic use (mainly to secure ample cultivated lands) by ignoring the facts of their ecological as well as environmental values of forest, and converting forest to agricultural land.

Fig. 17: Agricultural land expansion to open Belete-Gera natural forest

b. Illegal Settlement.

Illegal settlement is the second driving force which has high level of impact (61-80%) on decreasing Belete- Gera forest cover changes (Fig. 16). The 30 years change detection matrix analysis of Belete-Gera forest cover change pointed out that, 7,499.79ha of open forest and 1,189.49ha of closed forest was converted to settlement (Table 9. High illegal settlement was carried out with in Belete-Gera natural forest especially during transitional period of Ethiopian government (1991-1995) (FGD).

Fig. 18: Illegal settlement in Belete-Gera natural forest

c. Woody forest product extraction

Woody forest products extraction is the third driving force which has medium level of impact (41-60%) on decreasing of Belete-Gera forest cover changes (Fig. 16). People living within and around Belete-Gera forest uses woody forest products for subsistence purposes like for house construction, household furniture making, agricultural tools making, fence construction, and for fuel wood as energy source. These woody forest products were extracted from forest either legally or illegally. Illegally pity sawing which was produced from endangered tree species like *Cordial african* and *Aningeria adolfi-friendererici was* highly carried out in Belete-Gera natural forest. This is in line with driving forces of tropical deforestation reported by Geist and Lambin (2001) the extraction of wood or timber, be it clear-cutting or selective timber logging, occurs in more than half (52%), while the impact of fuel wood extraction (28%), pole wood extraction(20%), and charcoal production (10%) tend to be lower.

.

According to local household perceptions, in the past 30 years, the density endangered tree species of Belete-Gera forest has been decreased by more than 50 %. Extraction of woody forest products would affect the density of closed forest, and increases the probability of closed forest has been converted to open forest. The LU/LC change detection matrix analysis depicted that, within 30 years 14,456.9ha of closed forest was converted to open forest (Table 9).

Fig. 19: Illegal logging and fuel wood extraction in Belete-Gera natural forest

d. Free grazing

Free grazing is the last direct driving force which has very low level of impact (1-20%) on reducing of Belete-Gera forest cover changes. As described in study area description, the main livelihood of local household is mixed farming (agriculture with livestock). Livestock is an integral part of the cropping system in the study area. Peoples living in the high land of study area have large number of livestock and experienced free grazing in Belete-Gera natural forest. Free grazing has brought trampling and dying of naturally regenerated different tree seedlings. When naturally generated tree seedlings have been suppressed and died by livestock, through time closed forest has been converted to open forest. This is agreed with FAO (2003), estimated that over 80% of livestock are found in the high land of Ethiopia, causing widespread overgrazing and land degradation on both arable and grazing lands. The low survival of planted seedlings in re-afforestation programs are lead to deforestation.

Fig. 20: Animals free grazing in Belete-Gera open natural forest

4.6.2. Indirect drivers

Four in direct driving forces of Belete-Gera forest cover changes identified in the study area which accounted for 35 % total driving forces are population growth, accessibility, low awareness and poor governance and/ or intuitional. This is in line with Geist and Lambin (2001) at the broad aggregate level, it is striking that synergetic driver combinations rather than single variables are associated with tropical deforestation

a. Population growth

Population growth is the first indirect driving force which has medium level of impact (41-60%) on reducing Belete-Gera forest cover changes (Fig. 16). Population growth leads to an increasing demand for agricultural land, which usually ends up in converting more forest land into farmland/grazing land. Many farmers (probably the poorest) use areas that are highly susceptible to degradation (and should not be used for agriculture). Once the productivity of their land falls below acceptable levels, they move to new, mostly forestland that is marginal for agriculture until they have to move again. Substantial increases in demand for food have resulted in an expansion of croplands by encroaching on uncultivated areas, including closed forest, open forests and marginal lands. This is in line with Hylander et al. (2013), increasing population growth increases pressure on forest resources. Similarly, a recent study in developing countries by Jorgenson and Burns (2007) linked rural population growth to higher rates of deforestation. According to Geist and Lambin (2001) 51% tropical forest deforestation was driven by demographic factors.

Both the gradual, slow process of natural population growth and the rapid, drastic population increase following internal migration and settlement around forest areas are important underlying forces (Dessie and Christiansson, 2008; Mulugeta, 2011). Such continued population pressure on forest resources reflects the fast population growth unmatched by growth in agricultural productivity. Rapid population growth has triggered the transformation of forest resources in many parts of the world into other forms of agriculture. Accompanying this transformation are the problems of socioeconomic degradation and other natural systems from global warming (IPCC, 2001b).

b. Poor governance and/or institution

Poor governance and/or institution is the second indirect driving force which has low level negative impact (21-40%) on shrinkage of Belete-Gera forest cover changes (Fig.16). The role of local governance and institutions found in the study area play in implementing the policies and legislation to protect and/or sustainably manage forests can be considered a potential indirect driver of Belete-Gera forest cover changes. They are facing a low good governance and enforcement of policies and laws. This leads to accelerating deforestation activities, such as illegal logging, encroachment within natural forest, high agricultural expansion into natural forest, unsustainable forest management, etc. Forest regulations are generally not strictly followed. Law enforcement is loose particularly at the lower administrative levels. There is an urgent need for increased accountability and transparency in forestry governance. Clear objectives for forest management undertakings are also missing. Access to available technical knowledge is very limited. There is a lack of even the most basic databases to base decisions on in relation to forest management policies and regulations.

This agreement is in line with Demel Teketay and Tesfaye Bekele (2005), the organizational tradition of the Forest Service in Ethiopia is characterized by frequent restructuring. This has led to a fast turn-over of staff, low morale of employees, discontinuation of programs and projects, confusion of responsibilities and mandates, misplacement of documents and files resulting in loss of institutional memories, and progressive weakening of operations. The good intentions for a better integration of forestry and agriculture so as to create synergy, has resulted in less attention to forestry due to sectoral competition for scarce resources.

In the study area problems related to poor forest governance and/or institution are:-

- Lack of clarity and implementation of the existing forest rules and regulations.
- Lack of transparent, accountable, capable and competent public forest service (lack of proper and strong forest organization at different levels).
- Problems related to cross-sect oral linkages of forestry
- Incompatibility and conflicts of interest between forestry and other sectors mainly agriculture, settlement, and investment. Agriculture is continued to be horizontally expanded at the expense of forest and vegetation resources.
- Although, there is no policy in Ethiopia which is irrelevant to forestry, no sector has tried to integrate itself with forestry.
- As the result, there is lack of transparency, coordination, and integration among forest related sectors and lack of collective effort of relevant sectors against deforestation.

Therefore, the problem of poor governance and/or institution was seen mostly before eight years ago. But now, after PFM and OFWE have been established in Belete-Gera forest, the problem of poor governance and/or institution has been much decreased (FGD).

c. Accessibility

Accessibility is the third indirect driving force which has very low level of negative impact (1-20%) on shrinkage of Belete-Gera forest cover changes (Fig.16).Accessibility means the access of Belete-Gera forest to existing transportation site. High deforestation rate was observed in the area where the forest is more than 20km far away from available access roads. In the inaccessible area where out of reach of governmental bodies for supervision and to carry out different forest management activities, farmer's has been converted large area of natural forest to agricultural land. This is observed especially in the high land area of (greater than 2200m) Belete-Gera forest where agricultural activities highly carried out.

d. Low awareness

As accessibility, law awareness is the third driving force which has very low level of negative impact (1-20%) on shrinkage of Belete-Gera forest cover changes (Fig.16). Because of low education background (40.8%) of population in the study area, and low aware of the economical, ecological and environmental consequences of deforestation, they considered natural forest as west land and illegally encroached in natural forest.

4.7. Socio-economic survey

4.7.1. Family size

The result of the assessment of family size per household of the study area is given on Fig. 21

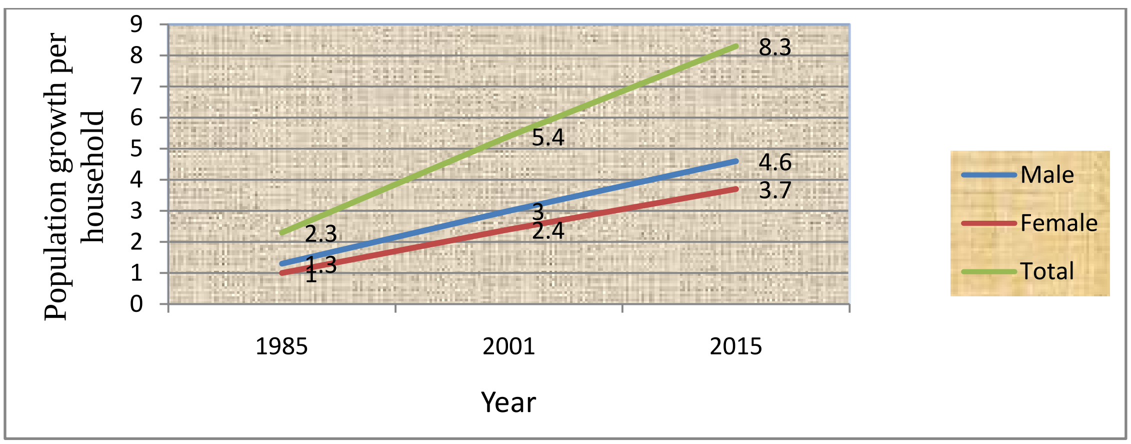

Fig. 21: Family size per household of the study area

The above figure illustrates family size of the study area per household has been increased from time to time. In 1985, 2001, and 2015 percent of male population is 56.5%, 55.5% and 55.5%, respectively. This shows male is the dominant population in the study area.

An average family size per household of the study area is 2.3, 5.4 and 8.3 in 1985, 2001 and 2015 years, respectively. This argument is in line with CSA of 2007, the total number of household in Jimma Zone can be classified in to urban and rural households. That estimate number of households are 672432 in 2001 and 6970350 in 2002. The average family size per the household is 4 and 5 of urban and rural. Therefore, an increasing family size per household of the study area, confirms population growth is one the underlying driving force of Belete-Gera forest LU/LC change.

4.7.2. Land holding

The assessment of average land holding in hectare (ha) per household and per family size of year 1985, 2001 and 2015 is given on Fig. 22.

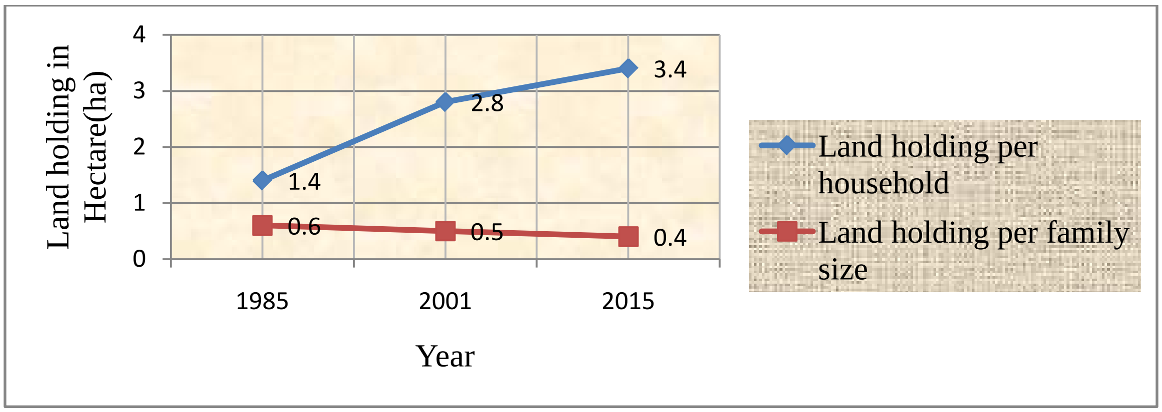

Fig. 22: an average land holding per household in hectare (ha)

The above figure illustrates an average land holding per household in 1985, 2001 and 2015 was 1.4ha, 2.8ha and 3.4ha, respectively. In the first and the second 15 years, an average land holding per household was increased by 100% and 21.4%, respectively. From time to time farmers have been expanded their agricultural land to forest land which resulted in decreasing Belete-Gera forest LU/LC change. Therefore, 100% increased land holding per household in agreement with those of high deforestation rate (0.75%/year) of Belete-Gera forest which was observed in the first 15 years (Fig.15). Similarly, high agricultural land expansion was occured in the first 15 years than in the second 15 years. That means agricultural land was increased by 53.9% and 11.5% in the first and second 15 years, respectively (Table 6).

In contrary, and average land holding per family size of the study area was decreased equally by 20 % in the first and second 15 years (Fig. 22). This indicated that land holding per family size was not proportionally increased with population growth. This argument is in line with Rembold et al. (2002) noted that in the past, farmers in the lakes region of Ethiopia were able to compensate for low productivity by cropping more lands but with increasing population density the size of cropland per household is diminishing because the limits of usable land have been reached.

4.7.3.. Education level

a. Family education level

The education level of family size of the study area was classified to illiterate, elementary school (Grade 1-8), grade 9-10, preparatory school (Grade 11-12), Diploma , Degree level and above (Fig. 23).

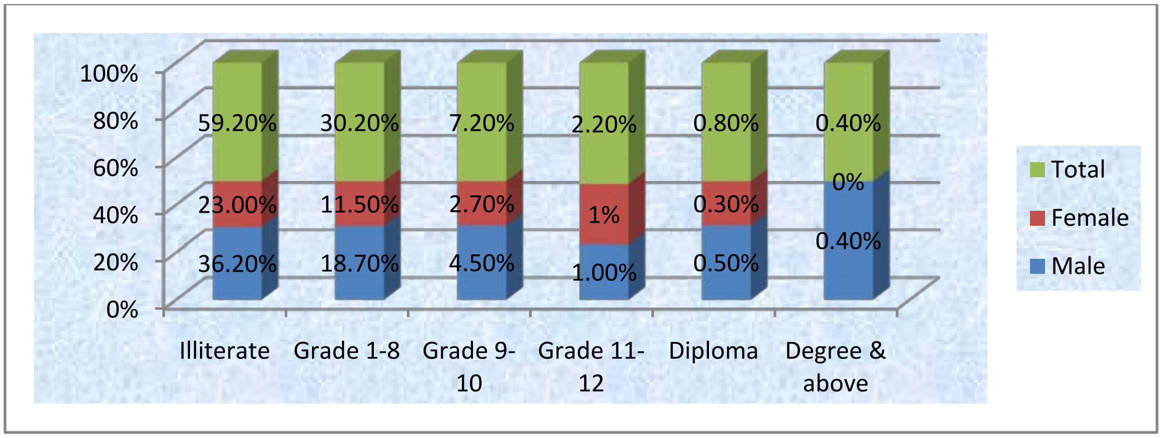

Fig. 23: Family educational level

The above figure illustrates most of population found in the study area are illiterate (59.2%). The elementary level (grade 1-8), grade 9-10 and grade 11-12 level of education is 30.2%, 7.5% and 2.2%, respectively. The Diploma and the Degree level of education is only 0.8% and 0.4%, respectively. The male and female education status of the study area is 60.5% and 39.5%, respectively. Because of the study area was dominated by cash crop (coffee and chet), most of youths gave due attention on recent income earning activities than education (FGD). Therefore, low education background of population in the study area(40.8%) leads to low aware of ecological and environmental, as well as socio-economic consequences of deforestations in the long run. .

b. Respondents education level

Educations levels of the respondents were classified to illiterate read and write .elementary school (up to grade eight) and above grade eight

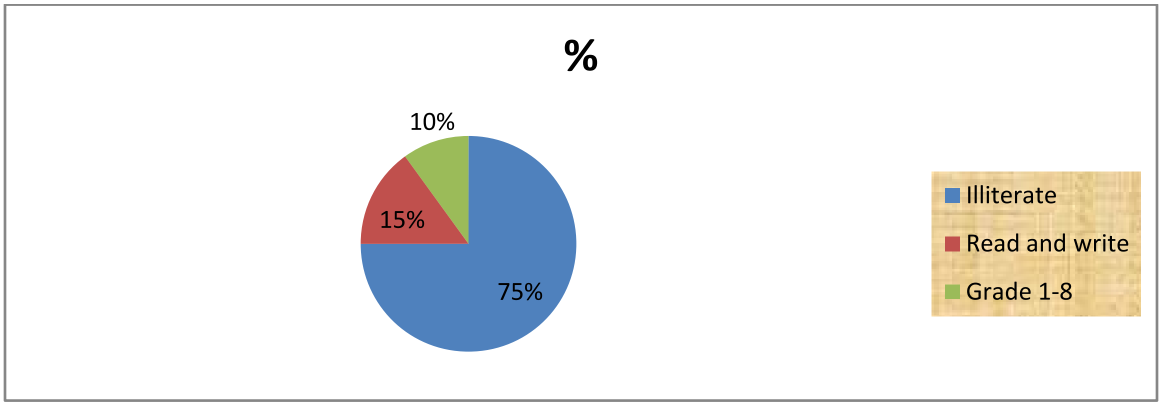

Fig. 24: Respondents education level

The above figure depicts 75% of the respondents are illiterate, whereas, 15 % only read and write. Only 10% the respondents have education level up to grade eight. This indicated that as mentioned on family education level discussion, the respondents have low knowledgeable and aware of the socio economic and ecological consequences of Belete-Gera forest deforestation.

Therefore, low education level of both respondents and family size give indication of, people living in the study area have low aware of socio-economic and ecological consequences of deforestation and degradation of Belete-Gera forest.

4.7.4. Land dependent income.

Based on socio-economic survey assessment, the main land dependent incomes of the study area are cereal crop, pulses, livestock, NTFPs (honey, coffee, bamboo, chat, spice and incense) and others (oil seed, woody forest products, fruit and vegetable). Summary of land dependent income of the study area of year 1985, 2001 & 2015 is given on Figure 25.

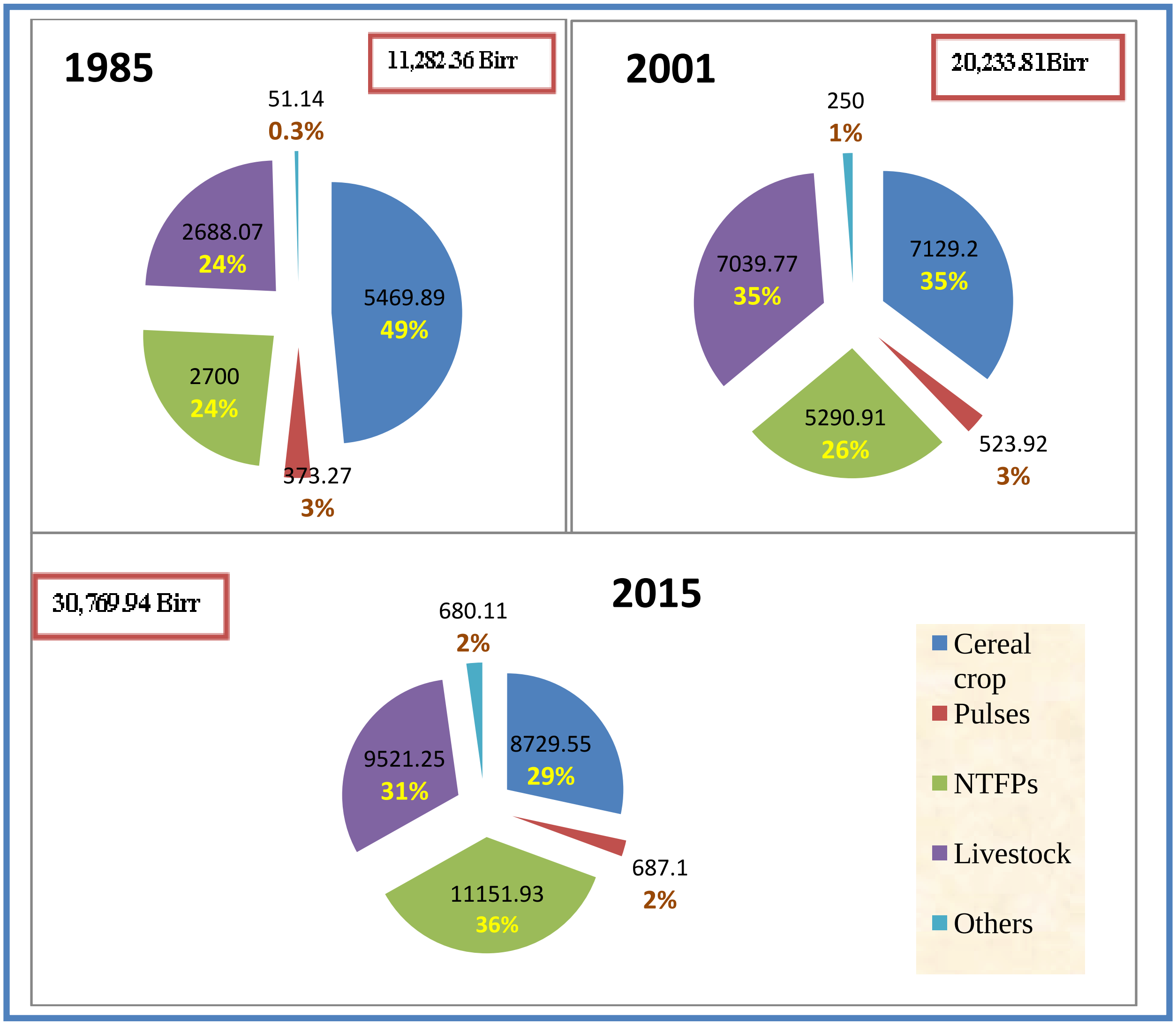

Fig.25: Annual income contribution of different land dependent incomes per household

The above Figure showed that in 1985, cereal crop income is the leading land dependent income in the study area and accounted for 49% of the total income. NTFPs and Livestock are the second and the third land dependent income, and they accounted for 24% and 24%, respectively.

In 2001, cereal crop is still the leading land dependent income, and accounted for 35% of the relative income. Livestock and NTFPs are the second and the third land dependent income, and they accounted for 35% and 26% of the relative income, respectively.

Meanwhile, in 2015 NTFPs is the leading land dependent income in the study area, and contributed to 11,151.93Birr (36%) of the relative income. Livestock and Cereal crops are the second and the third, and they contributed to 9521.25Birr (31%) and 8,729.55Birr (28%), respectively.

Even though, the land dependent income of both cereal and pulse crops have been increased in two study periods, their relative income contributions have been decreased. Cereal crops' relative income contribution decreased by 14% and 6% in the first and second 15 years, respectively. This indicated that decreasing Belete-Gera forest cover resulted in decreasing agricultural productivity of local households. This is in agreement with FAO (2000), reported that deforestation and forest degradation leads to excessive land degradation, and could lead to reduced average crop yields per unit area.

Livestock relative income contribution increased by 11% in the first 15 year, but decreased by 4% in the second 15 years. This is because of scarcity resources to accumulate large population of livestock. More than 30% total income contribution of livestock is in agreement with Ethiopian Economic Association (2000), livestock contribute about 30–35% of agricultural gross domestic product (GDP), about 13–16% of total GDP and more than 85% of farm cash income.

Therefore, decreasing Belete-Gera forest cover affect negatively the regulatory function of forest which conserves the soil fertility/productivity of the study area, which influences the productivity of agricultural crop income of local households. This leads to shifting of land dependent income to livestock in the high land area, and to NTFPs in the low land area of the study site.

4.7.5. Woody & NTFPs uses of Belete-Gera forest

The result of the assessment of woody & NTFPs/ non woody uses of Belete-Gera forest for local households is given on Figure 26.

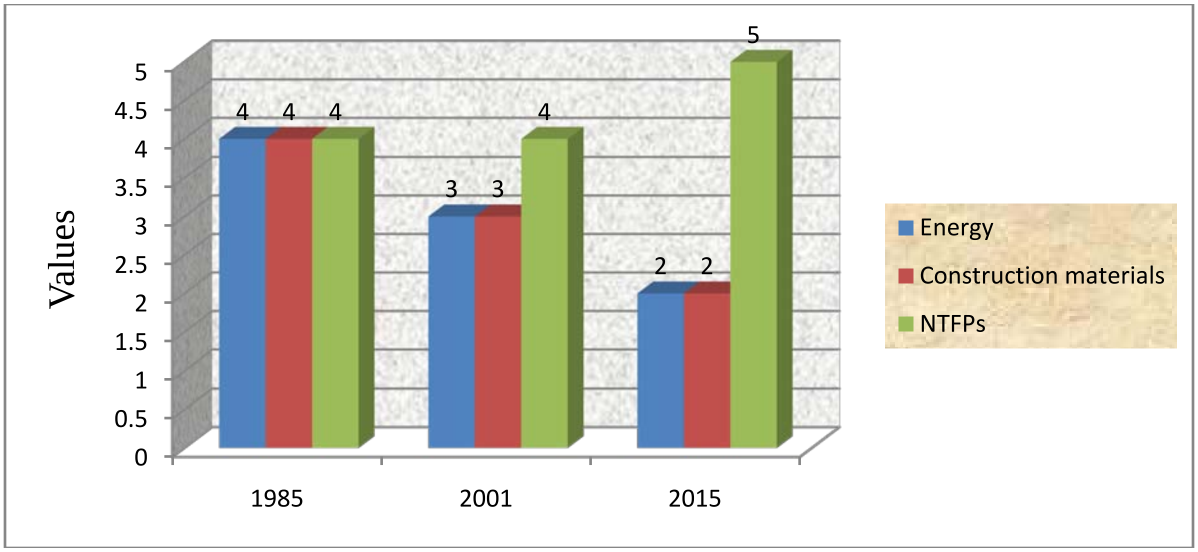

Fig.26: Woody & NTFPs benefit of local households from Belete-Gera forest.

Notes; *5 = Very high benefit (81-100%),* *2 = Low benefit (21-40%),*
4 = High benefit (61-80%), *1 = Very low benefit (1-20%)*
3 = Medium benefit (41-60%),

The above Figure depicted that in 1985, from Belete-Gera forest, local households' highly benefited (61-80%) non cash woody forest products like energy/fuel wood and different construction materials for subsistence purposed, and NTFPs/ non woody forest products like coffee, honey and spices. In 2001, the woody forest products benefit local households obtained from Belete-Gera forest was decreased to medium value (41-60%).But the NTFPs benefit was the same as that of 1985.

Meanwhile, in 2015 the woody forest products local household obtained from Belete-Gera forest was further decreased to low benefited value (21-40%). But in contrary the NTFPs benefit was increased to very highly benefited value (81-100%). As discussed in land dependent income part, decreasing agricultural productivity resulted in shifting land dependent income from crop to NTFPs (especially in the low land part of the study area). To enhance their livelihood income from NTFPs, local households illegally entered to Belete-Gera natural forest and carried out coffee farming activities.

Therefore, declining Belete-Gera forest cover resulted in decreasing almost by 40% the woody forest products local households have benefited from the forest. This is due to increasing the time spent to collect woody forest products from forest (fuel wood and construction materials), decreasing the density of high valued tree species used for construction materials (e.g. *Cordiaand Aningeria* tree species) and increasing dependent of local households on their own plantation (especially *Eucalyptus* species) . Decreasing fuel wood energy dependent on Belete-Gera forest resulted in local households have started using caw dung and crop residue as source of energy.

4.8. Socio-economic influences of Belete-Gera forest LU/LC change

Based on result assessment and discussion on socio-economic survey of the study area, Belete-Gera forest LU/LC changes negatively influences the agricultural crop productivity, non cash use of woody forest products, agricultural inputs and wildlife abundance of the area.

4.8.1. Influences on land dependent income

As discussed on land dependent income part, in 1985 cereal crop was the leading income in the study area (Fig.25). In this period households are highly depends on cereal crops like teffe, maize, wheat and barley. But due to decreasing the productivity of agricultural land to support agricultural crops, total income contribution of cereal and pulse crops were decreased from time to time. In 2015 year, local households are highly depending on NTFPs and livestock income than cereal and pulse crop incomes. Within 30 years of study period, household total income contribution of cereal crop was decreased by 20 %. According to local farmers' perceptions, in the past 30 years ago, cereal and pulses crops incomes per a unit of land have been decreased almost by three folds. As the result of this farmers have been looking over new uncultivated lands, and expand their agricultural land to forest to overcome the decline of agricultural income. The statistically t-test of cereal crop at 95% confident interval is (P-value) = 0.09. This showed that the relative income contribution of cereal crop significantly decreased in the study area.

Therefore, Belete-Gera forest LU/LC changes decreases significantly cereal crop total income contribution for local households. This agreement is in line with Garedew et al., (2009) farmers believed that declining of crop productivity and resultant food scarcity is caused by soil degradation due to the destruction of forests.

4.8.2. Influence on benefit of woody forest products

As seen on Figure 25 local households have benefited from Belete-Gera forest different woody forest products like fuel wood & construction materials. In the past 30 years, the amount of woody forest products local households have benefited from Belete-Gera forest was decreased by more than 40 percent.

4.8.3. Influences on agricultural inputs

The regulatory value of forest in regulating water, surrounding environment and conserving soil fertility is much known. Soil inherent natural fertility plays decisive role in increasing agricultural productivity, and in returns decreases agricultural input costs. Deforestation of Belete-Gera forest costs farmers additional agricultural input costs, especially on cereal and pulses crop production. Before 15 years ago, farmers had produced agricultural crops without using any artificial fertilizers (both Urea and DAP), but now, they are using 100kg of Urea and Dap per hectare (costs 1,500Birr) on their agricultural land (FGDs). During FGDs farmers said that "Even though we applied artificial fertilizers on our agricultural land to increase productivity, agricultural productivity was not productive as of before 15 years ago. This is due agricultural products produced by using artificial fertilizer was not as productive as by using natural fertilizer".

Secondly, agricultural seed input cost also increased. According to farmers perceptions before 15 years ago they were using 30kg/ha of seed for sawing. This was applied especially on teffe, wheat and barley agricultural crops. But now, they use 100kg of seeds per hectare. That means more fertile land needs less amount of seeds, but less fertile land needs large amount of seeds while sawing. This is because of the probability of a seed to produce multiple seedling after germinated is higher on fertile land than on unfertile land. Therefore, farmers said that "decreasing agricultural land productivity leads to additional cost of seed and artificial fertilizers".

4.8.4. Influences Wildlife abundance

Belete–Gera forest is enriched with different types of biodiversity and wildlife resources. Accordingly, there are many wild animals in the area, including endemic species. It is also common to see several bird species of different habitats (forest and water bodies). As mentioned on study site description the major wildlife found in Belete-Gera forest are *Black and White Colobus, Grivet Monkey, Giant Forest Hog, Warthog ,Buffalo, Civet Cat, Anubis Baboon, Black Leopard, Lion , Greater kudu, Civet, Pig, Spotted hyena, Bush back, Bush duiker, Fox, and Rabbit*. There are also small number of wild animals and birds with no special features in the forest. To the modern sense, human interference increased on forest and wildlife species is decreased.

During group discussion with elders they said that “the abundance of the above listed wildlife is decreasing from time to time”. This is especially observed on large wildlife like on Giant *Forest Hog, Warthog, Buffalo, Black Leopard and Lion*. Before 15 years ago these major wildlife are easily seen not only in the forest but around the boundary natural forest. But now they can be seen once within one or two years. This is due to decreasing the density and area coverage of Belete-Gera forest. Therefore, Belete-Gera forest LU/LC change influences the occurrence and abundance of major wildlife resources.

4.9. Summary of farmers' perception of Belete-Gera forest cover changes influences

Table 11: Farmers perceptions of Belete-Gera forest cover change influences

No	Farmers perceptions	Supported Findings/idea
1.	In the past 30 years cereal and pulse crops productivity in a unit of land has been decreased almost by three folds	In the past 30 years total household income contribution of cereal crop was decreased by 20%
2.	Land dependent income shifting from cereal and pulse crops to NTFPs production and livestock ranching	In the past 30 years ago, household income contribution of NTFPs and livestock was increased by 12.3% d 7.1%, respectively. In the high land part of the study area farmers are changing their agricultural land to grazing lands. But in the low land part, farmers are illegally planting coffee within Belete-Gera natural forest.
3.	Increases agricultural input costs	Every farmer has been forced by governmental bodies found in the study area to use artificial fertilizers on their agricultural lands.
4.	Using woody forest products from Belete-Gera forest was much decreased.	In the past 30 years ,the benefit local households obtained from woody forest products of Belete-Gera forest was decreased by more than 40%
5.	Decreases the abundance of major wildlife animals	Decreasing density of Belete-Gera forest because of woody forest product extraction, free grazing and coffee practicing in natural forest, and also decreasing Belete-Gera forest area coverage because of agricultural expansion may be leads to wildlife displacement and extinctions.
6	Decreases rain fall intensity, but increases rain fall fluctuation.	Forest degradation and deforestation leads to low transpiration and precipitation

5. CONCLUSION & RECOMMENDATION

5.1. Conclusion

Sequential satellite images, ERDAS imagine and GIS technologies in combination with field observations are the best tools used for analyzing forest cover change. 30 years Belete-Gera forest cover change analysis showed that great vibrations were observed on five major land use types identified in the study area in the two periods of comparisons have made. Closed forest is the dominant land use type, and highly deforested by anthropogenic factors. It was decreasing at the rate of 0.86 percent and 0.41 percent in the first and second 15 years, respectively. Deforestation rate of Belete-Gera forest was 0.48 percent in the first 15 years, but decreased to 0.24 percent in the second 15 years. Hence, PFM implemented in Belete-Gera forest and foundation of OFWE plays a decisive role in decreasing deforestation rate of Belete-Gera forest in the second 15 years.

Belete-Gera forest cover change was driven not only by single factors, but also by the interlinked effect of different direct and indirect anthropogenic factors. Agricultural expansion, illegal settlement, woody forest product extraction, free grazing, population growth, accessibility, law awareness and poor governance and/or institution are the main anthropogenic driving forces which negatively affect Belete-Gera forest cover changes. Agricultural expansion is the first and the main driving force of Belete-Gera forest cover changes.

However, declining of Belete-Gera forest cover change influences the regulatory function of forest to conserves and enhances soil fertility which leads to deteriorating of agricultural crop productivity of the study area. Once agricultural land productivity of local households falls below acceptable levels, they move to new, mostly forestland that is marginal for agriculture until they have to move again. Substantial increases in demand for food have resulted in an expansion of croplands by encroaching on uncultivated areas, including closed and open forests. Therefore, decreasing agricultural land productivity is the other driving force of Belete-Gera forest cover changes.

Therefore, in the past 30 years ago, immense Belete-Gera forest LU/LC changes were occurred, and the forest was disappearing annually at the rate of 0.48%. The changes were driven by interlinked direct (65%) and indirect (35%) anthropogenic factors. The forest cover changes negatively influence household's agricultural inputs, woody forest products benefit for subsistence purpose and productivity of agricultural crops. Declining agricultural productivity resulted in shifting of land dependent income from agriculture crop to livestock ranching in the high land area, and also to NTFPs in the low land area of the study site.

5.2. Recommendation

Based on the results obtained and actual field observations made during the study, the following recommendations are forwarded.

Population policy: Population growth is one of the driving forces Belete-Gera forest LU/LC change. To prevent the population pressure and its influences on the forest resources and there by improve the living conditions of the inhabitants, family planning awareness creation campaigns with adequate health services should be introduced and implemented.

Agricultural intensification: The amount of income farmers have got from their agricultural land is not proportional to the area land they owned. This means farmers have got small amount of income from large area of agricultural land. The current family size of the households in the study area will not be sustained by the existing farming practices. Hence, deforestation caused by agricultural expansion will be reduced via the introduction of agricultural intensification assisted by improved technologies and irrigation systems where viable (subsidizing of critical inputs for poor farmers should be considered).

Encouraging NTFPs production: If it supported by best management practices, NTFPs like coffee, honey and spice are friendly grow with forest. As discussed on land dependent income part, farmers gave due consideration on NTFPs (mostly on coffee, but less attention on spice and honey) income than other land dependent incomes. Therefore, the governmental bodies found in the study area will introduce to technology based NTFPs production and management like modern bee hive, improved coffee variety, and honey certification program .

Encouraging private forest: Encourage private forest developers by providing incentives such as land grants, interest free loans, technical and marketing. And also assist household and individual tree growers to add value to their primary products, and find markets for their products. Besides used as source of income for households, private forest will help to decrease pressure of extracting woody forest products (direct drivers of forest LU/LC change) from natural forest. So governmental bodies found in the study area will give due attention on private forest/plantation development and management.

Strengthen governmental institution: even though PFM has been implemented on Belete-Gera forest since 2003, due to lack of transparency, coordination, and integration among forest related sectors and lack of collective effort of relevant sectors against forest destruction, deforestation is still continued study area especially in the remote sites. Therefore, coordination and consolidation of governmental bodies found in the study area will abate deforestation problems in the study area.

Future line of work: Due to time and budget constraint, my research was focused on Belete-Gera forest LU/LC change/ of deforestation. It is better if further research study will be done on **forest degradation** (biomass destruction) and endangered species extinction in and surround Belete-Gera forest.

6. References

Bottomley, B.R., 1998. Mapping rural land use & LU/LC change In Carroll County, Arkansas utilizing multi-temporal Landsat Thematic Mapper satellite imagery. University of Arkansas, Arkansas

Bekele, M., Tesfaye, Y., Mohammed, Z., Zewdie, S., Tebikew, Y., Brockhaus, M. and Kassa, H., 2015. The context of REDD+ in Ethiopia: Drivers, agents and institutions (Vol. 127). CIFOR.

Bekele M. 2003. Forestry property rights: The role of the State and institutional exigency: The Ethiopian experience [Doctoral thesis]. Uppsala, Sweden: Department of Rural Development, Swedish University of Agricultural Science

CSA (2007): Central Statistical Authority; House and population census

CSA (2003): The Federal Democratic Republic of Ethiopia Central Statistical Agency: The 2003 projected Statistical Abstract.

Campbell, J.B. and Wynne, R.H., 2011. Introduction to remote sensing. Guilford Press

Carr, D.L., 2004. Proximate population factors and deforestation in tropical agricultural frontiers. Population and environment, 25(6): 585-612

Jorgenson, A.K. and Burns, T.J., 2007. Effects of Rural and Urban Population Dynamics and National Development on Deforestation in Less-Developed Countries, 1990–2000*. Sociological Inquiry, 77(3): 460-482.

CSA (2014). Ethiopia Mini Demographic and Health Survey 2014. Addis Ababa, Ethiopia: Central Statistical Agency.

CSE (1997b): Federal Policy on the Environment. Volume II. Federal Democratic Republic of Ethiopia, Environmental Protection Authority. 114

Congalton, R.G. and Green, K., 2008. Assessing the accuracy of remotely sensed data: principles and practices. CRC press.

Contreras-Hermosilla, A., 2000. The underlying causes of forest decline (No. CIFOR Occasional Paper no. 30, p. 25p). CIFOR, Bogor, Indonesia.

De Beenhouwer M., Mertens J., Geeraert, L., and Jocqué, M., (2015): Express Biodiversity Survey in Belete Gera forest, Ethiopia. BINCO Express Report 4. Biodiversity Inventory for Conservation. Glab-beek, Belgium, 24 .

Demissew S., Rasmussen, F(2004). Field guide to Ethiopian orchids. Royal Botanic Gardens, Kew, UK. 300 .

De Sherbinin, A., 2002. Land-use and land-cover change. A CIESIN Thematic Guide

Dessie G. (2007). Forest decline in south central Ethiopia: Extent, history and process [Doctoral dissertation]. Stockholm, Sweden: Department of Physical Geography and Quaternary Geology, Stockholm University

Dessie, G. and Christiansson, C., 2008. Forest decline and its causes in the south-central rift valley of Ethiopia: human impact over a one hundred year perspective. AMBIO: A Journal of the Human Environment, 37(4): 263-271.

El-Kawy, O.A., Rød, J.K., Ismail, H.A. and Suliman, A.S., 2011. Land use and LU/LC change detection in the western Nile delta of Egypt using remote sensing data. Applied Geography, 31(2): 483-494.

EFAP (Ethiopia Forestry Action Program) (1993): Draft Final Report, Volume II. The challenge for Development. Draft Final Report. Addis Ababa, Ethiopia. 78.

EPA (1999): National Action program to combat Desertification Vol.1. Addis Ababa, Ethiopia
Europe Forest Resource Assessment (2000): United Nation

Ethiopian Economic Association, 2000. Annual report on the Ethiopian economy (Vol. 1). The Association

FAO (2010): Global Forest Resources Assessment 2010 - Country Report Ethiopia. Food and Ag riculture Organisation (FAO), Rome, Italy (www. fao.org/forestry/ fra/fra2010/en/, accessed date September 15, 2010).

FAO (2006): Global Forest Resource Assessment 2005: Progress toward Sustainable Forest Management. United Nations Food and Agriculture Organization Forestry paper 147. Rome, Italy.

FAO (2003): Country paper: Ethiopia. Proceedings of Workshop on Tropical Secondary Forest Management in Africa: Reality and Perspectives, Nairobi, Kenya, 09 - 13 December 2002, Rome: The Food and Agriculture Organization of the United Nations

FAO (2001): Global Forest Resources Assessment 2000: Main Report. FAO Forestry Paper 140. FAO, Rome.

FAO (2000a): On definitions of forest and forest change. Forest Resource Assessment. Working Paper 33. Rome.14

FAO (2000b): LU/LC Classification System (LCCS): Classification Concepts and User Manual. http://www.fao.org/

FAO (1999): Land Use Classification for Agri-Environmental Statistics/Indicators. Submitted by Statistics Division, FAO, Rome. Working paper No.13

FARM Africa and SOS Sahel.2008. Household profile and settlement dynamics in four woredas of Oromiya National Regional State: Dallo Mena, Harana Buluq, Goba and Nansabo. Addis Ababa, Ethiopia: IRIS Consult P.L.C.

Federal Democratic Republic of Ethiopia (FDRE), 2011c. Readiness Preparation Proposal. Forest Carbon Partnership Facility, World Bank.

Federal Democratic Republic of Ethiopia (FDRE), 2010. Growth and Transformation Plan 2010/11 – 2014/15.Volume I: Main Text. Addis Ababa, Ethiopia: Ministry of Finance and Economic Development, FDRE.

Fisher, B., 2010. African exception to drivers of deforestation. Nature Geoscience, 3(6): 375-376

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K. and Helkowski, J.H., 2005. Global consequences of land use. science, 309(5734): 570-574.

Geist, H.J. and Lambin, E.F., 2002. Proximate Causes and Underlying Driving Forces of Tropical Deforestation Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. BioScience, 52(2): 143-150.
.
Geist, H.J. and Lambin, E.F., 2001. What drives tropical deforestation. LUCC Report series, 4, p.116.

Garedew, E., Sandewall, M., Söderberg, U. and Campbell, B.M., 2009. Land-use and land-cover dynamics in the central rift valley of Ethiopia. Environmental Management, 44(4): 683-694

Gibbs, H.K., Ruesch, A.S., Achard, F., Clayton, M.K., Holmgren, P., Ramankutty, N. and Foley, J.A., 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. Proceedings of the National Academy of Sciences, 107(38): 16732-16737.

Hosonuma, N., Herold, M., De Sy, V., De Fries, R.S., Brockhaus, M., Verchot, L., Angelsen, A. and Romijn, E., 2012. An assessment of deforestation and forest degradation drivers in developing countries. Environmental Research Letters, 7(4): 044009.

Hayes, D.J. and Sader, S.A., 2001. Change detection techniques for monitoring forest clearing and regrowth in a tropical moist forest. Photogrammetric Engineering and Remote Sensing, 67(9): 1067-1075.

Howard, J.A. and Howard, J.A., 1991. Remote sensing of forest resources: theory and application (No. 634.9285 H849). FAO, Roma (Italia).

Hurni H. (1990): Degradation and conservation of the soil resources in the Ethiopian highlands. In: African Mountains and Highlands: Problems and Perspectives . 51-64,

Hylander, K., Nemomissa, S., Delrue, J., Enkosa, W.,(2013). Effects of coffee management on deforestation rates and forest integrity. Conservation biology 27, 1031-1040.

IPCC, (2001b). Synthesis report 2001- contribution of working groups I, II, and III to the third assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 397

IAIA (2005): Biodiversity in Impact Assessment. Special Publication SeriesNumber 3.

Jensen, J.R. and Cowen, D.C., 1999. Remote sensing of urban/suburban infrastructure and socio-economic attributes. Photogrammetric engineering and remote sensing, 65: 611-622.

JICA (1998): The Forest Resources Management Study in the southwestern Part of Ethiopia. Interim Report & Maps. Japan Forest Civil Engineering Consultants Foundation Kokusai Kogyo, Japan

Kaimowitz, D. and Angelsen, A., 1998. Economic models of tropical deforestation: a review. Cifor

Lamichhane, B.R., 2008. Dynamics and Driving Forces of Land Use/Forest Cover Change and Indicators of Climate Change in a Mountain Sub-Watershed of Gorkha (Doctoral dissertation, Thesis submitted in partial fulfillment of the award of M Sc NRMRD to Tribhuvan University/Institute of Forestry, Pokhara, Nepal).

Kiefer, R.W. and Lillesand, T.M., 2004. Remote sensing and image interpretation (499). John wiley and Sons

Legesse, D., Vallet-Coulomb, C. and Gasse, F., 2003. Hydrological response of a catchment to climate and land use changes in Tropical Africa: case study South Central Ethiopia. Journal of Hydrology, 275(1): 67-85.

Lillesand, Ralph W. Kiefer, and Jonathan W. Chipman. 2008. Remote Sensing and Image Interpretation, Sixth edition Thomas M., john wiley and sons,. New Jersey.

Lillesand, T.M. and Kiefer, R.W. (2000) Remote sensing and Image Interpretation.John Wiley and Sons, Inc. Newyork

Larsson, R.Å. and Strömquist, L., 1991. A practical approach to satellite image analysis for environmental monitoring. Ministry of Agriculture and Marketing

Banerjee, A. and Madhurima, C., 2013. Forest degradation and livelihood of local communities in India: A human rights approach. Journal of Horticulture and, 5(8): 122-129

Manly, B.F., 2004. Multivariate statistical methods: a primer. CRC Press

McCann, J.C., 1997. The plow and the forest: Narratives of deforestation in Ethiopia, 1840-1992. Environmental History, 2(2): 138-159.

Mittermeier, R.A., Gil, P.R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and Fonseca, G.A., B.(2004) Hotspots revisited: Earth’s biologically richest and most endangered terrestrial ecoregions. Mexico City: CEMEX Books on Nature Series.

Mulugeta Lemenih & Alemayehu Negassa (2012): A study on the Process, Progress and Impacts of Belete-Gera Participatory Forest Management Project.

Oromia Forest Proclamation 72/2003

Place, F., Pender, J. and Ehui, S., 2006. Key issues for the sustainable development of smallholder agriculture in the East African Highlands. Strategies for Sustainable Land Management in the East African Highlands: 1-30

Plan for accelerated and sustained development to end poverty (PASDEP), 2006. Ethiopia: Building on progress: A plan for accelerated and sustained development to end poverty. Addis Ababa, Ethiopia: Ministry of Finance and Economic Development

Rembold, F., Carnicelli, S., Nori, M. and Ferrari, G.A., 2000. Use of aerial photographs, Landsat TM imagery and multidisciplinary field survey for land-cover change analysis in the lakes region (Ethiopia). International Journal of Applied Earth Observation and Geoinformation, 2(3): 181-189.

Sherefa B. 2006. Remote sensing & GIS for LU/LC/land use change detection and analysis in the semi-natural ecosystems and agriculture landscapes of the central Ethiopian Rift Valley (Doctoral dissertation, University of Dresden Professor Dr. Michael Köhl: Institute for World Forestry, University of Hamburg)..

Singh, A., 1989. Review article digital change detection techniques using remotely-sensed data. International journal of remote sensing, 10(6): 989-1003.

Stellmacher, T., 2007. The historical development of local forest governance in Ethiopia: From imperial times to the military regime of the Derg. Africa Spectrum, 42(3): 519-530.
.
Tadesse, W, Teketay, D., Denich, M. and Thomas, B., 2001. Diversity of traditional coffee production systems in Ethiopia and their contribution to the conservation of coffee genetic diversity. In Proceedings of the Conference on International Agricultural Research for Development, Deutscher Tropentag-Bonn, Bonn (1-11

Woody Biomass Inventory and Strategic Planning Project (WBISPP). 2004. Forest Resources of Ethiopia. Addis Ababa, Ethiopia: Ministry of Agriculture; WBISPP.

World Bank (2005): world development indicators. USA

WRI (World Resources Institute) (1997): The last frontier Forests: Ecosystems and Economies on the edge. Washington D.C., USA

World Meteorological Organization(WMO) (2005): Climate and Land Degradation. Soil conservation- Land Management- Flood forecasting- Food Security.

Zeleke, G. and Hurni, H., 2001. Implications of land use and LU/LC dynamics for mountain resource degradation in the Northwestern Ethiopian highlands. Mountain research and development, 21(2): 184-191.

Appendices

Annex 1:-Classification accuracy of land sat image 1985

No	Land Class Type	Ground Truth(GT)					total	Producer accuracy	User accuracy
		GT1	GT2	GT3	GT4	GT5			
1	Agriculture	**35**	2	3	7	2	49	87.5	71.4
2	Closed Forest	0	**47**	3	1	0	51	94	92.2
3	Open Forest	1	1	**30**	3	0	35	75	85.7
4	Settlement	4	0	4	**29**	0	37	72.5	78.4
5	Wet land	0	0	0	0	**28**	28	93.3	100
	total	40	50	40	40	30	200		
Overall accuracy = 84.5%									
Kappa coefficient = 0.81									

Annex 2: Classification accuracy of land sat image 2001

No	Land Class Type	Ground Truth(GT)					total	Producer accuracy	Users accuracy
		GT1	GT2	GT3	GT4	GT5			
1	Agriculture	**28**	1	4	0	1	34	70	82.4
2	Closed Forest	3	**44**	4	0	0	51	88	86.3
3	Open Forest	1	5	**29**	4	2	41	72.5	70.7
4	Settlement	7	0	2	**36**	3	48	90	75.0
5	Wet land	1	0	1	0	**24**	26	80	92.3
	total	40	50	40	40	30	200		
Overall accuracy = 80.5%									
Kappa coefficient = 0.75									

Annex 3:- classification accuracy of land sat image 2015

No	Land Class Type	Ground Truth(GT)					total	Producer accuracy	Users accuracy
		GT1	GT2	GT3	GT4	GT5			
1	Agriculture	**35**	1	0	2	4	42	87.5	83.3
2	Closed Forest	2	**49**	2	0	0	53	98	92.5
3	Open Forest	1	0	**38**	0	2	41	95	92.7
4	Settlement	2	0	0	**38**	1	41	95	92.7
5	Wet land	0	0	0	0	**23**	23	76.7	100
	total	40	50	40	40	30	200		
Overall accuracy = 91.5%									
kappa Coefficient = 0.89									

Annex 4: Livestock an average annual income contribution

No	Livestock type	An annual income contribution in Birr	Remark
1	Ox	2500	If an ox is given to somebody by local language "chimada in Oromiffaa" the owner of an ox will obtain 2.5 kuntal (250kg) of teff. Price of one kuntal of teff is 1000birr
2	Caw	2400	An average monthly income from one cow milk and other milky products are 400Birr. An average one caw produces milk and other milk products for six months. Total income = 400 X 6 = 2400Birr
3	Heifer	1100	On an average annually, farmers get 1000 Birr from one heifer
4	Bull	1100	Similar to that of Heifer
5	Sheep	1000	On an average annually, farmers get 1000 Birr from one sheep
6	Goat	900	On an average annually, farmers get 900 Birr from one goat
7	Equines (Donkey, Mule and Hors)	1200	On an average annually farmers get 1200 Birr from one horse/donkey or mule
8	Hen	350	On an average annually, farmers get 300 Birr from one female Hen

Annex 5: NTFPs market price

No	Types NTFPs	Unit	Price in Birr	Remark
1	Coffee	kg	50	The market price of agricultural products are varies from season to season. So I took an average seasonal price.
2	Honey	kg	60	
3	Spice	kg	80	
4	Chet	Hidha (15kg)	800	

Annex 6: cereal and pulse crops market price

No	Types agr. crops	Average market price of one kuntal or 100kg in Birr	Remark
1	Teff	1000	The market price of agricultural
2	Maize	400	
3	Wheat	900	

4	Sorghum	850	products are varies from season to season. So I took an average seasonal price.
5	Barely	800	
6	Pea	1200	
7	Beans	900	
10	Lentils	1600	
11	Nugi	1400	
12	Potato	600	

Annex 7: Woody and NTFP benefit of local households from Belete-Gera forest in 1985

used type	**1985**						**total**
	Values	5	4	3	2	1	
Energy	Respondents	9	106	35	18	9	**176**
	%	0.05	0.6	0.2	0.1	0.05	**1**
	Benefited value	0.25	2.4	0.6	0.2	0.05	**4**
Construction Materials	respondents	9	109	32	21	5	**176**
	%	0.05	0.62	0.18	0.12	0.03	**1**
	Benefited value	0.25	2.48	0.54	0.24	0.03	**4**
NTFPs	Respondents	28	137	11	0	0	**176**
	%	0.16	0.78	0.06	0	0	1
	Benefited value	0.79	3.11	0.19	0	0	**4**

Annex 8: Woody and NTFP benefit of local households from Belete-Gera forest in 2001

used type	**2001**						**total**
	Values	5	4	3	2	1	
Energy	N	0	44	97	21	14	**176**
	%	0	0.25	0.55	0.12	0.08	**1**
	Benefited value	0	1	1.65	0.24	0.08	**3**
Construction materials	Respondents	9	46	95	18	9	**176**
	%	0.05	0.26	0.54	0.1	0.05	**1**
	Benefited value	0.25	1.04	1.62	0.2	0.05	**3**
NTFPs	Respondents	26	132	18	0	0	**176**
	%	0.15	0.75	0.10	0.0	0	**1**
	Benefited value	0.74	3	0.31	0	0	**4**

Annex 9: Woody and NTFP benefit of local households from Belete-Gera forest in 2015

used type	**2015**						**total**
	Values	5	4	3	2	1	
Fuel wood	Respondents	0	18	26	127	5	**176**

	%	0	0.1	0.15	0.72	0.03	**1**
	Benefited value	0	0.4	0.45	1.44	0.03	**2**
Construction materials	Respondents	0	12	14	141	9	**176**
	%	0	0.07	0.08	0.8	0.05	**1**
	Benefited value	0	0.28	0.24	1.6	0.05	**2**
NTFPs	N	145	25	6	0	0	**176**
	%	0.82	0.14	0.03	0	0	**1**
	Benefited value	4.12	0.57	0.10	0	0	**5**