The Effect of Participatory Degraded Land Restoration on Plant Diversity, Biomass and Carbon Stocks the Case of Weforest Amhara Region, Ethiopia.

By: Workneh Edesa

Advisor: Engdawork Assefa (Phd)

A Thesis Submitted to Center for Environment and Sustainable Development College of Development Studies

Presented in Partial Fulfillment of the Requirements for the Master of Art in Environment and Sustainable Development

Addis Ababa University

Addis Ababa, Ethiopia

June, 2020

Addis Ababa University

School of Graduate Studies

This is to certify that the Thesis prepared by Workneh Edesa entitled, **"The Effect of Participatory Degraded Land Restoration on Plant Diversity, Biomass and Carbon Stocks the case of Weforest Amhara Region, Ethiopia"** and submitted in partial fulfillment of the requirements for the degree of Masters of Art (Environment and Sustainable Development) Complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by examining Committee:

Examiner ________________________ Signature ________________ Date ________________

Examiner ________________________ Signature ________________ Date ________________

Advisor __________________________ Signature _______________ Date _________________

____

Chair of the Department or Graduate Program Coordinator

ABSTRACT

The Effect of Participatory Degraded Land Restoration on Plant Diversity, Biomass and Carbon Stocks the Case of Weforest Amhara Region, Ethiopia.

Workneh Edesa

Addis Ababa University, 2020

In Ethiopia, land degradation triggered by deforestation has occurred for years. Government and NGO's have tried to restore degraded lands in many parts of the country and including the area. This study was conducted to evaluate the potential of degraded land restorations in improving plant diversity, biomass and carbon stocks in Weforest. Non-destructive method was used with two different allometric equations. Data for DBH, DSH and H was collected within fixed plot size nested at 20m x 20m. Woody species regeneration counted and their local and scientific names identified within sub plot fixed at 5m x 5m. Datas collected through questionnaires, FGD and key informants for examining participation. Descriptive statistics, t-test and ANOVA were used to analysis the data. The total carbon estimated to be 2.4 ton/ha before and 23.9 ton/ha after restoration and species regeneration diversity and abundance improved by 7.7 and 7.57 times after restoration respectively within 3.5 years of restoration period. There was a significant difference before and after restoration in biomass, carbon stock, woody species regeneration diversity and abundance with p value $< .05$. In degraded land restoration, community participation played significant roles at different stages of the project and also affected by diverse factors. Degraded land restoration is an essential approach for nature conservation and has to be further researched per other carbon pools and its implication on community's livelihood.

Key words: degraded land, restoration, tree planting, woody vegetation, biomass, carbon stock, regeneration, species diversity, abundance and community participation.

AKNOWLEDGMENT

First of all thanks to the Almighty God, your protection through all those difficulties saved me and now I could perform this study with your help, thanks again my Sevier!

My Sincere gratitude goes to my advisor Dr. Engdawork Assefa, for his great support, guidance and encouragement throughout this study, especially, in material provision, follow-up and persuading constructive comments on my work is a top-secret for the realization of my study. Special thanks to Dagne Getachew for his distinctive comments those were very important for my work and Dr.Tesfaye Zeleke for his great contribution to my enrolment in difficulty time. My great thanks also goes to Abebe Merga and Dereje likissa, especially for their contribution in directing to the right source of information and Heiru Sebrala for his great contribution by providing me relevant information's and data's for my work.

I would like to forward my great thanks to The Hunger Project Ethiopia for the great contribution to my work through logistic support during data collection and relevant data provision. I also forward my special thanks to Mr. Dechassa Jiru for his great contribution of professional support and Dr. Aklilu Nigussie for his inspiration to conduct the research in the area.

I would like to express my warm feelings and great thanks to Wogari Edessa "Eshetu" for his multi directional support and who was opened the gates and shaped my life to search and seek knowledge and all my families who were stand with me through all ups and downs in my life, you deserve a particular thanks.

All my ample friends shared all my sorrows and happiness; you deserve special thanks to your contribution in my success. Finally, I would like to acknowledge all students of my batch for their friendship and support during my enrolment.

Table of Contents

List of Tables:

List of Figures:

List of Pictures

Abbreviations and Acronyms

AGB	Above ground biomass
BGB	Below ground Biomass
C	Carbon
AGC	Above ground Carbon
BGC	Below ground Carbon
FGD	Focus group discussion
ACC	Abrupt climate change
PFM	Participatory Forest Management
CO2	Carbon dioxide
GHG	Greenhouse gas
CBO	Community-based organization
Gt	Giga ton
SOC	Soil organic carbon
Ton/ha	Tonnes per hectare
REDD+	Reduced Emissions from Deforestation and Forest Degradation, "plus" afforestation
CCFs	Community controlled forests
Mg	Mega gram
pg	Pentagram
IPCC	Intergovernmental Panel on Climate Change
RMPs	Recommended management practices
NTFPs	Non-timber forest products
THP/E	The Hunger Project Ethiopia
ERCM	Environmental resources conservation and management
CSA	Central Statistical Agency
DBH	Diameter at breast height(1.3m)
DSH	Collar Diameter(0.3m)
WBISPP	Woody biomass inventory and strategic planning project
NRNWS	Naturally regenerated native woody species

Chapter 1: Introduction

1.1. Background

Land degradation is a driver of climate change through emission of greenhouse gases and reduced rates of carbon uptake. Land degradation stretches to about 30 % of the total global land area and about three billion people reside in degraded lands (Nkonya and Mirzabaev, 2016). Of the land degradation processes, deforestation, increasing wildfires, degradation of peat soils and permafrost thawing contributed most to climate change through the release of greenhouse gases (Olsson, Barbosa et al. 2019). Since 1850, about 35% of the human caused emissions of CO2 to the atmosphere comes from land as a combined effect of land degradation and land-use change and about 38% of Earth's land area has been converted to agriculture(Foley, Ramankutty et al. 2011). Carbon dioxide (CO2) emissions from land use change during the last 150 years were estimated at about 136 (±55) Gt (i.e. 1 Gt = 109 tons), which is approximately one third of the total emissions in the atmosphere. These emissions predominantly resulted from forest removal about 87% (Houghton 1999). Estimates indicated that emissions of CO2 caused by deforestation could range between 1.1 to 3.9 billion tons by 2020 (Meehl, Stocker et al. 2007). Global forest loss, amounted to 230,000 kha (kilo hectors) from 2000–2012(Hansen, 2013) and Foley stated that, it contributes to climate change, biodiversity loss, water quality degradation, and other negative impacts on ecosystem services as referred by (Hosonuma *et al.*, 2012).

Deforestation continues across the tropics at alarming rates, with impacts on ecosystem Processes, carbon storage and long term sustainability. Tropical deforestation increased from approximately 6900 kha yr^{-1} in the first half of 2000-2012 to greater than 7900 kha yr^{-1} in the second half (Ordway and Asner, 2017). In this case, Agriculture is the dominant driver of forest conversion across the tropics, comprising > 80% of deforestation (Hosonuma *et al.*, 2012).

Human activities are driving widespread and rapid changes in woody biomass cover in Africa, with important implications for both the global carbon cycle and local livelihoods. Across the African region, there exists highly dynamic land cover change, with rapid deforestation and degradation underway in hotspots around population centers. Rising populations and mostly stagnant crop yields are thought to be driving horizontal expansion of agriculture and widespread deforestation. Therefore, the immediate higher returns from agriculture provide incentives for land-use changes, leaving the remaining forests at risk. Moreover, although the carbon dynamics of the continent show higher spatial variation, Africa is facing forest degradation often due to local timber harvesting or fuel wood harvesting (McNicol, Ryan et al. 2018). On the other hand, Forests are usually cleared because there is money to be made from doing so. For instance, the Amazon forest is being cleared primarily due to agricultural expansion, for cattle and soybean farming. In Asia, most of the tropical forests are under pressure because of conversion to plantations of oil palm and of fast-growing timber trees as inputs to the pulp industry(Kanninen, Murdiyarso et al. 2007).

In Ethiopia, population growth and investment followed by deforestation and land use change have led to a dramatic decline in forest land during the last decades (Berihu, Girmay et al. 2017). The major drivers of deforestation and forest degradation are agricultural expansion, overexploitation, urbanization, fire incidence, exotic species and villagization/resettlement, which are all driven by human population growth(Box and Tabor, 2017). The study conducted in the north-western highlands of Ethiopia revealed a decrease in natural forest cover from 27% in 1957 to 2% in 1982 and to 0.3% in 1995(Zeleke and Hurni 2001). The study also showed that between 1957 and 1995 about 99% of the forest cover was mainly lost to land cultivation with an increase of 77% in cultivated land, Which depicts a huge loss of biomass and soil carbon following land use changes (Assefa, Rewald et al. 2017).

Deforestation for farming purposes are the major threats to biodiversity resources of the country (Sci, 2004). Deforestation followed by subsequent cultivation, resulted in a more or less continuous exhaustion of seeds of woody species from the soil seed bank (SSB). This shows that deforestation, driven mainly by the need for more land for permanent agriculture is a threat to the regeneration diversity of the tropical dry Afromontane forest in the highlands of Ethiopia (Lemenih and Teketay, 2006). A report by Reusing (1998) showed that the annual rate of deforestation in Ethiopia is 163,600 ha, which is one of the highest in Africa, Such massive forest degradation is always accompanied by loss of genetic resources (Woldemariam and Teketay, 2001).

Moreover, deforestation imposing excessive socio economic problems in Ethiopia, it has led to soil erosion and decline in soil fertility, decline in biodiversity, shortage of wood and non-wood forest products, reduction in agricultural production and productivity, recurrent drought and famine, flooding, scarcity of water, degradation of wetlands, siltation of water bodies, desertification, climate change, and poverty (Box and Tabor, 2017) .

Conventional forest management has isolated the local communities from participating in forest conservation and protection in Ethiopia, which has led to illegal and unsustainable resource utilization; PFM was introduced in Ethiopia in the mid of 1990s, by International Non-Governmental Organizations, with the objective of promoting sustainable management and conservation of forest ecosystems and improving the livelihood of people living in or around these resources(Siraj, Zhang et al. 2018). Comprehensive review of previous studies on PFM in Ethiopia confirmed that there is an improvement in forest condition and livelihood in areas under PFM though the success is claimed to be mixed (Siraj, Zhang et al. 2018). Hence, Involving farmers and local people who live around the forests in tree planting and natural resource management is critical for conservation and the development of forestry. This can be done through participatory process where farmers and local peoples are involved in planning, design, and implementation of the management plan. such exchange of information's and creation of partnerships helps to build confidence and provide reassurance that, the programs are relevant to their needs and ensure that they have a sense of responsibility to the project (Bishaw 2001).

This study area also facing forest and land degradation challenges which has direct implication to climate change through carbon emission to the atmosphere. The study conducted at Dembecha area which is adjacent to this particular study area shown that the natural forest cleared between 1957 and 1995 amounts to 7259 ha. This clearly indicates the prevailing danger of land degradation and deforestation in the area (Zeleke and Hurni 2001).

Therefore, this study was aimed to demonstrate the multi directional benefit of degraded land restorations through community participation as a potential measure to avert the emerging challenges of land and forest degradations in improving woody species regeneration, enhancing woody vegetation biomass and carbon sequestration.

1.2. Statement of the problem

The world's forest influences climate through physical, chemical and biological processes that affects planet energy, hydrological cycle and atmospheric composition. These complex and nonlinear forest-atmosphere interactions can reduce or amplify the status of climate changes. Afforestation and reforestation of Tropical, temperate and boreal forests reduce global warming through carbon sequestration(Bonan 2008). The forest ecosystem service of carbon (C) sequestration is central to the well-being of the human society and the planet Earth. However, abrupt climate change (ACC) threatens the C sink in forests as a consequence of fossil fuel burning and land use changes. Thus, atmospheric CO2 concentrations and temperatures are increasing and precipitation regimes are altered which all may impact C sequestration processes in forest ecosystems (Lorenz and Lal 2009). Every year, between 1.6 and 2.4 Pg of carbon are released to the atmosphere from tropical forest clearing as sited by (Naughton-treves, 2004).

Ethiopia has the largest forest resources in the horn of Africa (Moges and Tenkir 2014).The country's forest resources play a significant roles in the livelihoods of the community and the national economy at large (Moges, Eshetu et al. 2010), through the provisions of energy, construction wood, timber and non-timber forest products that are very valued for their food, medicinal and commercial values(Asfaw, Mulatu et al. 2015). Moreover, forests play a vital role in climate change mitigation through sequestering carbon dioxide from the atmosphere. Ethiopia's forest resources have store 219 million ton of carbon in their living biomass (Mekonnen and Tolera 2019). But, despite their economic and environmental values, the countries forests resources are under threat. Deforestation and forest degradation activities are the main sources of forest carbon stock loss/GHGs emission, declining of biodiversity and loss of numerous woody species. According to (Economy 2011), 37% of the total greenhouse gas emission in the country comes from forestry due to anthropogenic activities (deforestation and forest degradation).

Deforestation and land degradation in Ethiopia, harming the capacity of forests and the land to contribute to food security and to provide other benefits such as fuel wood and fodder. The increasing populations have resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forests for fuel wood, fodder, and construction material(Bishaw 2001).

FAO, 2006 reported that, from 1990 to 2005 the area of tropical forest plantations increased from 69 million to 93 million hectares. While plantations account for 11 percent of the total forest areas in Asia and the pacific, it was only 2 percent in Africa, the two regions shared a trend towards increased involvement of the private sector and small-scale producers in plantation establishment, which previously was primarily government controlled as referred by (Nawir *et al.*, 2007). Ethiopia was undertaken many state lead tree plantation campaigns, henceforth, according to WBISPP(2004) reports, owns a total of 59.7 million ha covered by woody vegetation's as mentioned by (Tadesse, 2012) among which: 3.56 % are high forest (about 4.07 million ha), 49 % woodland (29.24 million ha) and 44.2 % shrub land or bush land (26.4 million ha) and Plantations cover estimated to 955,705 ha which is very small compared with others.

Different studies were conducted on carbon sequestration efficiency of woody vegetation's and other carbon pools at different places and time. Among them, Assefa et al., 2017 specified that Afforestation of degraded croplands and grazing lands with Eucalyptus tree increased soil organic carbon (SOC) stocks to nearly 70% of the natural forest levels within 30 years and enclosures only with native species regeneration merely increases SOC in the top soil. In other hand, Bajigo A et al. 2015 (Zone, 2015) were identified carbon stocks in different carbon pools along elevation gradients and different land uses; As a result, it was identified that, carbon in the above ground tree is significantly higher in woodlot than agroforestry 106.47 Mg/ha, and research conducted at mount Zequalla Ethiopia identified that the total mean of different carbon pools above and below ground was 348.8 t ha-1(Girma and Soromessa, 2014). But these studies and others on carbon stock estimation were conducted by ignoring the significant contribution of small trees within young restoration areas, in which, in almost all literature's, the carbon estimation was based on a single estimation model and DBH of trees >5cm to satisfy the model requirement. This study was aimed to conduct woody vegetation's carbon stock estimation, by using two different estimation models at the same time, purposely to include small woody species in to the valuation, in order to show their significance contribution to climate change.
Restoration approaches and woody species regeneration capacity of different forest management approaches was identified by different authors at variety of times. For instance, degraded land recovery can be achieved with plantation of rapidly growing tree species as well as exclosure in which Species richness was significantly higher in the exclosure than in the plantations(Abiyu *et*

al., 2011). I n other hand, (Senbeta and Teketay, 2003) stated that, Forest plantations can foster the regeneration of native woody species and increase biodiversity in the plantation stands with considerable variation among plantation species with respect to the density of naturally regenerated native woody species. Furthermore, they designated that; the exclosure can increase the diversity of naturally regenerated native woody species (NRNWS) more than the plantation after 30 years of its establishment. In both cases, it's indicated that both plantation and exclosures can support the woody species regeneration which contributes to the species diversity and then biodiversity. Particularly, this study was aimed at identifying the significance of restoration approaches in woody species regeneration diversity and abundance both through mixed species tree planting and exclosure at the same time, over the young restoration interventions.

Different studies were conducted on the state and determinants of community participation in tree planting and/or participatory forest management. Level of forest users participation at each stages of participatory forest management was identified in research conducted by (Tadesse, Woldetsadik and Senbeta, 2017) in which, factors affecting community participation including gender, family size, education level, income from the forest, distance of the forest from home, restriction on charcoal and timber harvesting, elite domination in decision-making processes, and lack of incentives. On the other hand, (Gebreegziabher and Mekonnen, 2010) suggested that household's decision to plant trees and the extent of tree planting depends on agro-ecological variability in addition to the various socio economic factors. Many other authors conducted studies on community's level of participation and factors determines their participation on forest management and/or tree planting at house hold level, watershed, forest users group and others in terms of socio economic and some other physical factors. But there are sparse and/or inaccessible studies in terms of knowledge, attitude and perception difference between restoration participant and non-participant community groups on degraded land restoration and carbon sequestration in forests. Therefore, this study was focused on assessing the state of community participation on degraded communal land restorations in one hand and factors demining communal land restoration participant and non-participant communities in the other hand, to fill research gap seen in the area.

In general, despite the fact that restorations have proved instrumental in the rehabilitation of degraded lands, knowledge on the contribution of small woody species on global climate change through carbon sequestration, the potential of young restorations in woody species regeneration diversity and abundance as well as the state of communities participation in such newly established restoration projects and factors determining restoration participants and non-participants in terms of knowledge, attitude and perceptions in addition to demography and socio economic conditions is specifically sparse and/or even no for some.

Therefore, this study was conducted to fill knowledge gap in small trees/shrubs contribution to global climate change other than multi-directional environmental benefits, contribution of young restoration projects through tree planting intervention on woody species regeneration diversity and the state and factors determining restoration participants and non-participant community's participation on such newly established restoration interventions.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study was to evaluate the potential of degraded communal land restorations through participatory tree planting in improving woody vegetation's above and below ground biomass and carbon sequestration, regeneration species diversity and abundance.

1.3.2. Specific Objectives

1. Estimate the above and below ground woody vegetation biomass and carbon stocks before and after restoration intervention.

2. Evaluate woody plants regeneration diversity and abundance before and after restoration intervention.

3. Assess the state and determinants of community participation in restoration intervention.

1.4. Research questions

Based on the objectives of the study, research questions for this study were the followings:

1. What amount of woody vegetation's biomass Kg/ha and carbon stock ton/ha stored above and below ground communal land before and after restoration intervention?

2. Is there any significant difference in woody vegetation's biomass, carbon sequestration, regeneration species diversity and abundance potential of degraded communal lands before and after restoration intervention?

3. At what states the communities were participated in degraded communal land restorations and what factors determines the involvement of participant and non-participant communities in degraded communal land restorations?

1.5. Hypothesis of the study

1. Degraded communal land restorations through tree planting and community participation can significantly improve woody vegetation's biomass and carbon sequestration potential of degraded lands after three and half years restoration intervention.

2. Degraded land restorations can significantly improve woody plants regeneration diversity and abundance of degraded communal lands after three and half years of the restoration intervention.

3. Most restoration participants actively involved per all stages of the restoration projects and per each restoration activities.

4. Restoration participants are significantly different from non-participants in demographic and socio-economic situations, knowledge on land degradation and benefit of tree planting, perceptions towards degraded land restorations and participatory tree planting, customs and practices in tree planting and receiving participation incentives.

1.6. Significance of the study

Greenhouse gases concentration in the atmosphere increasing and the threat of global climate change requires our attention. Syntheses of available data are needed; Gaps in our knowledge need to be researched. Information on forest carbon dynamics, carbon stocks, and the sequestration potential of forests is increasingly necessary, as forests play a significant role in mitigating climate change (Pan, Birdsey et al. 2011).

The estimated C-stocks can be used as a reference against which future changes in C-stocks can be compared (Mokria, Mekuria et al. 2018).

This study is very important in terms of awareness creation to the local communities on the value of forests beyond their earlier knowledge which was most of the time focuses on livelihoods and other local services. They will gate awareness on the values of forests in carbon sinking and in turn moderating climatic conditions locally and at global level as well as improves ecosystem services. The local communities will also get awareness on global carbon trading and they will start to value their existing and new forests to plant because they begin to think as it can be a source of income in its stand forms through carbon trading, which has positive impacts on sustainable existence and/or managements of forests.

The live wood biomass, which is involved in the regulation of atmospheric carbon concentrations, must be understood in terms of carbon status and flux in a given geopolitical unit for the assessment of carbon taxes and similar international CO2 mitigation measures has to be measured (Terakunpisut, Gajaseni et al. 2007). Therefore, this study may help the government as a sample data in the process of global carbon trading negotiation and for other management and decision making process.

This research filled scientific gaps especially in areas of restoration projects where there are sparse scientific evidences; it also helps donors and development organizations involved in restoration activities by displaying the values of their investment in the sector.

It develops the knowledge of the researcher in the area from others works and the result of this study itself. This study also used as a fulfillment for master's program graduation.

1.7. Scope of the study

This study evaluated the potential of degraded communal land restorations in improving woody vegetation's above and below ground biomass and carbon stocks based on 21 restoration sites intervened since 2017, which are found in four villages of Machakel district east Gojjam zone, Amhara region of Ethiopia.

The research examined the variation in carbon sequestration potential of degraded communal lands before and after restoration intervention in terms of woody vegetation's. It also evaluated woody vegetation's regeneration species diversity of sampled sites under study, before and after restoration intervention.

This study examined the state of land owning communities participation in restoration activities and identified factors determining participant and non-participant community's involvement in degraded communal land restorations.

1.8. Limitation of the study

This study did not estimated the biomass and carbon stocks of degraded communal lands before and after restoration intervention in terms of soil, litter and any other carbon pools except in terms of woody vegetation's.

The assessment of woody vegetation's regeneration species diversity both before and after restoration intervention represents only sampling plots of sampled restoration sites for the study.

The assessment of community's state of participation in communal land restoration was executed only based on participated restoration land owners and factors determining communities participation was conducted based on both intervened restoration land owners and non-participated adjacent communities.

1.9. Organization of the study

This thesis shows how a realistic combination of models helps to understand the real contributions of restoration interventions in reducing the effect of the hastily emerging global climate change and ecosystem improvements through local community's involvement. In order to answer each research questions this study was organized under 2- 5 chapters as follows.

Chapter 2: Introduced the broad vision of each research questions. First described what others did on areas of each specific research questions by reviewing available literatures and identified the gaps and what should be done to fill the gaps seen. Especially to identify which allometric questions/models has to be used to estimate the reliable biomass and carbon stocks of woody plants under the restoration project was greatly reviewed and dealt. The conceptual frame work of the study was designed for general understanding of the study concept.

Chapter 3: The study area was described in detail, research design, data sources and types, sampling design and size, method of data collection and method of data analysis including allometric equations/models detail descriptions to perform the study were described in detail for both biophysical and social study parts.

Chapter 4: The analyses were done per each defined variables and the output results organized and discussed per each research questions in detail. Synthesis of the overall research findings made and the interaction between each research objectives discussed.

Finally, in chapter 5, Synthesis of the overall research findings made and the interaction between each research objectives discussed and hypothesis findings briefed.

Chapter 2: Literature Review

2.1. Conceptual definition

Land degradation can be defined as it is a loss in productivity of the land (*Blaikie and brookfield 1987*) and/or is a long term decline in ecosystem function and measured in terms of net primary productivity (Bai *et al.*, 2017). It can be cause by either natural or anthropogenic factors which includes for instance in Ethiopia, rapid population increase, severe soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production (Taddese, 2001). This leads to the loss of vegetation cover and total ecosystem functions and services.

Loss of vegetation cover can be occurred through the process of deforestation, in which deforestation can be defined as, intentional and permanent transformation of forested land to other non-forest use (Bromley and Reis, 1999) and/or is the reduction in the capability of a forest to fulfill a particular function(Schmink, 1994). This process leads to the emission of carbon sink in vegetation's in to the atmosphere, in which it increases the effect of global climate change.

In reverse to deforestation and land degradation, degraded land restorations robust and re-vegetate the land and rebuilt the capability of the land to fulfill particular functions including atmospheric carbon sequestrations through vegetation's and other carbon pools in addition to environmental regulations and services.

In this case, carbon sequestration implies to the transfer of atmospheric CO_2 into other long-lived global pools including biotic(Lal, 2008) which includes forests and forest sequester carbon by capturing carbon dioxide from the atmosphere and transforming it into biomass through photosynthesis. Sequestered carbon is then accumulated in the form of biomass, deadwood, and litter and in forest soils. In such processes, degraded land restorations contribute to decreasing the effect of global climate change through atmospheric carbon sequestration in woody vegetation's. Therefore, such environmental benefits through biological processes could be achieved through active participation of communities living around the land and/or owning the land in the process of degraded communal land restorations. Thus, communities participated in restoration project at different state of participation and their involvement also determined with different factors.

In general, degraded communal land restorations can be successful with active participation of the local communities and the successful restoration improves the potential of degraded land in woody vegetation's regeneration species diversity and above and below ground carbon sequestration.

2.2. The effect of land degradation on forest carbon stock

Land use and land cover change through inappropriate agricultural practices and high human and livestock population pressure have led to severe land degradation in the Ethiopian highlands. This has led to further degradation such as biodiversity loss, deforestation, soil erosion and soil quality (Alemu 2015).

Natural exchange of carbon (C) compounds between the atmosphere, the oceans and terrestrial ecosystems is now being modified by human activities that release CO2 from fossilized organic compounds ('fossil fuel') and through land use changes. The earth is returned to a less vegetated stage of its history, with more CO2 in its atmosphere and a stronger greenhouse gas effect trapping solar energy by far the greatest proportion of the planet's C is in the oceans; they contain 39.000 Gt out of the 48.000 Gt of C (1 Giga ton (Gt) = 109 t = 1015 g). The next largest stock, fossil C, accounts for only 6.000 Gt. Furthermore, the terrestrial C stocks in all the forests, trees and soils of the world amount to only 2500 Gt, whilst the atmosphere contains only 800 Gt. The use of fossil fuels (and cement) releases 6.3 Gt C yr-1, of which 2.3 Gt C yr-1 is absorbed by the oceans, 0.7 Gt C yr-1 by terrestrial ecosystems and the remaining 3.3 Gt C yr-1 is added to the atmospheric pool (Assefa, Mengistu et al. 2013).

During the last few decades, land use changes have largely affected the global warming process through emissions of CO_2(Muñoz-Rojas, Jordán et al. 2015). Global forests are increasingly affected by land-use change, fragmentation, changing management objectives, and degradation. The area of global forests has declined by 3% since 1990 but the area of planted forest has increased in all regions of the world and now accounts for almost 7% of global forest land. The area of primary forest, which is typically defined as lacking direct human influence, is about 34% of all forest land according to country reports, but the area is declining especially in South America and Africa because of human-caused habitat fragmentation and degradation (Birdsey and Pan 2015).

2.3. The effect of degraded land restoration on woody vegetation species diversity

Ethiopia hosts one of the richest flora and fauna resources in tropical Africa. However, this rich bio resource is decreasing due to extensive deforestation. Conversion of natural forest into cultivated land (mosaics of home gardens and crop fields) typical of the smallholder system in the highlands of Ethiopia does not result in a dramatic loss of species but that the spatial distribution, density and species composition may be altered (Tolera, Asfaw et al. 2008).

The density of naturally-regenerated woody species in plantations was over three times the usual planting density in Ethiopia, indicating a high potential of forest plantations for restoring the natural forest ecosystems on degraded landscapes is comparatively a low cost(Yirdaw 2001). The establishment of exclosures on degraded communal grazing lands can be effective in restoring degraded native vegetation's, and with time, exclosures may obtain an important role as source of seeds of indigenous woody species(Mekuria and Yami 2013).

In the highlands of northern Ethiopia, remnants of the original Afromontane forest vegetation are largely restricted to church yards and other sacred groves in a matrix of cropland and semiarid degraded savanna. If seed dispersal from forest fragments into exclosures and subsequent tree recruitment are both successful, the vegetation type most likely to establish is Afromontane savanna woodland, and if managed properly, eventually dry Afromontane forest may arise. Increasing the size of small patches and placing forest plantations and exclosures in the vicinity of small forest fragments is expected to yield the most immediate results. This approach may increase the likelihood of patch colonization by frugivorous forest birds and thus foster the regeneration of native woody species(Aerts, Van Overtveld et al. 2006).

Exclusion of grazing animals and tree plantations were among the methods used for the rehabilitation of degraded lands in tropical semiarid areas. Exclosures can foster secondary forest succession by improving soil conditions, attracting seed-dispersal agents and modifying microclimate for understory growth. Therefore, exclosures are instrumental to improve the woody species diversity and soil properties in the dry lands(Gebremedihin, Birhane et al. 2018).

2.4. Tree plantation and implication to biomass and vegetation cover.

Forest is a significant part of global carbon cycle. Plants use sunlight to convert CO_2, water and nutrients in to sugar and carbohydrates which accumulates in leaves twigs, stem and roots. Plants respire, releases CO_2. Plants eventually die, releasing their stored carbon to the atmosphere quickly or to the soil where it decomposes slowly and increases soil carbon level. However, little information is exist on the process and diver's rates of soil carbon change (Gorte 2009).

Based on trends in the area of managed forest and regional studies, Established forests currently offset about 30% of global emissions of CO_2 from fossil fuel use, and there are mitigation opportunities involving forests that could increase the gross terrestrial C uptake from roughly 4.0 to 6.2 Pg C annually. A diversifying use of forest land may have significant consequences for maintaining or increasing the current rate of terrestrial carbon sequestration. In the future, indirect human influences such as increasing atmospheric CO_2 and climate change, along with the direct effects of land management and projected increasing demand for wood biofuel, are likely to become increasingly important elements that influence land management strategies and the role of forests in the global carbon cycle (Birdsey and Pan 2015).

Plantations of multi-purpose tree species can play an important role in restoring productivity, ecosystem stability, and biological diversity to degraded tropical lands(Parrotta 1992). The conversion of free grazing lands to exclosures has a significant potential to increase carbon sequestration, even in strongly degraded free grazing lands, both through additional below- and aboveground carbon storage. Expanding exclosures on degraded free grazing lands can thus contribute to mitigation of climate change (Mekuria, Veldkamp et al. 2009).

The many opportunities for mitigating atmospheric carbon emissions in developing countries include reforesting degraded lands, implementing sustainable agricultural practices on existing lands and slowing tropical deforestation. The analysis shows that over the next 10 years, 48 major tropical and subtropical developing countries have the potential to reduce the atmospheric carbon burden by about 2.3 billion tonnes of carbon. Given a central price of $10 per tonne of carbon and a discount rate of 3%, this mitigation would generate a net present value of about $16.8 billion collectively for these countries (Niles, Brown et al. 2002).

An improved vegetation cover has assisted to increase soil cover thus decreasing losses of soil moisture through evapotranspiration. Better soil cover has also been vital in facilitating improved water infiltration while decreasing soil erosion and increased litter deposition and carbon sequestration that would up-grade fertility to increase productivity(Wairore,Mureithi et al. 2015).

2.5. The role of community participation in degraded communal land restorations

Empirical evidence has shown that involvement of local communities in managing forests and other high value biomes and creating mechanisms for them to directly benefit from their conservation efforts lead to more effective protection than is the case with centralized protection (Nkonya, Mirzabaev et al. 2016).

REDD+ (Reduced Emissions from Deforestation and Forest Degradation, “plus” afforestation) is a tool that supports forest carbon-enhancing approaches in the developing world in order to mitigate and hopefully reverse climate change. A key issue within REDD+ is to appropriately bring in the almost 25% of developing country forests that are effectively controlled by communities. The quality of local level institutions may be important determinants of carbon sequestration. Developing country CCFs may therefore play a positive role within the context of REDD+ and other carbon sequestration initiatives (Beyene, Bluffstone et al. 2016).

Participatory forest management (PFM) was introduced in Ethiopia around the mid-1990s as a new system of forest governance. PFM was meant to avert the persistent problems of deforestation and to deliver better social and economic outcomes compared with the former centralized command-and-control resource management approach. In Ethiopian context, PFM is recognized as a co-governance institutional arrangement where forest management responsibilities and use rights are legally shared between a government agency and a community-based organization (CBO), such as forest user groups or forest cooperatives as stated by (Ayana, Vandenabeele et al. 2017).

The inception of PFM in Ethiopia was considered a radical departure from the centralized and technocratic forest management style to a more inclusive arrangement.

The PFM institutionalization process and its subsequent performance have proved controversial among scholars, policy-makers, practitioners and international development partners. Some claim that a major transformation has taken place consequent to PFM on the management of physical resources, institutional arrangements and livelihoods of resource-dependent communities. Proponents of PFM present performance indicators such as a decline in the deforestation rate and an increase in forest regeneration "(Takahashi and Todo 2012; Tsegaye et al. 2009)" and the establishment of community based forest management organizations "(Bradstock et al. 2007; Tsegaye et al. 2009)" as cited by(Ayana, Vandenabeele et al. 2017).

To change the perception and attitudes of local people around the forest, environmental education through awareness raising programs should be encouraged, and then addressing local development needs, ensuring real participation in PFM system if the new forest management system wants to win long lasting support of local communities to improve the forest condition and ensure sustainable rural livelihood (Tesfaye 2017).

Creating public awareness about PFM is crucial to alleviate the problems of deforestation and reduce the unsustainable use of the forest. As socio-economic variables that affect perceptions and attitudes of local people towards PFM may change over time (Tadesse and Teketay 2017).

Farmers can sustainably use their natural resources by introducing proper plant species on the steep slopes and degraded areas to improve soil fertility. Those species can be used as a source of for livestock and pollen for bees. This would increase the flexibility in the management of land use, fodder and livestock hence enabling households to make a living and diversify sources of livelihood but also address land degradation (Mekonen and Tesfahunegn 2011).

2.6.Biomass estimation models/Allometric equations

Reliable estimates of biomass are crucial as inputs for decision-making support in forest management, for monitoring forest conditions and as a basis for reporting changes in carbon stocks as provided by the REDD+ mechanism (Ubuy, Eid et al. 2018).

Accurate estimation of biomass is critical to quantifying changes in biomass and carbon stocks after restore degraded landscapes. However, there is a lack of site-specific allometric equations for above ground biomass estimation (AGB), which consequently restricts our understanding of the contributions of restoration efforts to climate change mitigation(Mokria, Mekuria et al.2018).

Biomass estimations for a forest can be based on field inventories alone or in conjunction with different methods of remote sensing. Plot biomass is normally derived from a sample plot inventory by summing the biomass of individual trees and shrubs (Ubuy, Eid et al. 2018).

Biomass of individual trees or shrubs may be quantified using indirect or direct methods (Brown 2002). The indirect method is based on the use of volume equations and biomass expansion factors (BEFs) and/or wood basic density. With the direct method biomass is determined through biomass models developed from destructively sampled data. These models are usually dependent on a combination of biophysical tree measurements such as diameter at breast height (dbh) and total tree height (ht). The direct method is by far the most used method today when individual tree data are available from a forest inventory, and is also considered the most accurate method.
A number of equation forms and variables are tested to determine what combination makes dry biomass the most reliable and unbiased predictors. The equation can then be used to estimate the biomass of other trees without damaging them. The quantity of carbon can then be estimated by converting biomass to carbon using the IPCC default carbon fraction of 0.47. Below ground tree root biomass is commonly estimated as a ratio of the aboveground tree biomass. The approach to collecting sample data must take into account the fact that tree allometry can vary across the area of interest, since trees of various types of forest and land use background can vary in morphology. DBH and wood density values are usually the easiest to obtain and most accurate inputs(Goslee *et al.*, 2012) .
Though it has been shown that height generates less skewed estimates of above ground biomass ((Rutishauser, Noor'an et al. 2013),(Chave, Réjou-Méchain et al. 2014), (Banin, Feldpausch et al. 2012) and (Feldpausch, Banin et al. 2011)), Precise measurement of tree heights in closed canopy forests is always daunting as it is difficult to read between adjacent trees Corlett and Primack, 2011 ; (Chave *et al.*, 2014), Larjavaara and Muller-Landau, 2013) and Because measuring angles in a precise, consistent way is even more difficult to do in hilly topography. As a result, the current height estimation methods consequences for high random degrees and systematic error. There is also a lack of agreement as to whether height measurements obtained from field inventory should be used in tropical forests as a predictor of AGB (Larjavaara and Muller-Landau, 2013).

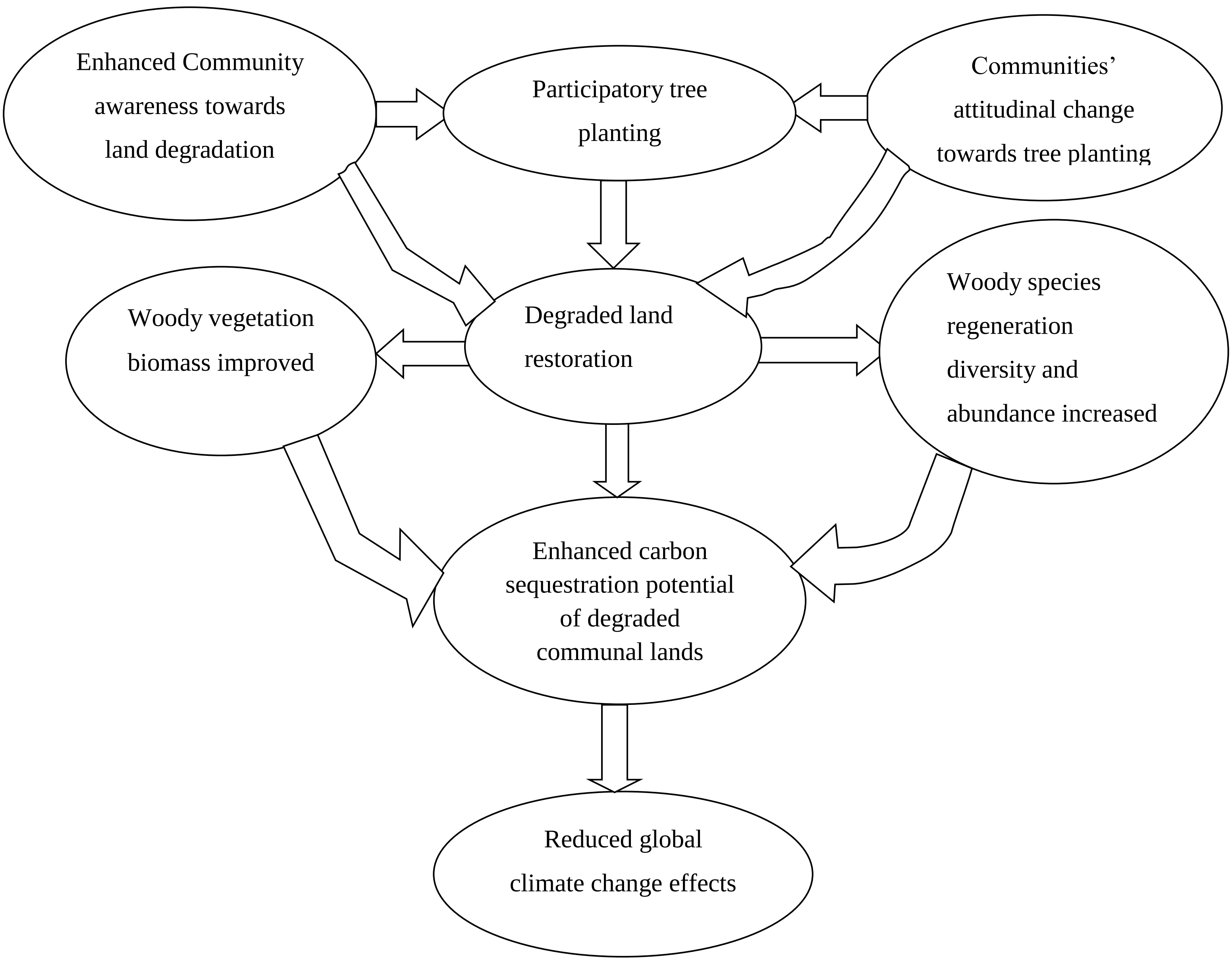
Species-specific equations can improve accuracy, but this may not always be the case (Fayolle, Doucet et al. 2013). Relationships between diameter and tree height were found to vary across environmental conditions, thus reducing the importance of the type of species in determining equation accuracy ((Banin, Feldpausch et al. 2012) and (Feldpausch, Banin et al. 2011)). Additionally, (Chave 2005) showed that a single equation including trunk diameter, wood specific gravity, and total tree height already provides an accurate estimate of above ground biomass, and that including site, succession status, continent or forest type only slightly improves fit quality. Including the wood density allows a species-specific element to be integrated into an overall equation. In the same way, even climate factors will allow equations to address differences based on elements specific to different regions (Jara, Henry et al. 2015).

A Global inventory of directly harvested trees at 58 sites across a wide variety of climatic conditions and forms of vegetation (trunk diameter of 4004 trees ≥ 5 cm). When trunk diameter, total tree height, and wood-specific gravity were used as covariates in the above-ground biomass model, a single model was found to hold across types of tropical vegetation, with no detectable regional or environmental effects (Chave, Réjou-Méchain et al. 2014).

The study conducted in northwestern Ethiopia, by Mokria, Mekuria et al.2018 developed a multi-species allometric equation ($AGB(Y) = 0.2451 * (D^2_{30} * H)^{0.7038}$) and investigated the spatial and temporal variation of C-stocks following the restoration of degraded landscapes. Through harvesting and weighted 84 trees from eleven dominant species of six grazing exclosures and adjacent communal grazing lands. The research provided the first allometric mixed species equations in northern Ethiopia for small-size trees. The model explained 82% of the variation in measured AGB. This confirms that the model is robust and reliably estimates AGB and C-stock of grazing exclosures and young secondary forests dominated by small trees. It's the best model compared to other generalized models from Ethiopia and elsewhere in Africa (Mokria, Mekuria et al. 2018). The Forest Reference Level Report for REDD+ implementation in Ethiopia (UNREDD,2016) generally recommended the use of the "pan-tropical" model developed by Chave et al. (2014) in the estimation of biomass for all the country's natural forests(Ubuy, Eid et al. 2018). Species specific wbd values should be applied because the wbd value recommended for REDD+ implementation by Ethiopia's Forest Reference Level Report (a mean of 0.612 g cm3 identified for 420 species in Ethiopia) (UN-REDD, 2016) may result in biases (Ubuy, Eid et al. 2018).

2.7.Conceptual frame work of the research

Forest carbon stock is highly variable due to various factors and processes' operating in the systems (Feyissa, Soromessa and Argaw, 2014) and it is also affected by different management factors such as: restoration, afforestation and protection of forests. Therefore, this study aims to identify the significance of restoration through participatory tree planting in improving degraded land carbon sequestration, woody species regeneration diversity and abundance. Based on the interlinking state of community participation, degraded land restoration, biophysical improvement, woody vegetation carbon sequestration and global climate change mitigation.



Chapter 3: Methodology

3.1. Description of the study area

3.1.1. Location and climate

Machakel is one of the 17 Districts of the East Gojjam Zone of the Amhara Region of Ethiopia. It is located between latitudes 10° 19' 75" to 10° 41' 00’’ North and longitudes 37° 16' 46" to 37° 45' 42" East. Its total area is 79,559 hectares (795.59 square kilometers). It is bordered to the South, East and North by the districts of Debre Elias, Gozamn, Sinan and Bibugn (East Gojjam Zone) and to the West by Dembecha District (West Gojjam Zone). Amanuel is the Administrative center of the woreda/district and lies about 30 km west of the zonal capital Debre-Markos. There are 24 rural and one urban kebele/villages administration in the woreda.

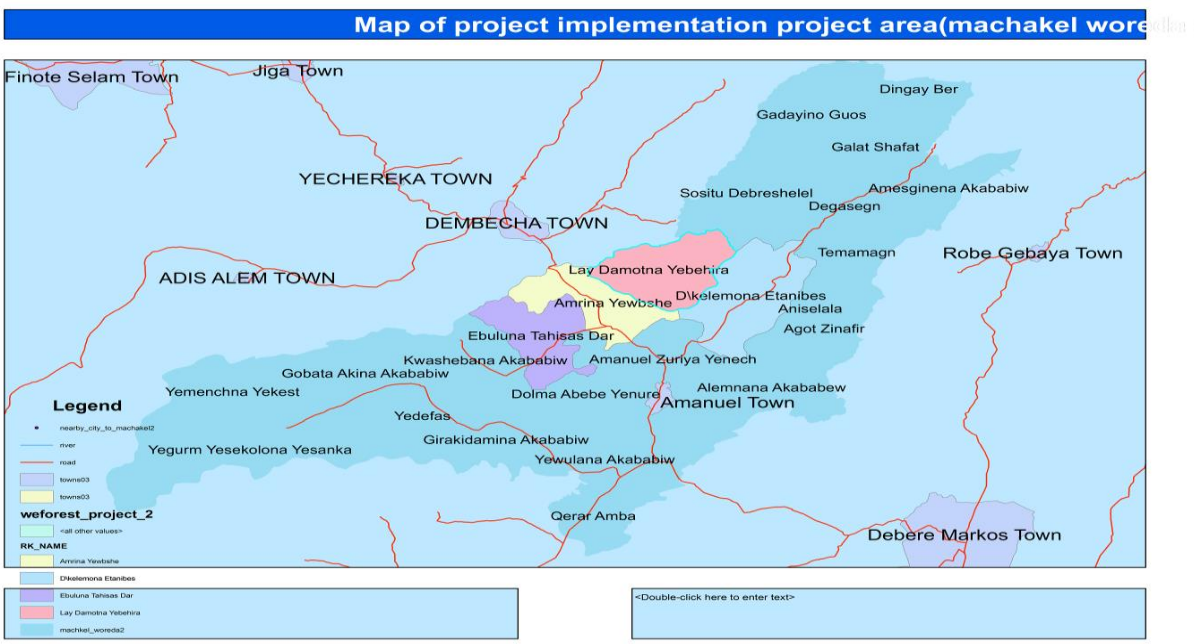


Figure 1: Map of Machakel District (Source THP/E).

Ethiopia’s agro-ecology is determined by a combination of altitude and climate and is classified into five categories, namely: Wurch, Dega, Woyna Dega, Kolla and Bereha. Machakel District elevation ranges from 1200 to 3200 meter above sea level (Woreda Agriculture and Natural Resource Office, 2016). 50% of the area of Machakel falls within the highland Dega (cold) agro-climatic zone, 39.1% in the Woyna Dega (midland with moderate temperature), 2.12% in the

Wurch (frost prone area) and 0.02% in the Kola (lowland with hot temperature) zone. The mean annual temperature varies between 20 and 24 °C at Gera kedamen kebele and 8 °C in Gaday kebele. The annual average rainfall ranges between 1500-1900 mm in the woreda (Leul 2011).

3.1.2. District and Intervention Villages Population

Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), Machakel has a total population of 118,097, an increase of 37.34% over the 1994 census, of which 58,529 are men and 59,568 women. Thus its population density is 148.4 people per square km, slightly less than the Zonal average of 153.8 people per square kilometer. There are a total of 27,967 households in the woreda, giving an average family size of 4.22 persons per household, and 27,143 housing units. The majority (98.8%) of the inhabitants are followers of Ethiopian Orthodox Christianity faith, while 1.1% is Muslims. Only 8,728 (7.4%) of the total population live in urban areas and the vast majority (92.6%) are rural. The level of urbanization lags behind not only the national and regional averages but also the zonal one which accounts to 10.14 percent (The Hunger Project Ethiopia, 2016).

The restoration project covers four villages in its first phase plantation program (2017), which was the study area to this particular research. The total populations of the four project intervention villages are 18,548 of which 9340 are females and 9208 are males as detailed in the table below per each village.

Table 1: Restoration projects village population (Source THP/E).

No	Villages	# Females	# Males	Total population
1	EmbuliTasasdar	2027	2235	4262
2	AmarieYewubesh	1900	1800	3700
3	Lay Damot	2586	2374	4960
4	Debra Kelamu	2827	2799	5626
Total		9340	9208	18,548

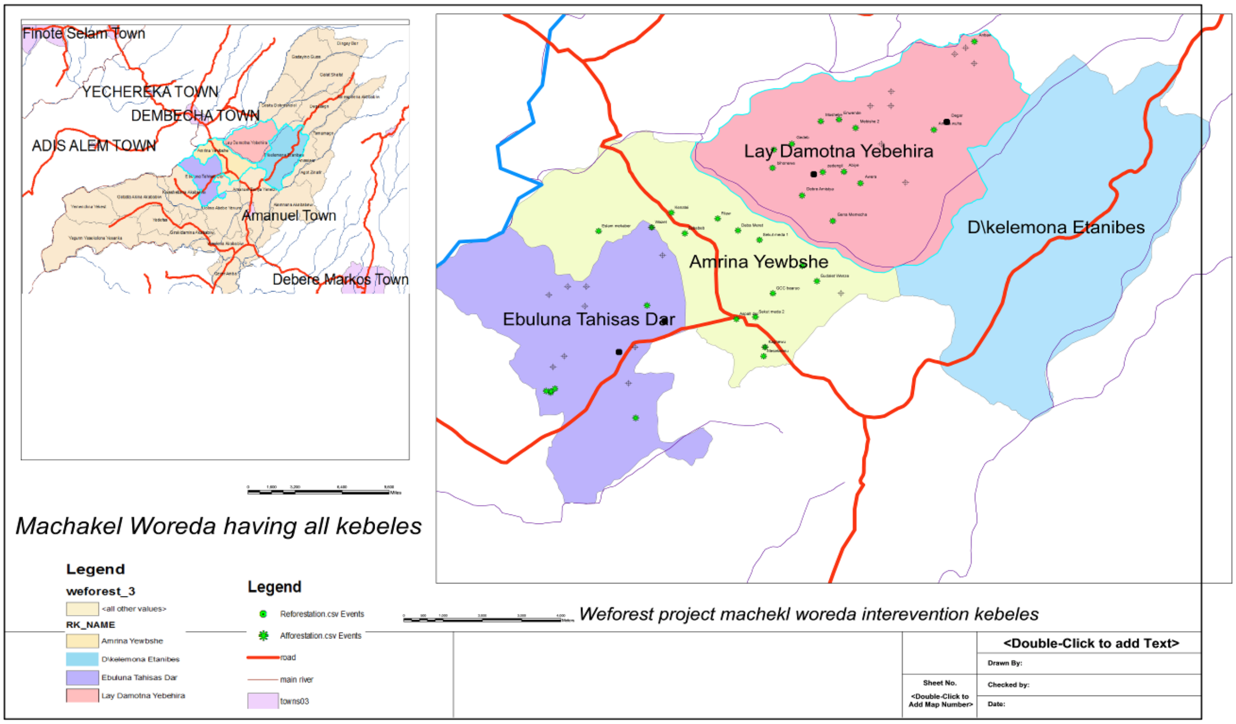


Figure 2: Map of Restoration project intervention villages (Source THP/E).

3.1.3. Agriculture and Forestry

Agriculture is the dominant economic activity and the base livelihood of the majority of residents of the study area, which practices mixed farming. The average land holding size in Machakel is 1.66 hectares. The most important cereal crops are Teff, Maize, Barley, Wheat and Engido (Tinctoria). The woreda has 39,349 hectares of cultivated land, of which 97.6% is used for annual crops and 2.4% for perennial crops (Alemu 2014).

The total forest coverage of the region is 12,884 km2 which is about 8.2 % of the total regional land area. Including bush lands, it is about 21,783 km2 which is about 13.85 % of the total land area. Woodlands, natural dense forest, riverine forest, bush lands and plantations are 740,808, 463,950, 20,653, 889,912, and 62,973 ha in area with percentage coverage of 4.71, 2.95, 0.13, 5.66, and 0.40 respectively (Mekonnen, Sewunet et al. 2016). In addition, there are 5274 hectares of natural and man-made forests in Machakel district (Alemu 2014).

3.1.4. Land use/land cover of the intervention villages

The land use/land cover of the four study villages are mainly categorized in to six based on the classification made by THP/E for the project intervention as detailed in the table below and illustrated on the map.

Table 2: The land use pattern of the 4 study/project villages

No	Land use type	Area coverage in(ha)	percentage
1	Bush land	258.93	2.05
2	Degraded land	1061.63	8.41
3	Farm land	7307.33	57.89
4	Forest land	514.11	4.073
5	Grazing land	1273.99	10.093
6	Homestead land	2206.74	17.48
Total		12622.73	100

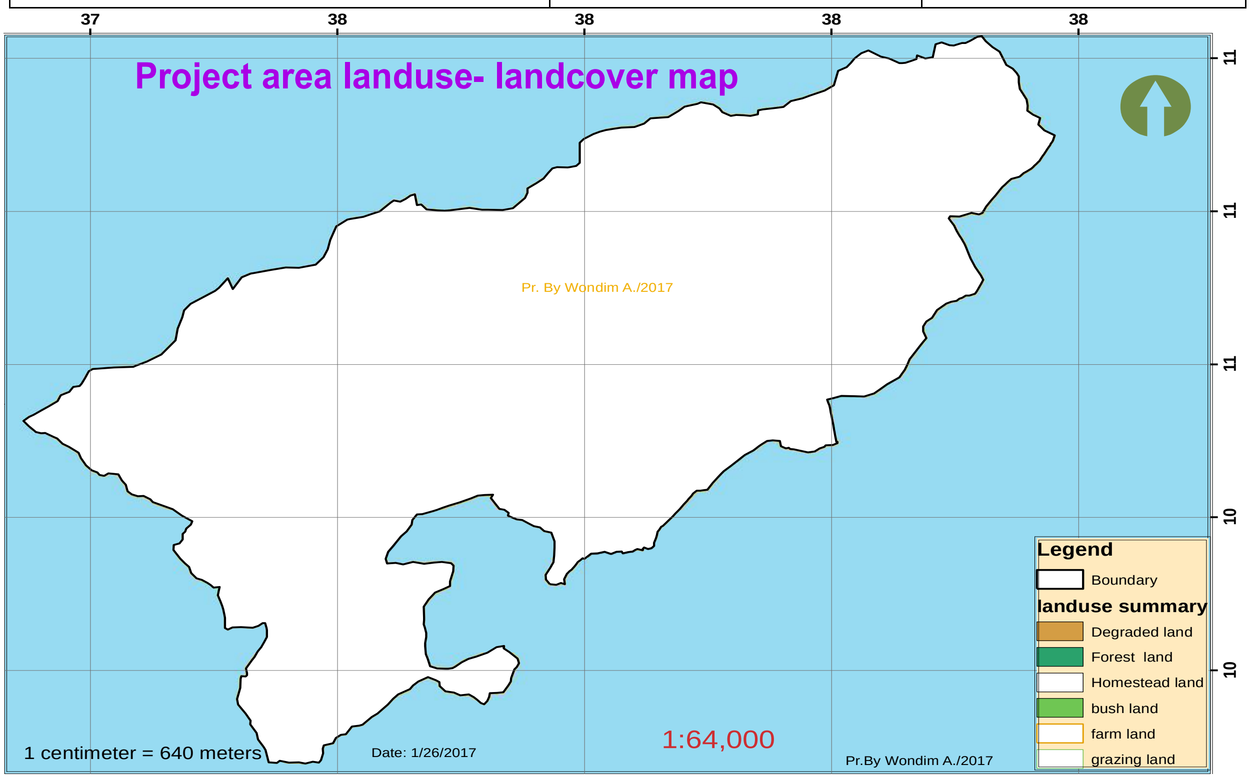


Figure 3: Land use/Land cover map of the study area in Machakel district (Source THP/E).

3.1.5. Restoration sites under study and their direct beneficiaries

Four restoration sites were randomly selected out of the total twenty one (21) restoration areas of the 2017 intervention sites of the Weforest project in four villages of the district. It includes Diba Mariet, Meskalimo, Genamemcha and Shola Amba in which the first two sites selected from Amarie Yewubesh village, Genamemcha from Lay Damot and Shola Amba from Debra kelamu villages. Therefore, the sum of sampled restoration areas land size is 21.1ha of the total restoration sites 56.14ha and the total population of the sampled sites are 162 of the total population of 883 direct beneficiaries of all the restoration sites.

Table 3: Sampled restoration sites and their direct beneficiaries.

No	Villages	Restoration sites	Land size(ha)	Main recipients		
				male	Female	Total
1	Amarie yewubesh	Diba Mariet	6	24	2	26
2	Amarie yewubesh	Meskalimo	11.25	37	2	39
3	Lay Damot	Genamemcha	1.5	42	0	42
4	Debra kelamu	Shola Amba	2.35	50	5	55
Total			21.1	153	9	162

3.2.Research Design

In this particular study, Descriptive research design was used to describe woody vegetation's regeneration diversity and abundance, biomass and carbon sequestration significance of degraded communal land restoration through participatory tree planting in relation to its before restoration intervention conditions.

On the other hand, the state of community participation and factors determines the involvements of non-participants were also described.

Based on observation, the research design of this particular study was prospective due to the data were gathered at different time before and after restoration intervention to evaluate the potential of degraded communal lands in terms of woody species regeneration diversity, abundance, biomass accumulation and carbon sequestration before and after restoration intervention. In this case, base line data was used to estimate and analyse before restoration and primary data was collected from direct field measurement to analyse after restoration intervention. In case of assessing the state of community participation and factors determines non-participants involvement, it was retrospective due to datas used for the analyses were collected at the same point in time.

In case of data used, this study's research design was both quantitative and qualitative research. Numeric datas were directly collected from field measurement and base line secondary datas collected from the office for biophysical studies which includes biomass and carbon stock estimation as well as woody plants regeneration diversity and abundance evaluation before and after restoration intervention. On the other hand, Qualitative datas were collected through questionary, focus group discussions (FDG) and key informant interviews and used to describe the state of community participation in communal land restorations and factors determining participation in restoration intervention.

3.3. Biophysical field survey and analysis

3.3.1. Data type and sources

Quantitative data was used to describe the biophysical potential of degraded communal lands before and after restoration intervention, in which primary data's was directly collected from field measurements for valuations after restoration intervention and secondary/baseline datas collected from office existing document.

3.3.2. Sampling Design

Probability sampling design was used for biophysical survey to give all units in the population equal chance of being chosen as a sample unit. A simple random sampling technique (lottery method) was used to pick the samples from the total population.

3.3.3. Sample size

The total population of interest was 21 restoration sites intervened during 2017 (the first phase of Weforest project restoration enactment) located in four villages of Machakel district. Of which, four sites were selected for sampling through simple random sampling (lottery method) which represents about 19 percent of the total population. Therefore, the sample unit was four restoration sites, in which the number of plots was determined based on the size of each restoration sites as specified under data collection method.

Restoration sites chosen for sampling using simple random sampling were: Shola Amba, Genamemcha, Meskalimo and Diba Mariet, the sizes of which are: 2.35, 1.5, 11.25 and 6 hectares respectively. Consequently, the corresponding plot numbers for each sampled restoration sites were 1, 1, 5 and 3 respectively and the total plot numbers for sampled restoration sites became 10 and the overall land size was 21.1ha. But due to only three plots baseline data were available for Meskalimo site, which land size is 11.25 ha; the total plot number reduced to 8 (eight) over the sampled sites.

3.3.4. Method of data collection

Baseline data was established before restoration physical intervention in 2017 and woody vegetation datas including DBH, DSH, H (Height), regeneration diversity and abundance were collected and documented. As a result, baseline secondary datas were collected from the office and primary datas from direct field measurement based on the same fixed plots established during baseline date collection and following the same methods and procedures. DBH (diameter at breast height (1.3m)) for trees and shrubs of DBH >5cm and DSH (Collar diameter (0.3m)) for small trees and shrubs of DSH 2cm to 10.1cm was measured using Caliper. The height (H) of trees and shrubs measured using hypsometer and measuring tape. Trees/Shrubs local and scientific names identified and recorded with their respective counted number per plots

Data was collected based on each fixed plot centers within the sampling units/restoration sites. Each fixed plot size nested at 20 m × 20 m and trees/shrubs paremeters measured. Plot numbers per restoration sites was determined based on restoration sites size and for sites less than 5ha plot number was one (site size < 5ha=1plot), for sites 5ha to 10ha, plot numbers were three (sites size 5ha to 10ha=3plots) and for sites greater than 10ha the plots were five (sites size >10ha=5plots). Each plots within the same restoration sites was adjusted at the distance of at least 150m far from each other and areas covered for data collection based on fixed plot centers was at least 5m inward to restoration sites to avoid boundary effects on the data’s.

- Parameters of woody vegetation (trees and shrubs) with a DBH >5cm measured within 20m × 20m nested plots.
- Parameters of woody vegetation (trees and shrubs) with DSH 2cm to 10.1cm measured within 5m × 5m nested plots.
- Woody vegetations regeneration identification and count was conducted within 5m ×5m sub nested plots.

Field data collection/measurement was carried out based on plot layout shown in Figure-4 below (Adopted from Weforest project base line data collection format).

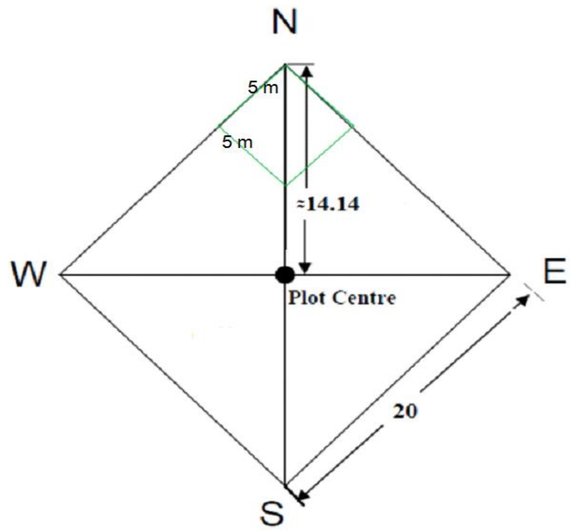


Figure 4: plot layout design for field data measurements.

3.3.5. Method of data analysis

Data from direct field measurements and baseline data from the office were first arranged and cleaned. The organized raw data were entered into Microsoft excel database and processed, then exported to SPSS tool for statistical analysis. The above and below ground biomass and carbon stocks of degraded communal lands were calculated before and after restoration intervention using selected models/allometric equations described here under. On the other hand, woody species regeneration diversity and abundance was counted and defined before and after restoration intervention. The cumulative biomass and carbon sequestration capacity of degraded communal lands was identified before and after restoration intervention and then the significant variation before and after restoration intervention was described and statistically tested using independent-sample t- test and ANOVA.

Similarly, woody species regeneration diversity and abundance of degraded communal lands before and after restoration intervention variation analysis was conducted using ANOVA and t-test. In this case, variation analyses were computed at 0.05 confidence level. Finally, datas were defined, aggregated and summarized for presentation in tabular, percentage and figure forms.

3.3.5.1. The Above ground biomass estimation(AGB)

To estimate woody vegetation's above ground biomass two different models were used. Multi-species pan tropical model developed by (Chave, Réjou-Méchain et al. 2014) was used to estimate the biomass of woody plants with trunk diameter greater than 5cm and the local model developed in Ethiopia by (Mokria, Mekuria et al. 2018) was used to estimate the biomass of small woody plants.

Model 1: Multi-species pan tropical allometric equation developed by (Chave, Réjou-Méchain et al. 2014). It is the latest model and was developed for tropical trees/shrubs from destructive sampling of 4004 tree species of tropical old growth and secondary forests of different continent and countries including Africa with no detectable effect of region or environmental factors. It includes the variety range of trees diameter (5<D<156cm) which is the highest range of diameter of the existing models. Different authors used the model in Ethiopia to estimate above ground biomass and then carbon stock. $REDD^+$ program in tropical countries and Ethiopia's using the model as a base for monitoring, verification and reporting the carbon stock of woody vegetation's as a means of mitigation measures for global climate change.

Based on model requirement, DBH and H (height) of trees/shrubs in each sample plots were measured and the above ground biomass of woody vegetation's with 5cm < DBH <156cm calibration interval was estimated using the model.

$$AGB = 0.0673 * (\rho * D^2 * H)^{0.976} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, AGB =Aboveground biomass (Kg)

ρ = Wood density (g/cm3)

D = Diameter at breast height (cm) and

H = Height (m)

In case of wood density (ρ), species specific density of ETHIOPIA'S FOREST REFERENCE LEVEL SUBMISSION TO THE UNFCCC, March 2017 and the average value of 0.612 g/cm^3 recommended by UN-REDD, 2016 for Ethiopia's forest reference level report of the $REDD^+$ program implementation was used for species not available in the reference list.

Model 2: Is a mixed species model developed by (Mokria, Mekuria et al. 2018). It was developed in Ethiopia, south Gonder zone Amhara region, which is the same region of this particular study area having nearly similar landscape and agro ecology. The model was developed based on degraded communal land restorations specially to include the role of small plants in climate change mitigation through carbon sequestration; which is the same case with this particular study. Consequently, it was used to include small woody plants in biomass estimation with calibration interval of DSH 2cm to 10.1cm.

$$AGB=0.2451 * (D_{30}^{2\,*}\,H)^{0.7038} \text{ ....} (2)$$

Where, AGB= Aboveground biomass (Kg)

D=Collar diameter (cm)

H= Height of woody vegetation (m)

3.3.5.2. Below ground biomass estimation

Belowground biomass was estimated using IPCC root to shoot ratio value of 0.26 for tropical dry forests (Eggleston, Buendia et al. 2006):

$$BGB = AGB \times 0.26 \text{ ……………………………} (3)$$

Where, BGB is belowground biomass (Kg),

AGB is above ground biomass and

0.26s conversion factor

3.3.5.3. Biomass conversion to units of carbon stock

The biomass was converted to a unit of carbon stock by multiplying the above and below ground biomass with a carbon fraction of 0.47 and 3.67 respectively (Eggleston, Buendia et al. 2006).

$$AGC = AGB*0.47 \text{ ………………………………} (4)$$

Where, AGC = Carbon in above ground tree biomass (ton C/ha)

AGB = Aboveground biomass (Kg)

0.47 = Conversion factor

$$BGC = BGB*3.67 \text{ …………………………….. } (5)$$

Where, BGC = Carbon in below ground tree biomass (ton/ha)

BGB = Belowground biomass (Kg)

3.67 = Conversion factor

3.3.5.4. Total above and below ground Carbon Stock

The overall above and below ground carbon stock density was determined by adding the carbon stock densities of the individual carbon pools using (Pearson, Walker et al. 2013) formulas:

$$CT_{ab}= AGC+BGC \text{ ………………………………….} (6)$$

Where, CTab = Total above and below ground carbon stock density (ton/ ha), AGC = Carbon in above ground tree biomass (ton C/ ha) and

BGC = Carbon in below ground biomass (ton C/ ha)

3.4. Social survey

3.4.1. Data type and sources

Qualitative data's was used to describe the state and determinants of community participation in degraded communal land restorations and it was collected from local peoples through survey questions, key informant interviews and focus group discussions.

3.4.2. Sampling design

Sample design to assess the state of community participation was purposive sampling method in which restoration participants total population was the all direct beneficiaries of 4 sampled restoration sites under biophysical study. It was selected purposely to its simplicity and direct analyses of its influence on the biophysical efficiency and samples drawn from participant's total population using simple random sampling.

Non-participants sample was selected using simple random sampling (lottery method) from the same and/or adjacent villages/sub villages of participants in proportional number.

3.4.3. Sampling size

Sample selection from restoration participants were entirely based on randomly sampled restoration sites for biophysical study, purposely to link the effect of community participation on woody species regeneration diversity and abundance, biomass and carbon sequestration improvement of degraded communal lands. Participants total population of the four sampled restoration sites are 162(F=9). The four randomly selected restoration sites are namely; Shola Amba, Genamemcha, Meskalimo and Diba Mariet and their respective participant communities are 55, 42, 39 and 26 respectively. Of which, 15% was selected randomly for sampling in proportion to each sites total participants. As a result, the total of 25 restoration participants was randomly selected for sample.

On the other hand, the same number samples of non-participants were randomly selected from the same and/or adjacent village/sub-villages of participant communities. Therefore, the sample size for communal land restoration participant and non-participant communities was 25 peoples per each and the total sample size for both participant and non-participants were 50 respondents.

Furthermore, two focus group discussions (FGD) was conducted, one per restoration participant members and the other per non-participants separately. Thus, totally two focus group discussions was accompanied and valuable data's was obtained. In this case, FGD was conducted with the group of seven peoples per participant members and eight per non-participants.

In addition, key informant interviews were conducted based on the 4 sampled restoration sites.

3.4.4. Method of data collection

Qualitative datas was collected through survey questions, focus group discussion (FGD) and key informant interviews per sampled participant and non-participant community members to assess the state of community participation in degraded communal land restorations and factors determining community's participation in degraded communal land restoration.

3.4.5. Method of data analysis

Datas collected through survey questions was first arranged, cleaned and coded. The arranged and coded datas were entered to SPSS the statistical analysis tool. Then, the datas were analysed and described for the state of community's participation in degraded communal restorations using descriptive statistics. In addition, the significant difference between restoration participant and non-participant communities in factors determining participation was tested using independent-sample T test.

Finally, the overall results was described and summarized in tabular, percentage and figures for presentation. Furthermore, data's obtained from focus group discussions and key informant interviews was processed and incorporated to the overall survey results for final reporting.

Chapter 4: Result and discussion

4.1. Impacts of restoration intervention on degraded land woody vegetation's biomass, carbon stocks, species regeneration diversity and abundance

4.1.1. Woody vegetation's biomass: before and after restoration intervention

The above ground biomass was estimated with two different models per medium to big and small woody plants separately. The estimates shows that the average AGB before restoration intervention was identified to be 1654.1kg/ha and it was enhanced to 16809.4 kg/ha after the restoration. Other study also shows that the mean AGB measured inside the exclosures was more than twice that of the adjacent grazing areas (Yayneshet, 2011). The average BGB before restoration was 428.1kg/ha and it became 4364kg/ha after the restoration. The total average above and below ground biomass before restoration intervention was found to be 2082.2 kg/ha and using same estimation method, the overall biomass of the degraded lands after restoration became 21173.4 kg/ha as described in Table 4 and Appendix-1. The Study conducted on the potential of exclosures and communal grazing lands biomass by (Mekuria and Veldkamp, 2012) indicated that all exclosures displayed higher biomass than the communal grazing lands in which it improves sites woody vegetation cover and abundance.

Table 4: Biomass description per sites before and after restoration intervention

Restoration Sites:		Mean	Std. Deviation	N
Before restoration total biomass kg/ha	Diba Mariet	1093.33	1120.952	3
	Genamemcha	6028		1
	Meskalimo	2450	2100.161	3
	Shola Amba	0		1
	Total	2082.25	2222.57	8
After restoration total biomass kg/ha	Diba Mariet	6211.67	1541.106	3
	Genamemcha	32955		1
	Meskalimo	19961.67	11683.488	3
	Shola Amba	57912		1
	Total	21173.38	18678.689	8

The variation in degraded land biomass accumulation potential before and after restoration intervention was analyzed using sample t test. As a result, biomass accumulation potential of the land after restoration intervention was significantly different from before restoration with p value < 0.05 as described in Table 5.

Table 5: Biomass variation test before and after restoration

Biomass Before and After restoration	t	df	Sig. (2-tailed)	Mean Difference
Before Restoration total biomass kg/ha	2.65	7	0.033	2082.25
After Restoration total biomass kg/ha	3.206	7	0.015	21173.375

The variation in the total mean values of biomass before and after restoration intervention shows the existence of evocative difference in biomass accumulation potential of the land after restoration intervention. It approved that there is a major increment in the total biomass storing potential of degraded land after restoration intervention by more than ten (10) times within short period of restoration intervention (three and half years). Therefore, degraded land restoration approaches with combination of exclosures and enrichment tree planting gets effective vegetation cover of degraded lands and biomass accumulation potential of the sites within short restoration period.

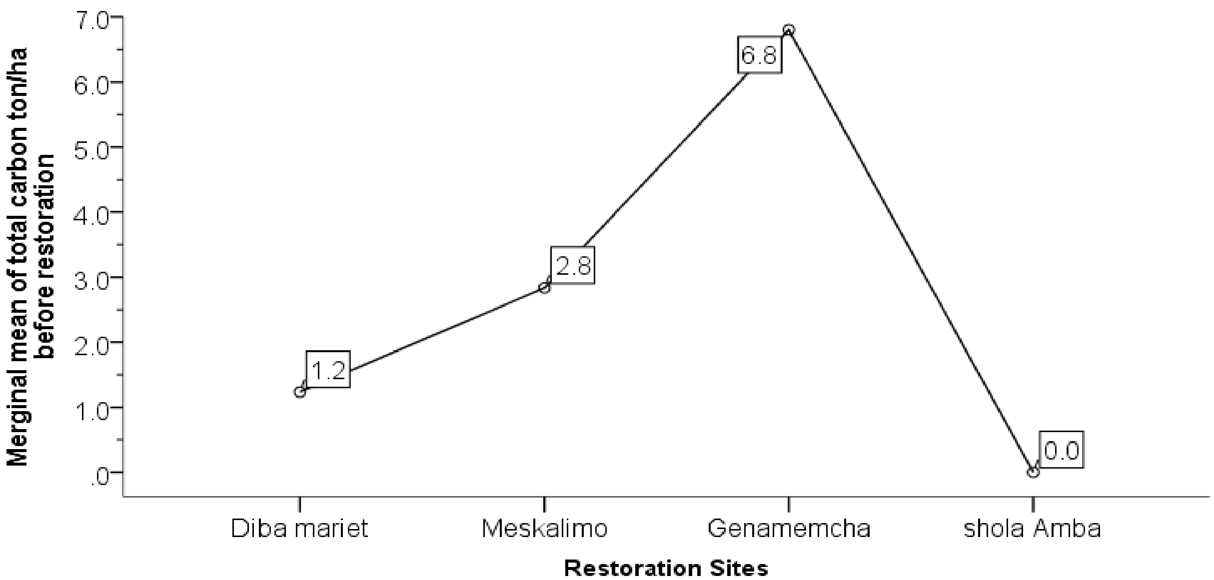
4.1.2. Carbon sequestration potential of the land: before and after restoration

4.1.2.1. Carbon sequestration and pattern of variations

Carbon sequestration implies to the transfer of atmospheric CO_2 into other long-lived global pools including biotic (Lal, 2008). Forest sequesters carbon by capturing carbon dioxide from the atmosphere and transforming it into biomass through photosynthesis. Sequestered carbon is then accumulated in the form of biomass, deadwood, litter and in forest soils. In such processes, degraded land restorations contribute to decreasing the effect of global climate change through atmospheric carbon sequestration in woody vegetation's.

Sampled sites carbon estimation outcome shows that the carbon sinking potential of degraded communal lands before restoration intervention ranges from 0.0 ton/ha to 6.8ton/ha. Sites minimum carbon sequestration potential was zero at Shola Amba restoration site and sites maximum carbon sinking potential was identified at Genamemcha site with 6.8 ton/ha as illustrated in Figure 5.

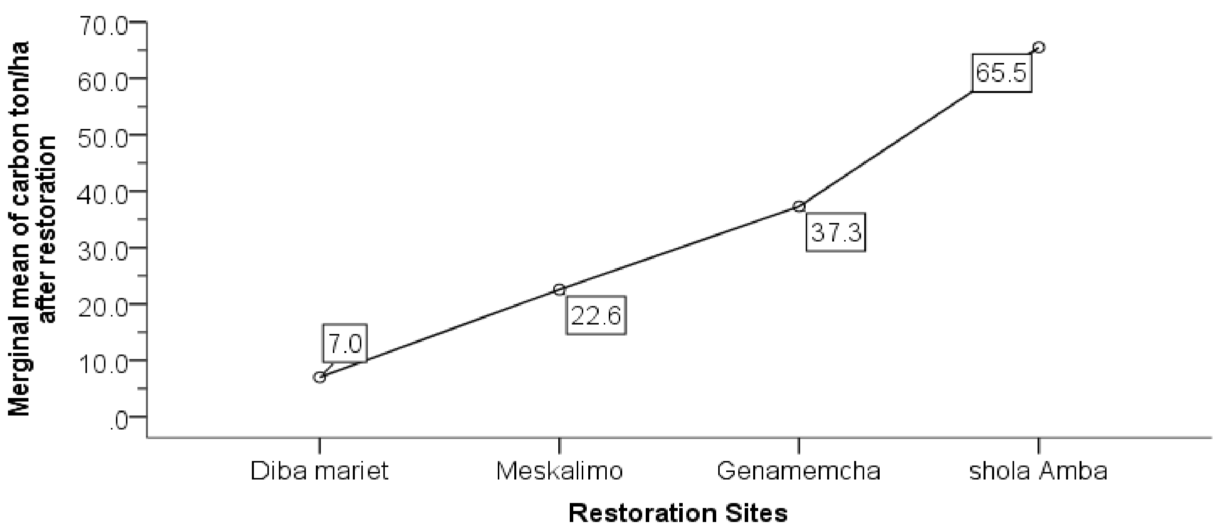
Figure 5: Sites Carbon sequestration performance before restoration intervention



The variations in carbon sinking potential among sites before restoration intervention was mainly generated from sites nature, degradation level, types of vegetation cover and growth level of woody plants in the sites. As a result, Shola Amba site was identified with zero carbon stocks as a consequence of sites under high land degradation pressure mainly due to overgrazing and soil erosion. As an effect, there was no any woody vegetation cover in the site from which the carbon is derived before restoration intervention. On the other hand, the highest carbon stock was recorded in Genamemcha site due to the existence of remnant single tree species of *Croton macrostachyus* scattered in the site. Diba Mariet was site under high forest and land degradation pressure due to intermingling factors of illegal cutting, overgrazing and land slide emanated from site nature including landform and seasonal river crossing through the site. As a result, there was few woody plants existed in the site within diametric range of carbon estimation models. Evidences from local residents shows that Meskalimo site was with dense natural forest before two decades but due to illegal cutting for fuel wood, construction material and forest clearing for agricultural land expansion, it was left with only stressed shrubs and some scattered tree species after a decade ago, as a consequence, sites carbon stocking potential became lower.

On the other hand, sites minimum carbon sequestration potential after restoration was found to be 7.0 ton/ha at Diba Mariet site which is dominated by small woody vegetation and grass cover due to the restoration was conducted with high emphasize on natural regenerations with minimal enrichment tree planting. The maximum carbon sinking potential after restoration intervention was recorded at Shola Amba site with 65.5 ton/ha in reverse to it's before restoration carbon sinking potential which was zero. Site carbon sinking potential was exceedingly improved mainly due to the site was dominantly planted with fast growing *Acacia decurrens* and densely covered with other planted tree species. The overall carbon stocking variation among sites after restoration intervention was as illustrated in Figure 6.

Figure 6: Sites Carbon sequestration performance after restoration intervention



The minimum carbon sequestration performance zero ton/ha realized at Shola Amba site before restoration intervention was meaningfully improved to 65.5 ton/ha mean values after the restoration. This makes it the highest improved site in carbon sinking potential after restoration intervention. Genamemcha site showed the highest mean value of 6.8 ton/ha carbon sinking potential before restoration intervention especially due to the remnant single tree species *Croton macrostachyus* found in the sampling plot. In the same manner, all sampled restoration sites showed an improvement in the average carbon sinking potential after restoration. In addition, Diba Mariet and Meskalimo sites showed relatively low carbon sinking performance both before and after restoration intervention due to two main reasons; first, both sites was degraded areas before restoration and dominated with regenerating small woody vegetation's after restoration and secondly, limited number of enrichment planting was made to both sites relatively.

In general, degraded land restoration enhanced the average above ground carbon sequestration potential of land from 0.8 ton/ha before to 7.9 ton/ha after restoration intervention. Studies conducted by (Aradóttir *et al.*, 2000) shows that the recovery of degraded land results in organic carbon sequestration in which the annual rate of sequestration in aboveground biomass ranged from 0.01 to 0.5 t C /ha per year in which, the amount depending on the recovery method used and site conditions. On the other hand, below ground carbon sequestration was improved from 1.6 ton/ha before to 16 ton/ha after restoration intervention. The overall average carbon sequestration potential of degraded land before restoration intervention was identified to be 2.4 ton/ha and the total average carbon sinking potential of the land after restoration was found to be 23.9 ton/ha as described in Appendix 3.This implies that degraded land restorations improved land carbon sequestration potential by approximately 10 times after three and half years intervention. Other study also dedicated that the total carbon stock was significantly higher in exclosures 61.3 Mg C ha^{-1} than degraded open grazing land 40.4 Mg C ha^{-1} and the change of degraded open grazing land to exlosures enhanced aboveground biomass carbon stock by 197% at the age of 12 years (Manaye, Negash and Alebachew, 2019).

The significance difference in land carbon sequestration potential before and after restoration intervention was tested with one sample t test, and As a result, statistically there was a significant difference in the mean carbon sinking potential of degraded communal lands after restoration intervention with p value < 0.05 as described in Table-6. Solomon *et al.*, 2017 indicated that, the C content of the total biomass for the managed natural forest and the exclosure were estimated as, 58.11 and 22.29 Mg ha^{-1}, respectively, while that for the grazing land was 7.76 Mg ha^{-1}, and the mean carbon content between the three land uses were significantly different ($p < 0.05$). Therefore, degraded land restoration is the proved mechanism for escalation of land carbon sequestration potential while the magnitude of its effectiveness depends on different factors.

Table 6: Land Carbon sinking potential variation depiction before and after restoration

Land carbon sinking potential before and after restoration	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Before restoration Carbon (ton/ha)	2.67	7.00	0.03	2.38	0.27	4.48
After restoration Carbon (ton/ha)	3.20	7.00	0.02	23.94	6.26	41.62

4.1.2.2.Carbon stocks and woody species contribution

Different species of woody plants were contributed to the carbon stocks of sampled sites both before and after restoration intervention. As a result, before restoration, four woody species was contributed to the carbon stocks of the study sites which includes *Rosa abyssinica, Carrisa edulis, Acacia abyssinica and Croton macrostachyus.* In this case, *Croton macrostachyus* contributed most of the carbon stocks before restoration which covers 90.47% of the total carbon stocks and *Acacia abyssinica* added the least 1.65%, *Rosa abyssinica* and *Carrisa edulis* contributed 2.9% and 4.98% respectively of the total carbon stocks before restoration intervention. On the other hand, eleven woody species was contributed to the carbon stocks of sampled restoration areas after the restoration. These includes *Croton macrostachyus, Acacia decurrens, Rosa abyssinica, Carrisa edulis, Acacia abyssinica, Cupressus lusitanica, Myrinse Africana, Euclea schimperi, Brucea antidysenteric, Gravillea robusta* and *Acacia saligna.* In this case, *Acacia decurrens* which was planted as an enrichment plantation contributed the most to restoration sites carbon stocks after restoration intervention, which accounts for 62.5% of the total, the existed remnant species of *Croton macrostachyus* contributed 18%, *Acacia abyssinica* 9.1% and *Rosa abyssinica, Carrisa edulis, Cupressus lusitanica, Myrinse africana, Euclea schimperi, Brucea antidysenteric, Gravillea robusta* and *Acacia saligna* were contributed land carbon stocks by 2.36, 4.73, 1.8, 0.2, 0.15, 0.21, 0.63, and 0.32% respectively.

4.1.3. Woody species regeneration diversity and abundance: before & after restoration

4.1.3.1. Woody plants regeneration diversity

Woody species regeneration diversity was assessed based on sampled restoration site's predefined plots and existed species local and scientific names identification. As a result, woody plants regeneration diversity before restoration intervention was found to be the total of three woody species such as *Acacia abyssinica*, *Maytenus arbutifolia* and *Carissa edulis* per all sampled restoration sites. The all species were recorded at Meskalimo site with different in numbers and one species *Acacia abyssinica*; double found at Diba Mariet site as shown in Table-8. The other two sampled restoration sites Genamemcha and Shola Amba had no any record of woody species regeneration before restoration intervention. For the reasons that, Genamemcha site was dominantly covered with grass species and some scattered trees, and the site was subjected to high overgrazing pressure. Shola Amba was highly degraded site and there were no any woody vegetation cover in the site. Large gullies were formed in the site mainly due to overgrazing pressure and may be other intermingling factors. These factors and may be others depressed sites woody species regeneration capability before the restoration.

On the other hand, the total number of species regeneration after restoration intervention was twisted out to 23 woody species, each with different in numbers per sites including the three regenerated species existed before restoration as shown in Appendix 2 and 4. As a result, Diba Mariet=11, Meskalimo=18, Genamemcha=0 and Shola Amba=9 as shown in Table-8. In all cases, species regeneration diversity was counted overlapped per each site. Meskalimo site was the most in woody plants regeneration diversity because; it was natural forest areas before the decades and dominantly covered with small woody species before the restoration which developed the basis for better woody species regeneration performance after restoration interference. Diba Mariet site was covered with some small woody plants before restoration, which puts the basis for its moderate regeneration diversities after restoration interference. Shola Amba was highly degraded and bare site before restoration and due to it was enclosed from any animal and human interference after the restoration with enrichment tree planting, the site was encouraged for hastened woody species regeneration diversity. The study conducted by (Gebremedihin, Birhane et al. 2018) confirmed that exclosures can foster secondary forest succession by improving soil conditions, attracting seed-dispersal agents and modifying microclimate for understory growth. Differently, there was no any woody species regeneration found at Genamemcha site after the restoration. This happened mainly due to the site was dominated with densely planted *Acacia decurrens* and *Eucalyptus globulus* which puts pressure on the understory growth and it was predominantly covered with grass species before the restoration and as a result, there may be no/less tree seeds or vegetative roots in sites soil bank. Therefore, As a result of degraded land restorations, woody species regeneration diversity was improved from three (3) species before restoration to 20 after restoration intervention without including regenerated species existed in the sites before the restoration. This indicates that, woody species regeneration diversity potential of degraded communal lands was improved by 7.7 times after short restoration intervention of three and half years. Other studies also confirmed that the diversity of woody plants was higher in the exclosures than in the grazed areas (Yayneshet, 2011) and it was found that 39 tree species naturally regenerating in the restored area in addition to the five originally planted species (Omeja *et al.*, 2011).

The variation in woody species regeneration diversity before and after restoration intervention was tested using one sample t test and it was significantly different in sites regeneration diversity with p values < 0.05 as described in Table-7.

Table 7: Woody species regeneration diversity variation depiction before and after restoration

Diversity before and after Restoration	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Woody species diversity before R	2.50	7.0	0.041	0.88	0.05	1.70
Woody species diversity after R	4.34	7.0	0.003	7.00	3.18	10.82

Therefore, degraded land restorations through exclosures and enrichment tree planting are instrumental to improve the woody species regeneration diversity and effective land rehabilitation with vegetation cover within short intervention period.

Table 8: Woody species regeneration diversity and abundance before and after restoration

Woody vegetation species			Diba Mariet			Meskalimo			Genamemcha	Shola Amba	
Before restoration number of woody species regeneration per sites/plots											
			Sampled restoration sites								
No	Local name	Scientific name	P1	P2	P3	P1	P2	P3	P1	P1	Total
1	Yehabesha grar	*Acacia abyssinica*	0	3	0	4	0	0	0	0	7
2	Atat	*Maytenus arbutifolia*	0	0	0	25	5	73	0	0	103
3	Agam	*Carissa edulis*	0	0	0	0	3	1	0	0	4
		Ground Total	0	3	0	29	8	74	0	0	114
After restoration number of woody species regeneration per sites/plots											
1	Yehabesha grar	*Acacia abyssinica*	3	67	4	3	0	0	0	3	80
2	Chifrig	*Sida tenuicarpa*	10	0	0	0	10	0	0	0	20
3	Gorgo	*Erythrina abyssinica*	5	2	0	0	0	0	0	0	7
4	Atat	*Maytenus arbutifolia*	2	0	0	32	53	280	0	0	367
5	Anfar/Nechilo	*Budeleia polystachya*	21	0	0	2	4	9	0	11	47
6	Yeferanj tid	*Cupresus lusitanica*	16	0	0	0	0	10	0	3	29
7	Dikerens zaf	*Acacia decurrens*	0	10	0	20	0	0	0	29	59
8	Kega	*Rosa abyssinica*	0	15	0	3	0	0	0	0	18
9	Agam	*Carissa edulis*	0	0	6	19	9	0	0	0	34

10	Sasbania/Girangire	*Sesbania sesban*	0	0	9	3	6	0	0	4	22
11	Nechbaher zaf	*Eucalyptus globulus*	0	0	3	0	0	0	0	0	3
12	Enjori	*Rubus steunberi*	0	0	0	4	0	0	0	0	4
13	Saligna	*Acacia saligna*	0	0	0	2	0	0	0	2	4
14	Abalo	*Brucea antidysenterica*	0	0	0	3	0	5	0	2	10
15	Qacamo	*Myrinse africana*	0	0	0	76	0	20	0	0	96
16	Limich	*Causena anisata*	0	0	0	7	0	8	0	0	15
17	Fiyelfej	*Cutia abyssinica*	0	0	0	5	5	8	0	0	18
18	Dingayseber/Misar gaftir	*Ilex mitis*	0	0	0	3	0	8	0	0	11
19	Gangarita	*Vernonia oriculifona*	0	0	0	0	2	5	0	0	7
20	Koshim	*Dovyalis abyssinica*	0	0	0	0	0	1	0	0	1
21	Djigitta	*Euclea schimperi*	0	0	0	0	0	5	0	0	5
22	Gravilla	*Grevillea robusta*	0	0	0	0	0	0	0	3	3
23	Azamir	*Bersama abyssinica*	0	0	0	0	0	0	0	3	3
	Ground Total		57	94	22	182	89	359	0	60	863

4.1.3.2. Woody species regeneration abundance

Sites woody plants regeneration density was identified both before and after restoration intervention and as a result, the total of three woody species regeneration was identified per all sampled sites with different in numbers. Diba Mariet site had identified with a single species regeneration of *Acacia abyssinica* which was only three (3) in numbers per the three sampling plots of the site and/or per 75m^2. Meskalimo site was recorded with three woody plants regeneration, with different numbers which include *Acacia abyssinica*=4, *Maytenus arbutifolia*=103 and *Carissa edulis*=4 per the total sampling plot area of 75m^2. The others two sampled restoration sites Genamemcha and Shola Amba were identified with no woody species regeneration before restoration intervention as shown in Table-7. It was due to possible reasons mentioned under 4.1.3.1. Thus, the total number of wood plants regenerated per sampled plots, before restoration intervention was found to be 114 per 200m^2 (the sum of all sites sampling plots area). In this case, *Maytenus arbutifolia* takes the greatest share which was 103 of the total 114 regenerated trees/shrubs as shown in Appendix 2.

On the other hand, woody species regeneration abundance after restoration intervention was assessed and as a result, twenty three (23) regenerating woody species were identified including regenerating species existed in the sites before restoration with the total number of 863 per 200m^2 the total sampling plot area which was the same for before restoration assessment. Of the twenty three identified regenerating species, *Maytenus arbutifolia* holds the highest number 367 which covers 42.5% of the total, *Myrinse africana*=96(11%), *Acacia abyssinica*=80(9.3%) *and* the left backs 37.2% shared among the other twenty (20) regenerating woody species as shown in Appendix 4.

Overall, the total regeneration abundance before restoration intervention was identified to be 114 woody plants per the sum of eight sampling plot areas (200m^2) and 863 after the intervention per the same sampling plot area of 200m^2; which was proportionally 5700 to 43100 regenerating woody species per hector before and after the restoration respectively. This indicates that, woody species regeneration abundance of degraded lands, improved by 7.57 times after three and half years of restoration intervention. The study conducted to identify species richness, diversity and biomass among different aged exclosures and the adjacent communal grazing land, was ensured that, All exclosures displayed higher plant species richness than the communal grazing lands and also higher at old exclosures than at young (Mekuria and Veldkamp, 2012).

In this case, sampled sites variation in woody plants regeneration abundance before and after restoration intervention was depicted using T-test and as a result, it was significantly different with p value < 0.05 after restoration intervention as described in Table-9.

Table 9: Woody species regeneration abundance variation test before and after restoration

Regeneration abundance before and after restoration	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Regeneration abundance before R.	1.54	7	.166	14.25	-7.56	36.06
Regeneration abundance after R.	2.65	7	.033	107.88	11.51	204.24

Therefore, restoration approaches with exclosures plus enrichment tree planting is the best instrument to improve degraded land's woody species regeneration abundance within short restoration period of three and half years.

Picture 1: Sample photos during biophysical data collection from the field.

4.2. The state & determinants of community participation in degraded land restoration

4.2.1. Demographic and socio economic characteristics of the respondents

Most respondents age was found in between 41-60 years which covers 54% of the total respondents whereas 32% of the respondents are in age between 21-40 years while others 8%, 4% and 2% are in age between 61-80, $\leq$20 and >80 years respectively. On the other hand, most respondents are males which cover 92% of the total and 8% females as described in Table-10.

Table 10: Respondents age and sex descriptions

Respondents age and sex categories:		Frequency	Percent
Age	$\leq$20	2	4
	21-40	16	32
	41-60	27	54
	61-80	4	8
	>80	1	2
	Total	50	100
Sex	Male	46	92
	Female	4	8
	Total	50	100

An educational level of most respondents was in between 1-5 grades which covers 43.8 % of the total respondents and 20.8% of the respondents was attended adult educations while 18.8% are not attended any education. The other 14.6 % were attended $5\text{-}10^{th}$ grade while only a single individual attended $10\text{-}10^{+4}$. On the other hand, all respondents' main occupation is farming.

Regarding respondents marital status, 84% was married of the total**,** 8% divorced, 4% unmarried and the other 4% widowed. On the other hand, 90% of the respondent's household's type was male headed while 10% was female headed household.

Most respondent's family size was in between 4-6 members which covers 56% of the total, while 28% respondents' family size was in between 1-3 and 16% respondents family size was greater than 6 individuals.

In terms of respondent's income, most respondent's yearly cash income was in the range of 10001-15000 birr, which covers 34.8% of the total respondents. 21.7% of the respondents yearly cash income was identified to be < 5000 birr, 17.4% respondents in between 15001-20000 birr, 13% respondents income 5000-10000 birr and another 13% respondents yearly cash income was greater than 20,000 birr as described by Figure-7.

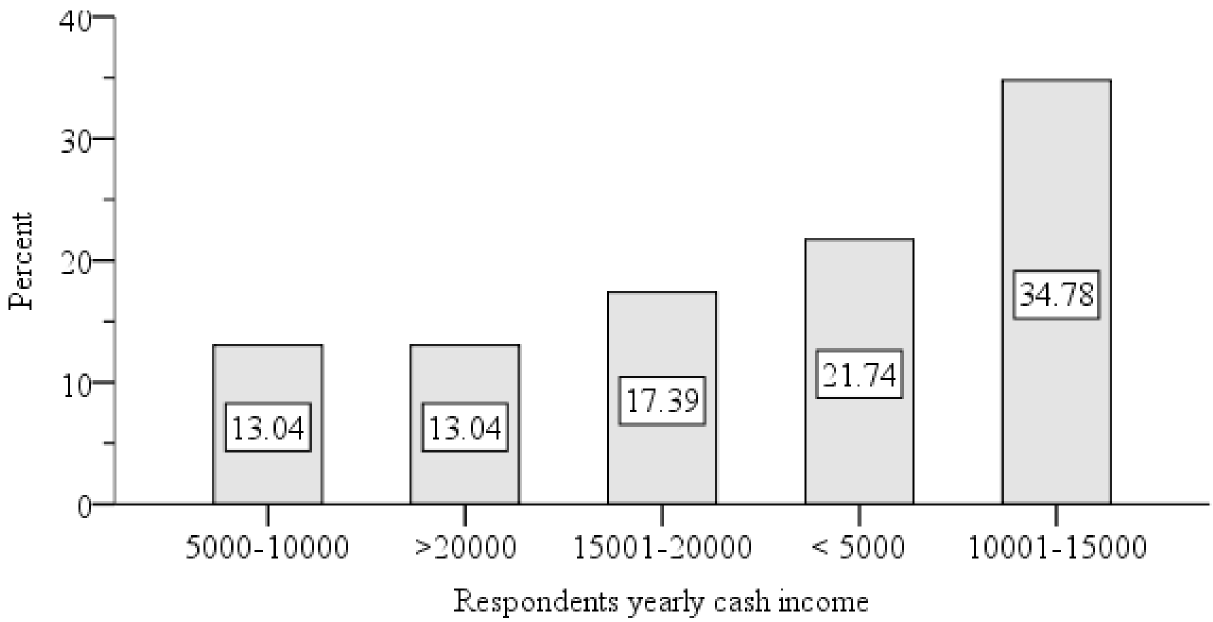


Figure 7: Respondent's yearly cash income percent

In case of respondent's period of residence in the area, most respondents, 86% are living in the area throughout their life. 6% are living for 1-5 years, 4% are for 26-35years, 2% are living for 16-25 years and the others 2% are living in the area for 6-15 years.

4.2.2. The State and level of community participation in degraded land restoration

4.2.2.1. Community participation per stages of the restoration project

Community participation per different stages of the restoration project were assessed based on each participants percent of involvement per each performed tasks and/or time attended by the participants of the total time he/she was assumed to attend per tasks. Accordingly, for tasks performed by the participants and/or time attended > 80% of the total expected, the participation level was labeled as very high, 60-80% high, 50-60% medium, 30-50% low and <30% very low. Based on such scaling, data collectors identified each participant's extent of participation per different stages of the project such as planning, implementation; monitoring and evaluation. Accordingly community participation was examined per all stages of the project.

Project planning: Is one of the project stages at which what to do, in what amount, when to do, who will do, with what financial source and amount and others designed. At the planning stage of the restoration project, communities were participated in the way that; all communal land owners came together and plan each and every activities to be performed with time frame, sources of materials and inputs, size of land to be restored and finally by law and agreements developed and signed among participant communities with the facilitation of project partners. In such a ways, all restoration participant respondents were involved in the planning stage of the project at different level of participation, in which, 40% were participated at high, 32% very high and 28% were at medium participation level while there was no low level of participation in the planning stage of the project as described in Table-11. Those participated at very high level (32%) was involved in almost all public meetings and discussions made for project planning and actively contributed their inputs and experiences at project planning stage while those participated at medium(28%) was attended the planning session and contributed inputs for 50-60% of the total gatherings made for restoration project planning by the community.

Table 11: Description of community participation extent at project planning stage

Level of participation	Frequency	Percent
Very high	8	32
high	10	40
medium	7	28
Total	25	100

Project implementation: Is one of the project stages at which all planned activities physically realized on the ground. At this stage of the project, communities were participated through restoration area demarcation, local material, cash and food contribution, labor contribution for restoration sites physical and social fencing (communities collective action for looking and protecting the site from any interference), pitting, seedling transportation from main or pilot nurseries to restoration sites, planting tree seedlings, silvicultural management including weeding, hoeing and tinning. Per all those implementation activities, all communal land owners were expected to participate equally and actively and As a result, most participants (64%) were involved at very high extent of participation, in which they were involved per all restoration activities such as; restoration site identification and demarcation, contribution of labor, material, cash and food for work. Some were participated at high involvement level (28%) whereas the few (8%) at medium level, in which, high and medium level participants were involved at 60-80% and 50-60% of the total activities in terms of tasks performed and/or time taken to perform the activities respectively. Hence, all restoration participant respondents were participated in all project implementation activities with different extent of involvement, in which the most were participated at very high pace of involvement as described by Table-12.

Table 12: Description of community participation extent at project implementation stage

Level of participation	Frequency	Percent
Very high	16	64
high	7	28
medium	2	8
Total	25	100

Project monitoring*:* Is the stage at which communities overlook for restoration project out comes, shortcomings encountered and action for corrections identified. At this stage of the project, the communities were involved by physically identifying restoration sites overall status, improvement level, shortcomings and providing information for public discussions. Then, through community discussions, further arrangements identified for collective actions. As a result, all respondents were participated in monitoring stage of the project but at different extent of involvement in which, 52% of the respondents participated at high level, 24% very high, 20% medium and 4% low level as described in Table-13. In this case, those participated at very high level was involved in physical supervision of the sites and identifying all best performances and weaknesses for further action and they were actively participated in all community discussions, while those participated at high level was actively participated per all project monitoring community discussions. Medium and low level participants were involved in project monitoring programs for 30-50% and less than 30% respectively. Generally, most participants (52%) were involved in monitoring stage of the project at high participation level whereas 24% participated at very high level, which was mostly included, the sites committees whose were responsible for continuous sites overseeing, due to additional duties set to them by the communities.

Table 13: Description of community participation extent at project monitoring stage

Level of participation	Frequency	Percent
Very high	6	24
high	13	52
medium	5	20
low	1	4
Total	25	100

Project evaluation*:* is the project stage at which the communities participated to evaluate the overall output of the project. In this stage, different stakeholders including the communities came together and value the project impact in which the communities takes part in pining out the real impacts of the project. To this effect, unlike other stages of the project, at restoration project evaluation, only a few respondents were participated. As a result, only 20% of sampled restoration participants were involved, but at very high extent of participation. On the other hand, 80% of the respondents were not participated at project evaluation stage as described in Table-14. This was mainly due to only the restoration site committees were participated in project evaluation program.

Table 14: Description of community participation extent at project evaluation stage

Level of participation	Frequency	Percent
Very high	5	20
Not participated	20	80
Total	25	100

In general, community participation at each stage of the restoration project was described and As a result, all the respondents were participated in project planning, implementation and monitoring stages with different level of involvement. But at project evaluation stage, only 20% of the respondents were participated. The level to which the respondents where participated per each stage of the restoration project was varying. Thus, at project planning and monitoring stages, most participants were involved at high level. In different from other stages of the restoration project, at implementation stage, most respondents (64%) were participated at very high level of involvement. Through focus group discussion (FGD), it was known that, most communities were participated in project implementation stage at very high level mainly due to; 1. It was a stage at which resource ownership right for future use was confirmed. Communal land owners, those participated in most of project implementation activities would have resource ownership right whereas those not participated would not have ownership right based on communities preceding agreement. 2. There was also a serious social responsibility through local institution called "Idir" which enforces the member communities to participate at each project implementation activities. If the member communities not participated, it imposes penalty in cash and even withdrawn from ownership right of the resource, if the penalty in cash was repetitive, based on the agreement and bylaws signed among the communities. On the other hand, at project evaluation stage, only 20% of the respondents were involved at very high level whereas the most 80% was not participated due to different reasons. During focus group discussions (FGD), it was identified that most communities were not participated in project evaluation, mainly due to only restoration site committees were attended the project evaluation session for duties overlapped related with campaigns organized by the local government.

Totally, all respondents were participated per the first three stages of the project and only 20% participated in the evaluation stage. In this case, community participation was performed with different extent of involvement per different project stages. As a result, community participation was performed mostly at very high level in the implementation stage of the project, in which 64% of the respondents were involved, and at the planning stage, 32% of the respondents were participated at very high level. On the other hand, 24% of the respondents were participated in the monitoring stage of the project at very high level and at project evaluation stage; the all participants (20%) of the respondents were participated at very high level. These indicate that, most communities were participated at best enhanced level in project implementation stage than other stages of the project.

4.2.2.2. Community's motives for participation in degraded land restoration

Community motives for participation in degraded communal land restoration were assessed through survey questions and focus group discussions. Results of both approaches indicate that, communities reason of participation was not entirely depends on a single reason but it was originated from multiple reasons. As a result, most respondent's reason of participation in degraded communal land restorations was; recognizing the extreme challenges of land degradation problems happening in their localities (56%). other respondent's; 28% and 16% recognized the problem of land degradations as a reason for their participation but it was not the first and the only reasons for their participation.

On the other hand, 28 % of the respondents were participated entirely due to social responsibility imposed on them through local institution known as "Idir", whereas 40%, 24% and 4% of the respondents were participated because of social duties at high, moderate and low levels respectively in addition to other reasons and 4% of the respondents was totally not participated due to social responsibilities as described in Table-15.

Table 15: Survey summary for community's reasons to participate in land restoration

No	Respondents reasons for participation in restoration	Motives and extent for participation						Total responses
		Very high	high	medium	low	very low	no	
1	Recognized problem of land degradation	14	7	4	0	0	0	25
		56%	28%	16%	0	0	0	
2	Social obligation through local institutions Idir & Ekub	7	10	6	1	0	1	25
		28%	40%	24%	4%	0	4%	
3	To make life better of restoration benefits	8	13	4	0	0	0	25
		32%	52%	16%	0	0	0	
4	To get cash income	1	3	8	2	6	5	25
		4%	12%	32%	8%	24%	20%	
5	Due to other reasons	0	0	0	0	0	25	25
		0%	0	0%	0%	0	100%	

During focus group discussions (FGD) it was identified that some community members were participated in communal land restorations because of social duties through local institutions especially “Idir”. This was happened when the land identified for restoration is owned by “Idir” members and most members agreed to restore their common land. Then they enforce the members for their collective action in degraded land restoration activities through their existing local institutions and finally sharing its related benefits equally.

Additionally, some respondents were participated in degraded communal land restorations fully or partially for anticipated restoration benefits. Hence, 32 % of the respondents were participated in degraded communal land restorations awfully to make their lives better of the anticipated restoration benefits. Also, 52% and 16% of the respondents were participated in degraded communal land restorations highly and partially for its expected benefits respectively.

Furthermore, it was understood that some communities were participated in degraded communal restorations to earn cash income from the restoration works at different degrees of intentional level. In this case, only 4% of the respondents were participated in degraded land restorations highly for cash income imbursement whereas 12% and 32% of the respondents partially participated for cash income from the intervention. Others, 8% and 24% of the respondents was participated in communal land restorations with low and very low expectations of cash income from the intervention respectively whereas, 20% of the respondents were participated without any expectations of cash income from the intervention.

Therefore, communities were participated in degraded communal land restoration for different overlapping reasons and/or interest including recognizing the problem of land degradation in their locality, social duties through local institution ‘Idir”, restoration expected benefits and cash income from the restoration works. In focus group discussion (FGD), the team was explained that, the severity of land degradation, the intensified gully formation in the area and loss of land productivity are some of the land degradation problem as a reason for their participation in degraded communal land restoration. In addition, they also explained that some community members participated in restoration works for the expected benefit of the restoration including grass harvesting from the restoration sites, opportunity of bee farming, cattle fattening, improved milk production, selling of trees when gets matured for communal and/or shared individual benefits, fruit trees and other multipurpose agroforestry trees provided to communal land restoration participants individually as an incentives for their participation and some others participated to earn cash income from employment opportunities at tree seedling production nurseries and other daily work opportunities.

4.2.2.3. Purpose of plantations and tree species selection

Types of tree species planted for degraded land restorations through community participation was identified from direct field observation, key informant interview, survey questions and focus group discussions (FGD). Result from experts in key informant interview shows that the aim of the restoration project was to plant greater number of indigenous tree species and less exotics species in 80:20 ratios as an enrichment plantation respectively with more focuses on nature restoration. But this approach faced the great challenges from restoration land owners in which the communities prefers fast growing commercial trees including *Eucalyptus* and *Acacia decurrens* species for their relatively fast economic benefits. After continuous discussions and awareness raisings made, the communities came to consensus with some modifications on tree species ratios and finally both native and exotic tree species was planted for degraded land restoration with active community participation. As a result, through focus group discussions and direct field observations the same result was confirmed with the key informant interviews. In addition, results from survey analysis described in table-16 comes with the same results in which both indigenous and exotic tree species were panted for degraded communal lands restoration.

Table 16: Description on tree species planted for degraded land restorations

Tree species planted for restoration	Frequency	Percent
Indigenous	0	0
Exotic	0	0
Indigenous and Exotic	25	100
Total	25	100

Survey analysis on community's purpose of tree plantation on degraded communal lands shows that, most of the respondents (72%) were planted both native and exotic tree species on their degraded communal lands mainly for environmental protection and commercial purposes in which, they assumed for environmental protection as it is the mitigation measure for the emerging land degradation challenges in their localities by reducing soil erosion, minimizing runoff, gully rehabilitation and improving local weather conditions and for commercial purposes through harvesting of trees when it gets matured for economic gains. In addition, some respondents (16%) were participated in degraded land plantation by assuming only trees commercial purposes for economic benefits whereas a few respondents (12%) purpose of plantation was identified to be only for its environmental services as described in Table-17. On the other hand, analysis of expert's view on the purpose of enrichment tree plantations on degraded communal lands was identified to be mainly for environmental protection and the entire nature conservation purpose.

Table 17: Description for communities' purpose of tree plantation

Communities purpose of tree plantation	Frequency	Percent
Environmental protection	3	12
Commercial	4	16
Environmental protection and commercial	18	72
Total	25	100

4.2.2.4. Community's level of participation per restoration activities

Community's level of participation per restoration activities was assessed through survey questions, focus group discussions and key informant interviews. The overall survey analysis shows that, most respondents (56%) were participated at very high level per all restoration activities. Others 26.8% were involved at high level whereas 13.2%, 2.4% and 1.2% respondents participated in restoration activities at medium, low and very low level of involvement respectively as described in Table-18.

The level to which, each respondents participated per all restoration activities indicates the level of their commitment for degraded land restoration which in turn designates the successful or failure of the restoration project intervention. The very high level of community participation shows, the highly they are committed and the intensive communities involvement which then leads to the successful restoration project implementation on the degraded communal lands. Based on the assessment, the most overall community participation level to the degraded land restoration was at very high level in which the most respondents (56%) were participated per all restoration activities.

Table 18: Summary of community participation level per restoration activities

		Respondents level of participation						
No	Participation activities	Very high	High	Medium	Low	Very low	Not participated	Total responses
1	Information and experience sharing	5	8	9	2	1	o	25
2	Restoration site identification & Delineation	7	8	7	2	0	1	25
3	Decision making on land for restoration	13	6	5	1	0	0	25
4	Food and cash contribution	6	9	7	1	2	0	25
5	Local material contribution	22	3	0	0	0	0	25
6	Site preparation for plantation	18	5	2	0	0	0	25
7	Tree seedlings transportation	17	7	1	0	0	0	25
8	Tree planting	17	8	0	0	0	0	25
9	Site fencing	18	7	0	0	0	0	25
10	Site guarding	17	6	2	0	0	0	25
	Total Responses	140	67	33	6	3	1	

Data's from focus group discussions (FGD) conducted with a team of consisting seven restoration participants, on communities level of participation in the restoration activities shows, most of restoration land owning communities were participated in eleven different restoration activities with narrowed difference in level of participation among the participants. FGD was identified one more activities to which the communities were participated, which is the post plantation silvicultural management, which was not identified in the survey analysis. Therefore, results from survey data's and focus group discussions(FGD) identified that, the communities were participated at eleven(11) restoration implementation activities including information and experience sharing, restoration site selection and delineation, decision making on communal lands for restoration, food and cash contribution, local materials contribution, plantation site preparation, tree seedlings transportation, tree planting, restoration sites fencing, guarding the restoration sites and post plantation silvicultural management of the restoration sites with different level of participation per activities as described in Table-18.

Picture 2: Sample photos during FGD and Survey data collection (Restoration participants)

Overall, the involvement of local communities in managing forests and other high value biomes and creating mechanisms for them to directly benefit from their conservation efforts lead to more effective protection than is the case with centralized protection (Nkonya, Mirzabaev et al. 2016). Farmers can sustainably use their natural resources by introducing proper planting species on the steep slopes and degraded areas to improve soil fertility. Those species can be used as a source for livestock feeding and pollen for bees. This would increase the flexibility in the management of land use, fodder for livestock and hence enabling households to make livelihood diversification and also address land degradation (Mekonen and Tesfahunegn 2011).

The states in which the communities were participated in degraded communal land restoration were identified in terms of: 1. Communities participation and level of involvement per different stages of the restoration project. In this case, all restoration participants were participated per all stages of the project, but they were involved at different level per each stages of the project. Hence, most of the restoration participants, consists of 64%, were participated at very high level of involvement in the implementation stage of the project and least involved at project evaluation stage which consists only 20% of the total participants but they were involved at very high level of participation. 2. Communities motives for participation in degraded communal land restoration. In this case, the most communities (56%) were mostly participated in degraded land restoration due to the communities were recognized the emerging land degradation challenges in their localities. Other study also indicated that, when the local communities are aware of the degradation they are willing to participate in the management of communal grazing lands by contributing labor and cash(Amare, Mekuria and Belay, 2017). Others, consists 32% of the restoration participants were participated in degraded land restoration for expected restoration benefits. (Brown *et al.*, 2011) on his side realized that, communities were able to harvest fodder and firewood within a year of project initiation and wild fruits and other non-timber forest products within three years and farmers are also using agroforestry for both environmental restoration and income generation. The study conducted in northeastern Ethiopia shows that, even if the local farmers had perceived the existence of land degradation and it's possible causes, however, the benefit sharing was satisfied the communities moderately (Mengesha and Denoboba, 2015), social responsibility through local institution called 'Idir' was also another reasons for communities participation in restoration activities in which 28% of the respondents were participated and a few consists of 4% were participated for cash income expectation from the restoration project. 3. Communities Purpose of plantation and tree species planted. In this case, both native and exotic tree species were planted as an enrichment planting per all restoration sites and most respondents (72%) purpose of plantation were for environmental protection and commercial purposes while the others 16% and 12% purpose of plantation was only for commercial and environmental protections respectively. 4. Communities level of participation per restoration implementation activities. Regarding this, the communities were participated per eleven (11) different restoration implementation activities in which, most respondents (56%) were participated at very high level per all identified restoration activities and others involved at different level of participation per each activities. Datas from Focus group discussions (FGD) and key informant interviews was resulted in addition results besides most of the complementary results with the survey analysis which includes; the reason for less community participations at the evaluation stage of the project, and it was due to only restoration site committees participated because the others were at another public duties organized by the local government at the time. On the other hand, the communities had been participating in post plantation silvicultural management of the restoration site through weeding, hoeing and direct sawing of local tree seeds. Therefore, the states in which the local communities were participated in degraded communal land restoration were very crucial for the successful restoration intervention.

4.2.3. Factors determining community participation in degraded land restoration

4.2.3.1. Demographic and socio-economic factors

The variation between restoration participant and non-participant respondent's demographic and socio-economic situations was analyzed as a factor for community's participation in degraded land restoration. The variation analysis between the groups was conducted in terms of respondents: Age, Sex, Educational level, Marital status, hh type, Family size, yearly cash income and time of residence in the area. The analysis was conducted using one-way ANOVA and as a result, there was no significant difference between restoration participant and non-participant groups of the communities in demography and socio-economic conditions with a p value > 0.05 in all cases and there was no any difference in respondent's main occupation between the groups as described in Table-19.

Table19: Demographic & socio-economic variation test b/n Participants and non-participants

Inquiries categories	Sum of Squares	df	Mean Square	F	Sig.
Age	.080	1	.080	.137	.713
Sex	0.000	1	0.000	0.000	1.000
Educational status	2.420	1	2.420	2.234	.142
Main occupation	0.000	1	0.000		
Marital status	.720	1	.720	1.146	.290
Household type	.020	1	.020	.214	.646
Family size	0.000	1	0.000	0.000	1.000
Yearly cash income	.080	1	.080	.058	.810
Time of residence	.980	1	.980	.858	.359

4.2.3.2. Knowledge on land degradation and benefits of tree planting

The variation between restoration participants and non-participants in Knowledge on land degradation and benefits of tree planting was assessed based on selected inquiries through survey questions and focus group discussions. Both groups of respondents were reacted on the same inquiries and the significance difference between the two groups was tested using one-way ANOVA per each inquiry as described in table 20.

Land degradation: Survey analysis shows that, all members of both participant and non-participant respondents have knowledge on land degradation, in which, all respondents replied "yes" to the land degradation acquaintance assessment question. The way they got the knowledge on land degradation and its potential causes was similar for both groups in which, mostly got through awareness raising workshops/short orientations provided by the local government and NGO's operating in the area. Respondents own physical experience contributed a lot to their knowledge on land degradation and its potential causes. On the other hand, mass media and formal school learning was contributed a few to their knowledge for both groups.

Causes of land degradation*:* Regarding the causes of land degradation, both participant and non-participant respondents were similarly agreed on; the most causes of land degradation in their localities were soil and water erosion. In addition, both groups were mentioned that; population growth and miss land using system was moderately another proximate causes of land degradation in their localities. Both groups were less agreed on farmer's short term perspective as the potential causes of land degradation. On the other hand, restoration participants were better agreed on overgrazing and deforestation as a potential causes of land degradation in their localities while non-participants less agreed on.

Carbon stocks in forest*:* Both participants and non-participants knowledge regarding carbon stocks in forests were assessed through survey questions and focus group discussion. As an outcome, most respondents of the two groups had information about carbon stocks in forests which they were articulated in different ways. As a result, 80% of restoration participant's knows about carbon stocks in forests whereas 20% don't know. On the other hand, 72% of non-participants know about carbon stocks in the forests while 28% don't know. In this case, both participant and non-participant respondents better got the awareness on carbon stocks in forests through short orientation workshops provided by the restoration project and local government in different times at village and district levels.

Planting trees and forest carbon: alike awareness of respondents on carbon stocks in forests, 80% of the participants knows about planting trees enhances forest carbon stocks and 72% of non-participants were conscious about the issues, of which, 40% of the restoration participants very well knows about planting trees enhances forest carbon stocks while 28% of the non-participants very well knows about it. On the other hand, 20% and 28% of the participants and non-participants had no information about the issues respectively.

Carbon sequestration in trees and global climate change: Respondents Knowledge about carbon sequestration in trees reduces the effect of global climate change was assessed and as a result, all restoration participants were aware of about carbon sequestration in trees reduces the effect of global climate change while 32% of them very well knows about the it. On the other hand, 76% of non-participants knows about carbon sequestration in trees reduces the effect of global climate changes and of which 12% very well knows about the issues while the others 24% had no information.

In general, both participant and non-participant respondent's knowledge about land degradation and benefits of tree planting was assessed in terms of six conceptual inquiries such as: respondents knowledge on land degradation, causes of land degradation, understanding of current land degradation conditions of their localities, knowledge about forest carbon stocks, benefit of trees in terms of carbon sinking and about the effect of carbon sequestration in trees on global climate change. Consequently, the significant difference between participants and non-participants knowledge as a factor determining communities participation, determined using one-way ANOVA. As a result, statistically there was no significant difference between restoration participants and non-participants knowledge concerning land degradation and benefits of tree planting with p value > 0.05 as described in Table-20.

Table 20: Knowledge variation test between restoration participant and non-participant groups

No	Knowledge assessment inquiries	Sum of Squares	df	Mean Square	F	Sig.
1.	Population growth and miss land use system Vs. land degradation	.180	1	.180	.252	.618
2.	Overgrazing Vs. land degradation	.960	1	.960	1.366	.248
3.	Soil and water erosion Vs. land degradation	0.000	1	0.000	0.000	1.000
4.	Farmers short term perspective Vs. land degradation	.180	1	.180	.191	.664
5.	Deforestation Vs. land degradation	1.62	1	1.62	2.4	0.128
6.	Understanding on land degradation condition	2.000	1	2.000	2.290	.137
7.	Carbon stocks in forest	.020	1	.020	.112	.739
8.	Planting trees Vs. forest carbon	.500	1	.500	.134	.716
9.	Carbon sequestration Vs. global climate change	2.000	1	2.000	.609	.439

4.2.3.3.Community's perception towards land restoration and participatory tree planting

As a factor of determining community's participation in degraded land restorations, community's perception towards degraded communal land restorations and participatory tree planting was examined based on five selected inquiries.

Importance of tree planting on degraded land*:* Respondent's perception towards the importance of planting trees on degraded communal lands was assessed through survey questions and FGD per both restoration participants and non-participants. As a result, restoration participants were strongly agrees on the importance whereas non-participants less agrees. The significance variation between the two groups was tested using one-way ANOVA and as a result, there was statistically a significant difference between the groups with $p < .05$ as described in Table 21.

Responsibility to manage forest: Attitudinal difference between restoration participant and non-participant respondents were assessed regarding the responsible bodies to manage forest resources to its ecosystem services and economic benefits. As a result, most participants' consists of 52% revealed that it is the responsibility of both the local communities and the government whereas 44% of the participants assumed it is the responsibility of the three parties including the local communities, government and non-governmental organizations/other institutions and the other 4% of the participants considers as it is the responsibility of government and non-governmental organizations to manage forest resources. On the other hand, most non-participants comprise 56% reflected, the only responsible to manage forest resources is the government whereas 16% assumed it is the collective responsibility of the local communities, the government and NGO's/any other institutions. As well, 12% of non-participants meditate the responsibility for managing forest resources to the government and NGO's/other institutions whereas the other 16% of non-participants assumed the local communities and the government are responsible to manage forests to its environmental and economic benefits. As a result, there was statistically a significant perceptional difference between the two groups with alpha or p value = .001 which is less than 0.05 using one-way ANOVA as described in Table 21. Therefore, most participants assumed that it is the responsibility of the local communities and the government to develop and manage forests whereas most non-participants considers government is the only responsible to manage forests to its environmental and economic benefits.

Importance of Participatory tree planting for sustainable land and forest management : Both participant and non-participant respondent's perception concerning the importance of participatory tree planting for sustainable land and forest resources management was assessed through survey questions and focus group discussions. As a result, both source data analysis shows that there was no perceptional difference between the two groups on the importance of communities participation in tree planting for sustainable land and forest resources management, due to all respondents of the both groups were agrees on. Furthermore, respondents perceptional assessment was conducted per specific participation inquires such as: does participation gives the communities authority to control over the resources, does it builds communities capacity to manage forest resources, does it creates communities sense of ownership, does it reduces land degradation and environmental depletions and could it be a solution for global climate change. Based on such inquiries, the perceptional variation between the two groups was statistically tested using one-way ANOVA and as a result, both groups were strongly agrees on participation can creates communities sense of ownership than other specific inquires. But, basically there was no statistically significant perceptional difference between the two groups per each specific analyses and the general concept of community's participation importance in tree planting for sustainable land and forest resources management with p value > 0.05 in all cases as described in

Table 21. In this case, the same result was added from focus group discussions with the survey analysis result on respondent's perception towards the importance of community participation for sustainable land and forest resources management.

Perceptions on forest cover before and after the restoration*:* Respondent's perception concerning the forest cover of their localities before and after restoration intervention was identified and most respondents of the both groups were agreed that the forest cover of their locality before restoration intervention was highly decreasing and after restoration, it was increasing. Moreover, 24% of the participant's reflected that, the forest cover of their localities after restoration intervention was highly increasing whereas the same proportion 24% of the non-participants responded that, there was no change in forest cover of their localities even after the intervention. The overall perceptional difference between the two groups on the forest cover of their localities before and after restoration intervention was examined using one-way ANOVA statistical analysis. As a result, with p values > 0.05, there was no significant perceptional difference between restoration participants and non-participants concerning forest cover of their locality before and after restoration intervention as described in Table-21.

Table 21: Perceptional variation description on land restoration and participatory tree planting

No	Community's perceptional assessment inquiries	Sum of Squares	df	Mean Square	F	Sig.
1.	Do you agree on the importance of planting trees on degraded lands?	3.38	1	3.38	8.485	0.005
2.	Do you agree on the forest cover of your locality was highly decreasing before four years?	0.32	1	0.32	0.674	0.416
3.	Do you agree on the forest cover of your locality was increasing after four years?	0.98	1	0.98	1.217	0.275
4.	Who do you think is responsible to manage forests for its benefits?	40.5	1	40.5	12.623	0.001
5.	Do you agree community participation in tree planting is important for sustainable land and forest mngt?	0	1	0		

6.	Do you agree community participation in tree planting gives them authority to control the resource?	0.18	1	0.18	0.635	0.429
7.	Do you agree community participation in tree planting built community's capacity to manage their resources?	0.02	1	0.02	0.091	0.764
8.	Do you agree community participation in tree planting creates sense of ownership?	0.18	1	0.18	0.635	0.429
9.	Do you agree community participation in tree planting reduces land degradation and environmental depletion?	0.98	1	0.98	3.178	0.081
10.	Do you agree that participatory tree planting is a solution for global climate change?	0.083	1	0.083	0.138	0.712

4.2.3.4. Community's customs and practices in tree planting

Both restoration participant and non-participant community members experience on tree planting were assessed and it was found that 92% of the participants had tree planting experience while only 8% had no the experience. On the other hand, 68% of the non-participants had experience of tree planting while 32% had no experience. The variation between the two groups was tested using F-test, and as a result, statistically there was a significant difference in tree planting experience between the two groups with p value < 0.05 as described in Table 22. Therefore, restoration participants had more tree planting experiences than non-participants.

In terms of tree species planting experience, both participants and non-participants had more experience of planting exotic tree species than native in which 82.6% of the participant's had an experience of planting exotic tree species while 17.4% had an experience of planting both exotic and native tree species whereas 84.2% of non-participants experienced planting only exotic tree species while 15.8% had experience of planting both species. In this case, there was no experience difference between the two groups as p value > 0.05 as described in Table 22.

Regarding respondent's purpose of tree planting experience, of the total restoration participants had tree planting experience; 52.2% had been planting trees both for environmental protection and commercial purposes while 47.8% had been planting only for commercial purposes. In case of non-participants, 36.8% had been planting trees both for environmental and commercial purposes while 63.2% only for commercial purposes. As a result, statistically there was no significant difference between restoration participants and non-participants in purpose of tree planting experience with p value = .332 which is > 0.05 as described in Table 22.

Table 22: Tree species planting experiences and purpose of plantation variation analysis

Tree planting experience inquire	Sum of Squares	df	Mean Square	F	Sig.
Did you ever plant trees on your own or communal lands?	.720	1	.720	4.747	.034
What species did you planted?	.003	1	.003	.018	.893
For what purpose did you planted?	.245	1	.245	.963	.332

4.2.3.5. Participation incentives

An assessment on participation incentives to the communities shows that, all the restoration participants were received participation incentives in terms of capacity building trainings as a group and in kind incentives individually. On the other hand, 60% of non-participants were received incentive for participation to degraded communal land restorations while 40% of them did not receive any incentives for participation.

During focus group discussions with restoration participants and non-participants separately, it was identified that participation incentives was provided before restoration physical works started and after the restoration. Hence, restoration participants were received incentives both before and after restoration works, in which they were received participation incentives before restoration physical works started in terms of capacity building trainings and awareness raising workshops whereas they were got incentives post communal land plantations in terms of high value fruit trees and other multipurpose trees for individual homestead development and inputs for bee farming as a group per restoration sites beneficiaries. On the other hand, non-participants were received participation incentives only before restoration physical works started in terms capacity building trainings and awareness raising workshops due to they were withdrawn from participating in communal land plantations after the trainings and awareness raisings workshops, and as a result, they did not received incentives after restoration. Therefore, statistical variations in receiving participation incentives between restoration participants and non-participants was tested using F-test and as a result, there was a significant difference between the two groups in receiving participation incentives with p values = .001 which is < 0.05 as described in Table 23.

Table 23: Participation incentives Variation analysis between participant and non-participants

Incentive assessment inquiries	Sum of Squares	df	Mean Square	F	Sig.
Did you get any incentives for participating in communal land restoration?	2.00	1.00	2.00	16.00	0.00
What type of incentives did you get?	35.04	1.00	35.04	1426.70	0.00

4.2.3.6. Ground causes for non-participants un involvement in the restoration scheme

An assessment was made on reasons for non-participants un involvement in degraded communal land restorations, through survey questions and focus group discussions. Consequently, survey analysis result shows that, they were not participated mostly due to; first, they need to plant only fast growing trees for its relatively fast economic gain which means they don’t want to plant indigenous trees of low growth rate, in which, 72% of the respondents were reflected this thoughts strongly. This indicates that, the main objective of the restoration project, which was aimed to nature conservation, was basically not complemented with non-participants preference. Secondly, they prefer the land for grazing in which 64% of the respondents were supported at high and very high levels. There were also some other minor reasons reflected by a few respondents which includes; less access to alternative grazing land, unwilling to contribute labor, forest attracts wild life which attacks home animals and damage farms, land boundary conflict and no need of forest at all.

In focus group discussions (FGD) and key informant interviews, complementary results were added with the survey analysis and other additional results which were not obtained in survey analysis, which includes: the complexity of communal lands ownership system and fear of losing land ownerships right after restoration. In case of problem with land ownership system, different groups of peoples from diverse directions owning the land, in which, some are very near to the site who’s used the land for grazing at most due to accessibility and others those far from the site were less using for grazing due less accessibility. Consequently, those far from the area or less access to use the land regularly desires the land for restoration while others near to the site resists the communal land for restoration because they are very accessible for intensively using the area. On the other hand, because there was no legally registered ownership certification for most communal lands, anyone complains for ownership right at the time of discussion on the identified land for restoration which would not simply solved. In addition, the land owning communities' fears for losing land ownership right after the restoration because they doubt losing of their ownership right by some bodies after the restoration, especially, due to the communities perceives that, forest management and controlling right relies to the government, in which they think that the government would overtake the resource after restoration. Bishaw, 2001 also stated that, there is no clear legal base for determining ownership of community forests, and farmers tend to assume that the forests belong to the State. Therefore, due to these two other reasons, non-participants involvement in communal land restoration was hindered in addition to community's preference for fast growing exotic tree species and land for grazing.

Picture 3: Sample photos during FGD and Survey data collection with non-participants

In general, participatory forest management (PFM) was meant to avert the persistent problems of deforestation and to deliver better social and economic outcomes compared with the former centralized command-and-control resource management approach. In Ethiopian context, PFM is recognized as a co-governance institutional arrangement where forest management responsibilities and use rights are legally shared between a government agency and a community-based organization (CBO), such as forest user groups or forest cooperatives (Ayana, Vandenabeele et al. 2017). However, in this study factors determining communities participation was assessed in terms of demographic and socio economic status, communities knowledge on land degradation and benefit of tree planting, community's perceptions toward degraded land restorations and participatory tree planting, communities customs and practices towards tree planting and participation incentives. Thus, the significant difference between restoration participants and non-participants was investigated per each factor. As a result, there were no significant differences between the two groups per most factors. But there was a significant difference between the two groups in terms of, perceptional differences on the responsibility to develop and manage forest resources and the importance of planting trees on degraded lands, tree planting experiences and participation incentives. In case of forest management responsibilities; most participants were recognizing the responsibility to develop and manage forest resources as a collective duties of both government and local communities whereas, most non-participants were perceives as it is the only government's responsibilities. Regarding the importance of tree planting on degraded lands, most restoration participants were agrees on the importance of planting trees on degraded lands whereas most non-participants were not agrees. Concerning tree planting experiences, most restoration participants are more experienced than non-participants. On the other hand, restoration participants were received more participation incentives than the non-participants, but in this case, participation incentives difference between the two groups was happened after the restoration physical implementation which was provided as an incentive to the participants. Due to the non-participants were withdrawn from participating in the restoration activities, they did not gate post restoration incentives. The initial participation incentives was equally provided to the both groups before the restoration physical implementation started and because of this, even if there was participation incentives difference after the restoration, it could not be the factor for non-participation because it was the same before the restoration physical works started.

In addition, causes for non-participants un involvement in degraded communal land restoration was separately assessed through survey questions and focus group discussions and finally it was identified that the main reasons for non-participants un involvement in degraded communal land restoration includes; most of non-participant communities need only fast growing exotic trees for its relatively fast economic gain, need the land for free grazing, complexity of communal land ownership system, communities fear for land ownership loss after the restoration.

In general, Community's participation in degraded communal land restoration was affected by different factors including: Community's perceptional sate up of perceiving the responsibility to develop and manage community forests only to the government, perceiving planting trees on degraded lands as less important, communities preference to fast growing tree species of exotic origins for its relatively fast economic gain and the degraded lands for free grazing, experience on tree planting, complexity of communal land ownership system and communities trust loss on the ownership right of the resources after the restoration intervention. According to (Engida and Mengistu, 2013) communities participation in forest management determined by demographic, economic, and biophysical factors, Furthermore, lack of incentives and weak legal actions taken on illegal users were some of the hindrances that adversely affect communities participation in PFM . (Kassa *et al.*, 2018) on his side indicated that community participation in forest and exclosures management affected by unclear ownership right of the resource and use right.

Chapter 5: Overall Synthesis

Community participation was contributed a lot for the successful degraded land restorations, through active participation of the local communities per most stages of the restoration project and in all restoration implementation activities. The community was engaged in degraded land restorations mostly due to understating the highly emerging land degradation challenges in their localities. Community participation brings restoration biological efficiencies due to their commitments from deciding the lands for restoration than free grazing, active participation per each restoration implementation activities and further commitments on continuous restoration sites protection through physical and social fencing in sense ownership with less support of external bodies. Furthermore, due to communities' continuous involvement in degraded land restorations, the land biophysical state was significantly improved in terms of woody vegetation biomass, carbon stock, wood species regeneration diversity and abundance within short restoration period of three and half years. This indicates that community participation is critically importance for effective nature conservation. (Stone *et al.*, 2008) in his side stated that, community participation is viewed as a key to success in ecosystem restoration.

Non-participant community's participation in degraded communal land restoration was affected different factors such as: Community's perceptional sate up of perceiving the responsibility to develop and manage community forests only to the government, perceiving planting trees on degraded lands as less important, communities preference to fast growing tree species of exotic origins for its relatively fast economic gain, Preferring the degraded lands for free grazing, experience on tree planting, complexity of communal land ownership system and communities trust loss on the ownership right of the resources after the restoration intervention. All these factors affecting community's participation in degraded land restoration leads to further deterioration of natural resources because every plot of land found everywhere can't be restored and managed by the government alone. On the other hand, preference of local communities to fast growing exotic tree species has the impact on loss of native species or loss biodiversity in general and also the communities preference of the already degraded land for further free grazing leads to further loss of soil, woody species and all land covers which then leads to serious environmental and social crisis.

It can be summarized that, if the communities were not participated, communal land restoration was even not initiated because without the willingness of the land owners, there was no land to implement on the restoration activities and even if it was forcefully implemented, it was no longer stay/disappeared within short period of time because it could not be under social protection rather it may faces social attacks. In this case, the situations happened during 2017, between the local communities and Amhara forest enterprise was the best example, in which a huge number of trees planted on 34ha of communal lands with hired external labors without full consensus of the local communities. Consequently, after a month it was disappeared by the local dwellers at night within the same village of this study area. To this effect, (Meseret, 2016) stated that, land resource management can be successfully realized with greater participation and involvement of the local communities.

5.1.Hypothesis findings:

1. Degraded communal land restorations through tree planting and community participation can significantly improve woody vegetation's biomass and carbon sequestration potential of degraded lands after three and half years restoration intervention.

Degraded communal land restorations through tree planting and community participation was improved woody vegetation's biomass and carbon sequestration potential of the land in which the total woody vegetation's biomass both above and below ground was improved from 2082.25

Kg/ha before restoration to 21173.38 kg/ha after restoration intervention whereas the carbon sequestration potential of the land was improved from 2.4 ton/ha before to 23.9ton/ha after restoration intervention. The significance difference in biomass accumulation and carbon sequestration potential of the land before and after the restoration was tested using t-test and with p value < 0.05 it was significantly different, in which, the improvement was made by approximately 10 times within three and half years of the restoration intervention.

2. Degraded land restorations can significantly improve woody plants regeneration diversity and abundance of degraded communal lands after three and half years of the restoration intervention.

Woody plants regeneration diversity was identified to be 3 species before restoration intervention and it became 23 species after the restoration per the same sampling plots. On the other hand, woody plants regeneration abundance was found to be $114/200m^2$ before restoration whereas it became $863/200m^2$ after restoration intervention. Therefore, the significance variation before and after restoration intervention in woody plants regeneration diversity and abundance was tested with one sample t-test and it was confirmed that there was statistically a significant difference with $p < 0.05$ in both cases. In this case, the improvement was made by 7.7 and 7.57 times per regeneration diversity and abundance respectively after the three and half years of restoration intervention.

3. Most restoration participants actively involved per all stages of the restoration projects and per each restoration activities.

All restoration participants were involved per all stages of the restoration project at different levels of participation per each stages, for instance, most participants consists of 64% were participated at very high level of involvement per implementation stage of the project. On the other hand, all participants were involved per all identified restoration activities in which, 56% were involved at very high level of participation per all activities.

4. Restoration participants are significantly different from non-participants in demographic and socio-economic situations, knowledge on land degradation and benefit of tree planting, perceptions towards degraded land restorations and participatory tree planting, customs and practices in tree planting and receiving participation incentives.

The significant variation between restoration participants and non-participants in terms of demographic and socio economic situations, knowledge on land degradation and benefit of tree planting, perceptions towards degraded land restorations and participatory tree planting, customs and practices in tree planting and participation incentives was examined with t-test. As a result, there was no significant differences in most cases between the two groups, except in some cases and certain sub specific inquiries such as; perceptions on the responsibility to develop and manage forests and the importance of tree planting on degraded lands and tree planting experiences. Therefore, the hypothesis was partially rejected and partially accepted since there was a significant difference per some factors and no difference per others between the groups.

Conclusion:

This study was aimed to evaluate the potential of degraded communal land restorations through participatory tree planting in improving woody vegetation's above and below ground biomass and carbon stocks, regeneration species diversity and abundance. To come up with the result, data's from direct field measurements and existing baseline data's used for woody vegetation's biomass and then carbon stock estimation as well as for identifying the woody species regeneration diversity and abundance. On the other hand, data's collected through structured questionnaire's, focus group discussion and key informant interviews was used for analyzing the state of community participation and factors determining participation. For biomass and carbon stock estimation, non-destructive or indirect method was used with two different allometric equations one per medium to large size woody plants and the other for small trees and shrubs. For data analysis, descriptive statistics and f-test and t-test was used for variation analysis.

The above and below ground woody vegetation's biomass of degraded communal lands was estimated both before and after restoration intervention and the variation was examined. As a result, the total biomass before restoration was estimated to be 2082.25kg/ha and after restoration intervention it became 21173.38kg/ha and it was significantly different with p value < 0.05. Degraded communal land restorations through enrichment tree planting and community participation effectively improved woody species biomass by 10 times after three and half year of the restoration age.

The above and below ground woody vegetation's carbon stocks of degraded communal lands, estimated before and after restoration intervention. As an effect, the total woody plants carbon stock of degraded communal lands before restoration estimated 2.4 ton/ha and after restoration intervention 23.9ton/ha and with variation test, it was significantly different with p value < 0.05. Degraded communal land restoration with enrichment tree planting and active community participation successfully improve the potential of degraded land in woody plants carbon sequestration by approximately 10 times within three and half years of restoration intervention.

The evaluation of degraded communal lands woody species regeneration diversity and abundance before and after restoration intervention was resulted in; the regeneration diversity of 3 species before and 23 after the restoration including the former existing species whereas woody plants regeneration abundance before restoration was 114/200m^2 and after restoration intervention 862/200m^2 in which, the variation before and after the restoration was significant in both cases and the improvement was made by 7.7 and 7.57 times after restoration intervention respectively. Therefore, mixed restoration approaches with exclosures and enrichment tree planting can significantly improve woody vegetation's regeneration diversity and abundance even within less than four years of restoration period.

The states to which the communities participated to the restoration project and factors determining participant and non-participant communities involvement was assessed and to that effect, the communities were participated in states; all participants were participated per all stages of the restoration project in which, most participants consists of 64% was actively participated in the implementation stage of the project, they were participated with the first most (64%) motives of the highly emerging challenges of land degradation and the second most (32%) motives for the expected restoration benefits, they were planted both native and exotic tree species for the most (72%) purpose of commercial and environmental protection and all participants involved per all restoration activities in which most participants (56%) participated at very high level of involvement per all identified restoration activities. on the other hand, non-participant communities involvement in degraded communal land restoration was affected by multiple overlapping factors including: communities preference to fast growing exotic tree species for economic benefit, land preference for free grazing, perceptions on forest development and management as duties left for government, perception on less importance of planting trees on degraded lands, complexity of communal land ownership system and communities luck of trust on land ownership right after the restoration. Therefore, the local communities' participation in degraded communal land restoration is the central key for the effective biophysical improvements and communities' participation can be affected by biophysical, economic, social and political factors.

Recommendations:

Mixed restoration approaches with exclosures and enrichment tree planting is better for quick and effective degraded land restoration and the overall biophysical improvements.

As it could be understood from communities knowledge analysis, most respondents were got the knowledge on land degradation and its causes, environmental benefits of tree planting, carbon sequestration in forests and its relationship with global climate changes through awareness raising workshops and short orientations provided by the local government and non-governmental organizations operating in the areas at village and district levels. Therefore, to enhance communities understanding on the extremely emerging environmental problems, it is better to invest more on communities training and awareness raising programs for better community's collective actions for solutions.

Clear and effective communal land ownership system has to be exists with strong system to enforce effective use of the land resources to meet the need of current and next generations.

More investigations have to be made on the methods to include small woody vegetation's in to biomass and carbon stock estimations because in most cases, especially, in the restoration areas where small trees and shrubs dominating, only a sparsely scattered large woody species included in the biomass and carbon stock estimation and the contributions of the dominant small plants in the global climate change always ignored due to luck of models to include in to the estimation.

Further studies have to be conducted on the impacts of young degraded land restorations in terms of soil carbon and other terrestrial carbon pools.

Researches have to identify the implication of degraded communal land restoration on the livelihood of the communities living around the site.

References:

Abiyu, A. *et al.* (2011)‘Status of Native Woody Species Diversity and Soil Characteristics in an Exclosure and Plantations of Eucalyptus globulus and Cupressus lusitanica in,31(2), pp.144–152.

Aerts, R., et al. (2006). "Species composition and diversity of small Afromontane forest fragments in northern Ethiopia." Plant Ecology 187(1): 127-142.

Alemu, B. (2014). Practices, Challenges and Prospects of Agricultural Land Management in Machakel Woreda, East Gojjam Zone, Ethiopia, Addis Ababa University.

Alemu, B. (2015). "The effect of land use land cover change on land degradation in the highlands of Ethiopia." J Env Earth Sci 5(1): 1-12.

Amare, D., Mekuria, W. and Belay, B. (2017) ‘Willingness and Participation of Local Communities to Manage Communal Grazing Lands in the Lake Tana Biosphere, Ethiopia’, *Society and Natural Resources*. Routledge, 30(6), pp. 674–689. doi: 10.1080/08941920.2016.1264649.

Asfaw, Z., et al. (2015). Enhancing the Role of Forestry in Building Climate Resilient Green Economy in Ethiopia: Strategy for scalling up effective forest management practices in Southern Nations, Nationalities and Peoples Regional State with particular an emphasis on agroforestry.

Assefa, D., et al. (2017). "Deforestation and land use strongly effect soil organic carbon and nitrogen stock in Northwest Ethiopia." Catena 153: 89-99.

Assefa, G., et al. (2013). "Training manual on: Forest carbon pools and carbon stock assessment in the context of SFM and REDD+." Hawassa University Wondo Genet College of Forestry and Natural Resources, Wondo Genet.

Aradóttir, Á. L. *et al.* (2000) Carbon accumulation in vegetation and soils by reclamation of degraded areas.

Ayana, A. N., et al. (2017). "Performance of participatory forest management in Ethiopia: institutional arrangement versus local practices." Critical Policy Studies 11(1): 19-38.

Bai, Z. *et al.* (2017) ‘Global assessment of land degradation and improvement 1: identification byremotesensing'.Availableat:https://stgwedocs.unep.org/bitstream/handle/20.500.11822/19788/Report_2008_01_GLADA_internationalREV_Nov_200.pdf?sequence=1(Accessed:4June 2020).

Banin, L., et al. (2012). "What controls tropical forest architecture? Testing environmental, structural and floristic drivers." Global Ecology and Biogeography 21(12): 1179-1190.

Berihu, T., et al. (2017). "Soil carbon and nitrogen losses following deforestation in Ethiopia." Agronomy for sustainable development 37(1): 1.

Beyene, A. D., et al. (2016). "Community forests, carbon sequestration and REDD+: evidence from Ethiopia." Environment and Development Economics 21(2): 249-272. with the same

Bishaw, B. (2001). "Deforestation and land degradation in the Ethiopian highlands: a strategy for physical recovery." Michigan State University Press 8(1): 7-25.

Birdsey, R. and Y. Pan (2015). "Trends in management of the world's forests and impacts on carbon stocks." Forest Ecology and Management 355: 83-90.

Birhane, E.,et al. (2006). "Actual and potential contribution of exclosures to enhance biodiversity of woody species in the drylands of Eastern Tigray." Journal of the Drylands 1(2): 134-147.

Bonan, G. B. (2008). "Forests and climate change: forcings, feedbacks, and the climate benefits of forests." science 320(5882): 1444-1449.

Box, P. O. and Tabor, D. (2017) 'REVIEW ARTICLE MAJOR DRIVERS AND CONSEQUENCES OF DEFORESTATION IN ETHIOPIA ':

Bishaw, B. (2003) 'Agroforestry and Community Forestry for Rehabilitation of Degraded Watersheds on the Ethiopian Highlands'.

Bremer, L. L. and Farley, K. A. (2010) 'Does plantation forestry restore biodiversity or create green deserts ? A synthesis of the effects of land-use transitions on plant species richness', pp. 3893–3915. doi: 10.1007/s10531-010-9936-4.

Bromley, D. W. and Reis, E. J. (1999) 'Deforestation — Institutional Causes and Solutions', in. Springer, Dordrecht, pp. 95–105. doi: 10.1007/978-94-011-4746-0_9.

Brown, D. R. *et al*. (2011) 'Poverty alleviation and environmental restoration using the clean development mechanism: A case study from Humbo, Ethiopia', *Environmental Management*. Springer, 48(2), pp. 322–333. doi: 10.1007/s00267-010-9590-3.

Brown, S. (2002). "Measuring carbon in forests: current status and future challenges." Environmental pollution 116(3): 363-372.

Chave, J. (2005). "Measuring wood density for tropical forest trees: a field manual for the CTFS sites. 2005." Toulouse, France.

Chave, J., et al. (2014). "Improved allometric models to estimate the aboveground biomass of tropical trees." Global change biology 20(10): 3177-3190.

Corlett, R. and Primack, R. (2011) "*Tropical rain forests: an ecological and biogeographical* comparison." on JSTOR (12 August 2020).

Don, A., et al. (2011). "Impact of tropical land-use change on soil organic carbon stocks–a meta-analysis." Global change biology 17(4): 1658-1670.

Economy, E. C. (2011). The river runs black: the environmental challenge to China's future, Cornell University Press.

Eggleston, S., et al. (2006). 2006 IPCC guidelines for national greenhouse gas inventories, Institute for Global Environmental Strategies Hayama, Japan.

Engida, T. G. and Mengistu, A. T. (2013) 'Explaining the Determinants of Community Based Forest Management : Evidence from Alamata , Ethiopia', 1(2), pp. 63–70. doi: 10.11634/233028791301431

Fayolle, A., et al. (2013). "Tree allometry in Central Africa: testing the validity of pantropical multi-species allometric equations for estimating biomass and carbon stocks." Forest Ecology and Management 305: 29-37.

Feldpausch, T. R., et al. (2011). "Height-diameter allometry of tropical forest trees." Biogeosciences.

Feyissa, A., Soromessa, T. and Argaw, M. (2014) 'Forest Carbon Stocks and Variations along

Altitudinal Gradients in Egdu Forest: Implications of Managing Forests for Climate Change Mitigation', *Science, Technology and Arts Research Journal*. African Journals Online (AJOL), 2(4), p. 40. doi: 10.4314/star.v2i4.8.

Foley, J. A., et al. (2011). "Solutions for a cultivated planet." Nature 478(7369): 337-342.

Gebreegziabher, Z. and Mekonnen, A. (2010) 'Household Tree Planting in Tigrai , Northern Ethiopia', 2473(432).

Gebremedihin, K. M., et al. (2018). "Restoration of degraded drylands through exclosures enhancing woody species diversity and soil nutrients in the highlands of Tigray, Northern Ethiopia." Nature Conservation Research **3**(1): 1-20.

Girma, A. and Soromessa, T. (2014) 'Forest Carbon Stocks in Woody Plants of Mount Zequalla Monastery and It ' s Variation along Altitudinal Gradient : Implication of Managing', 7522(June), pp. 132–140.

Goslee, K. *et al.* (2012) 'Standard Operating Procedures for Terrestrial Carbon Measurement: Version 2012', *Winrock International*, pp. 1–44.

Gorte, R. W. (2009). Carbon sequestration in forests, DIANE Publishing.

Hansen, J. (2013) 'Climate forcing growth rates : doubling down on our Faustian bargain'. doi: 10.1088/1748-9326/8/1/011006.

Hosonuma, N. *et al.* (2012) 'An assessment of deforestation and forest degradation drivers in developing countries'. doi: 10.1088/1748-9326/7/4/044009.

Houghton, R. (1999). "The annual net flux of carbon to the atmosphere from changes in land use 1850–1990." Tellus B 51(2): 298-313.

Jara, M. C., et al. (2015). "Guidelines for documenting and reporting tree allometric equations." Annals of Forest Science 72(6): 763-768.

Kanninen, M., et al. (2007). Do trees grow on money? The implications of deforestation research for policies to promote REDD, Cifor.

Kassa, H. *et al.* (2018) ‘Shared strengths and limitations of participatory forest management and area exclosure: two major state led landscape rehabilitation mechanisms in Ethiopia’, *International Forestry Review*. Commonwealth Forestry Association, 19(4), pp. 51–61. doi: 10.1505/146554817822330560.

Lal, R. (2008) ‘Carbon sequestration’, *Philosophical Transactions of the Royal Society B: Biological Sciences*. Royal Society, pp. 815–830. doi: 10.1098/rstb.2007.2185.

Larjavaara, M. and Muller-Landau, H. C. (2013) ‘Measuring tree height: A quantitative comparison of two common field methods in a moist tropical forest’, *Methods in Ecology and Evolution*, 4(9), pp. 793–801. doi: 10.1111/2041-210X.12071.

Lemenih, M. and Teketay, D. (2006) ‘Changes in soil seed bank composition and density following deforestation and subsequent cultivation of a tropical dry Afromontane forest in Ethiopia’, 47(1), pp.1–12

Leul, Y. (2011). Assessment of Problems of Sustainability of Rural Water Supply and Management Systems in Machakel Woreda, Amhara Region, Addis Ababa University.

Lorenz, K. and R. Lal (2009). Carbon sequestration in forest ecosystems, Springer.

Manaye, A., Negash, M. and Alebachew, M. (2019) ‘Effect of degraded land rehabilitation on carbon stocks and biodiversity in semi-arid region of Northern Ethiopia’, *Forest Science and Technology*. Taylor and Francis Ltd., 15(2), pp. 70–79. doi: 10.1080/21580103.2019.1592787.

McNicol, I. M., et al. (2018). "Carbon losses from deforestation and widespread degradation offset by extensive growth in African woodlands." Nature communications 9(1): 1-11.

Meehl, G. A., et al. (2007). "Global climate projections."

Mekonen, K. and G. B. Tesfahunegn (2011). "Impact assessment of soil and water conservation measures at Medego watershed in Tigray, northern Ethiopia." Maejo International Journal of Science and Technology 5(3): 312.

Mekonnen, A. and M. Tolera (2019). "Carbon Stock Estimation Along Altitudinal Gradient in Sekele-Mariam Dry Evergreen Montane Forest, North-Western Ethiopia." Agriculture, Forestry and Fisheries 8(2): 48.

Mekonnen, M., et al. (2016). GIS and remote sensing-based forest resource assessment, quantification, and mapping in Amhara Region, Ethiopia. Landscape dynamics, soils and hydrological processes in varied climates, Springer**:** 9-29.

Mekuria, W., et al. (2009). Carbon stock changes with relation to land use conversion in the lowlands of Tigray, Ethiopia. Conference on International Research on Food Security, Natural Resource Management and Rural Development. University of Hamburg.

Mekuria, W. and M. Yami (2013). "Changes in woody species composition following establishing exclosures on grazing lands in the lowlands of Northern Ethiopia." African Journal of Environmental Science and Technology 7(1): 30-40.

Mekuria, W. and Veldkamp, E. (2012) 'Restoration of native vegetation following exclosure establishment on communal grazing lands in Tigray, Ethiopia', *Applied Vegetation Science*. John Wiley & Sons, Ltd, 15(1), pp. 71–83. doi: 10.1111/j.1654-109X.2011.01145.x.

Mengesha, M. A. and Denoboba, M. A. (2015) 'Mengistu Asmamaw Mengesha, Mekuria Argaw Denoboba. Assessing Farmers' Perception of Enclosures, Kewot District, Northeastern Ethiopia', *International Journal of Environmental Protection and Policy*, 3(6), pp. 181–187. doi: 10.11648/j.ijepp.20150306.11.

Meseret, D. (2016) 'Land Degradation in Amhara Region of Ethiopia: Review on Extent, Impacts and Rehabilitation Practices', *undefined*.

Meshesha, D. T., et al. (2014). "Land-use change and its socio-environmental impact in Eastern Ethiopia's highland." Regional Environmental Change 14(2): 757-768.

Metz, B., et al. (2001). Climate change 2001: mitigation: contribution of Working Group III to the third assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Moges, Y., et al. (2010). "Ethiopian forest resources: current status and future management options in view of access to carbon finances." Addis Ababa.

Moges, Y. and E. Tenkir (2014). "Overview of REDD+ process in Ethiopia, REDD+ report." Ministry of Environment and Forest, Addis Ababa.

Mokria, M., et al. (2018). "Mixed-species allometric equations and estimation of aboveground biomass and carbon stocks in restoring degraded landscape in northern Ethiopia." Environmental Research Letters 13(2): 024022.

Muñoz-Rojas, M., et al. (2015). "Impact of land use and land cover changes on organic carbon stocks in Mediterranean soils (1956–2007)." Land Degradation & Development 26(2): 168-179.

Nawir, A. A. *et al.* (2007) 'Stimulating smallholder tree planting – lessons from Africa and Asia', 58, pp. 53–58.

Niles, J. O., et al. (2002). "Potential carbon mitigation and income in developing countries from changes in use and management of agricultural and forest lands." Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences 360(1797): 1621-1639.

Nkonya, E., et al. (2016). Economics of land degradation and improvement: a global assessment for sustainable development, Springer International Publishing Cham, Switzerland.

Omeja, P. A. *et al.* (2011) 'Intensive tree planting facilitates tropical forest biodiversity and biomass accumulation in Kibale National Park, Uganda', *Forest Ecology and Management*. Elsevier, 261(3), pp. 703–709. doi: 10.1016/j.foreco.2010.11.029.

Olsson, L., et al. (2019). "Land Degradation: IPCC Special Report on Climate Change, Desertification, Land 5 Degradation, Sustainable Land Management, Food Security, and 6 Greenhouse gas fluxes in Terrestrial Ecosystems."

Ordway, E. M. and Asner, G. P. (2017) 'Trends in size of tropical deforestation events signal increasing dominance of industrial-scale drivers Erratum : Trends in size of tropical deforestation events signal increasing dominance of industrial-scale drivers (2017 Environ .'

Pan, Y., et al. (2011). "A large and persistent carbon sink in the world's forests." science 333(6045): 988-993.

Parrotta, J. A. (1992). "The role of plantation forests in rehabilitating degraded tropical ecosystems." Agriculture, Ecosystems & Environment 41(2): 115-133.

Pearson, T., et al. (2013). "Sourcebook for land use, land-use change and forestry projects."

Rutishauser, E., et al. (2013). "Generic allometric models including height best estimate forest biomass and carbon stocks in Indonesia." Forest Ecology and Management 307: 219-225.

Sayer, J., Chokkalingam, U. and Poulsen, J. (2004) 'The restoration of forest biodiversity and ecological values', 201, pp. 3–11. doi: 10.1016/j.foreco.2004.06.008.

Schmink, (1994) "The socioeconomic matrix of deforestation."..pdf, nd

Senbeta, F. and Teketay, D. (2003) 'Regeneration of indigenous woody species under the canopies of tree plantations in Central Ethiopia', 42(2), pp. 175–185.

Sci, J. (2004) 'Feature article RESTORATION OF NATIVE FOREST FLORA IN THE DEGRADED HIGHLANDS OF ETHIOPIA: CONSTRAINTS AND OPPORTUNITIES Mulugeta Lemenih 1', 27(1), pp. 75–90.

Siraj, M., et al. (2018). "Does participatory forest management save the remnant forest in Ethiopia?" Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 88(1): 1-14.

Solomon, N. *et al.* (2017) 'Carbon stocks and sequestration potential of dry forests under community management in Tigray, Ethiopia', *Ecological Processes*. Springer Verlag, 6(1), p. 20. doi: 10.1186/s13717-017-0088-2.

Stone, K. *et al.* (2008) 'Factors influencing community participation in mangroves restoration: A contingent valuation analysis', *Ocean and Coastal Management*. Elsevier, 51(6), pp. 476–484. doi: 10.1016/j.ocecoaman.2008.02.001.

Stringer, L. C., et al.(2007)."From global politics to local land users: applying the United Nations Convention to combat desertification in Swaziland." Geographical Journal 173(2): 129-142.

Sukhdev, P. (2010) ‘The Economics of Ecosystems & Biodiversity’, (October).

Taddese, G. (2001) ‘Land degradation: A challenge to Ethiopia’, *Environmental Management*. Springer, pp. 815–824. doi: 10.1007/s002670010190.

Tadesse, W. (2012) ‘The status of forestry development in Ethiopia: Challenges and Opportunities’.

Tadesse, S. A. and D. Teketay (2017). "Perceptions and attitudes of local people towards participatory forest management in Tarmaber District of North Shewa Administrative Zone, Ethiopia: the case of Wof-Washa Forests." Ecological Processes 6(1): 17.

Tadesse, S., Woldetsadik, M. and Senbeta, F. (2017) ‘Forest users ’ level of participation in a participatory forest management program in southwestern Ethiopia’. Taylor & Francis, 0103. doi: 10.1080/21580103.2017.1387613.

Terakunpisut, J., et al. (2007). "Carbon sequestration potential in aboveground biomass of Thong Pha Phum national forest, Thailand." Applied ecology and environmental research 5(2): 93-102.

Tesfaye, S. (2017). "Assessment of local community perception of and attitude towards participatory forest management (PFM) system and its implications for sustainablity of forest condition and livelihoods: The case of Chilimo-Gaji forest in Dendi District, West Shewa Zone, Oromia, Ethiopia." Journal of Earth science and Climate change 8(382): 1-10.

Tolera, M., et al. (2008). "Woody species diversity in a changing landscape in the south-central highlands of Ethiopia." Agriculture, Ecosystems & Environment 128(1-2): 52-58.

Ubuy, M. H., et al. (2018). "Aboveground biomass models for trees and shrubs of exclosures in the drylands of Tigray, northern Ethiopia." Journal of Arid Environments 156: 9-18.

Wairore, J. N. u., et al. (2015). "Characterization of enclosure management regimes and factors influencing their choice among agropastoralists in North-Western Kenya." Pastoralism 5(1): 14.

Yayneshet, T. (2011) ‘Restoration of Degraded Semi-Arid Communal Grazing Land Vegetation Using the Exclosure Model’, *International Journal of Water Resources and Arid Environments*, 1(5), pp. 382–386.

Yirdaw, E. (2001). "Diversity of naturally-regenerated native woody species in forest plantations in the Ethiopian highlands." New forests 22(3): 159-177.

Zeleke, G. and H. Hurni (2001). "Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian highlands." Mountain research and development 21(2)184-192

Zone, W. (2015) ‘Ecosystem & Ecography Estimation of Carbon Stored in Agroforestry Practices in Gununo’, 5(1)

APPENDICES

Appendix 1: Before and After Restoration Woody Vegetation's Total Biomass

R. Site names	Plot ID	Before Bm 20*20m	Before Bm 5*5m(*16)	Before total Bm Kg/0.04ha	Before total Bm kg/ha	After Bm 20*20m	After Bm 5*5m(*16)	After total Bm kg/0.04ha	After Total Bm kg/ha
Diba Mariet	DM_P1	0	0.0	0.0	0.0	104.4	208.0	312.4	7810.0
Diba Mariet	DM_P2	0	89.6	89.6	2240.0	10.0	233.6	243.6	6090.0
Diba Mariet	DM_P3	0	41.6	41.6	1040.0	24.6	164.8	189.4	4735.0
Meskalimo	MK_P1	0	99.2	99.2	2480.0	8.5	1312.0	1320.5	33012.5
Meskalimo	MK_P2	13.4	0.0	13.4	335.0	57.5	598.4	655.9	16397.5
Meskalimo	MK_P3	83.8	97.6	181.4	4535.0	103.8	315.2	419.0	10475.0
Genamemcha	GM_P1	241.1	0.0	241.1	6027.5	841.4	476.8	1318.2	32955.0
Shola Amba	SA_P1	0	0.0	0.0	0.0	73.3	2243.2	2316.5	57912.5
Ground Total		338.3	328.0	666.3	16657.5	1223.5	5552.0	6775.5	169387.5
Mean/Avg.					**2082.19**				**21173.44**

Appendix 2: Before Restoration/Base Line Woody Vegetation Regeneration Count

Villages	Site name	Plot ID	GPS coordinates	Alt(m)	Trees local name	Trees Scientific name	Total number/plot
A/Yewubesh	Diba Mariet	DM_P1	N=10.516217 E=037.534617	2122	0	*0*	0
A/Yewubesh	Diba Mariet	DM_P2	N=10.518467 E=037.535367	2100	Yehabesha grar	*Acacia abyssinica*	3
A/Yewubesh	Diba Mariet	DM_P3	N=10.517267 E=037.534050	2103	0	*0*	0
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Yehabesha grar	*Acacia abyssinica*	4
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Atat	*Maytenus arbutifolia*	25
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Atat	*Maytenus arbutifolia*	5
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Agam	*Carissa edulis*	3
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Atat	*Maytenus arbutifolia*	73
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Agam	*Carissa edulis*	1
L/Damot	Genamemcha	GM_P1	N=10.515483 E=037.560033	2169	0	*0*	0
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	0	*0*	0
Total							**114**

Appendix 3: Before and After Restoration Woody Vegetation's Total Carbon stock

Site name	Plot ID	Before R Carbon 20*20m	Before R Carbon 5*5m(16)	Before R T Carbon kg/0.04ha	Before R Total Carbon kg/ha	Before R Total Carbon ton/ha	After R carbon 20*20m	After R carbon 5*5m(16)	After R T.carbon kg/0.04	After R T.carbon kg/ha	After R T.carbon ton/ha
Diba Mariet	DM_P1	0.0	0.0	0.0	0	0.0	118.1	235.2	353.3	8832.5	8.8
Diba Mariet	DM_P2	0.0	100.8	100.8	2520	2.5	11.3	264.0	275.3	6881.7	6.9
Diba Mariet	DM_P3	0.0	48.0	48.0	1200	1.2	27.8	185.6	213.4	5335.0	5.3
Meskalimo	MK_P1	0.0	115.2	115.2	2880	2.9	9.6	1484.8	1494.4	37360.1	37.4
Meskalimo	MK_P2	15.2	0.0	15.2	380	0.4	64.9	676.8	741.7	18542.5	18.5
Meskalimo	MK_P3	94.6	112.0	206.6	5165	5.2	117.3	355.2	472.5	11812.5	11.8
Genamemcha	GM_P1	272.6	0.0	272.6	6815	6.8	951.0	539.2	1490.2	37255.0	37.3
Shola Amba	SA_P1	0.0	0.0	0.0	0	0.0	82.9	2536.0	2618.9	65472.5	65.5
Overall sum		382.4	376.0	758.4	18960	19.0	1382.9	6276.8	7659.7	191491.7	191.5
Mean/Avg.						**2.4**					**23.9**

Appendix 4: After Restoration Woody Vegetation Regeneration count

Villages	Site name	Plot ID	GPS coordinates	Alt. (m)	Tree species local name	Tree species Scientific name	Total number
A/Yewubesh	Diba Mariet	DM_P1	N=10.516217 E=037.534617	2122	Yehabesha grar	*Acacia Abyssinica*	3
A/Yewubesh	Diba Mariet	DM_P1	N=10.516217 E=037.534617	2122	Chifrig	*Sida tenuicarpa*	10
A/Yewubesh	Diba Mariet	DM_P1	N=10.516217 E=037.534617	2122	Gorgo	*Erythrina abyssinica*	5
A/Yewubesh	Diba Mariet	DM_P1	N=10.516217 E=037.534617	2122	Atat	*Maytenus arbutifolia*	2
A/Yewubesh	Diba Mariet	DM_P1	N=10.516217 E=037.534617	2122	Anfar/Nechilo	*Budeleia polystachya*	21
A/Yewubesh	Diba Mariet	DM_P1	N=10.516217 E=037.534617	2122	Yeferanj tid	*Cupresus lusitanica*	16
A/Yewubesh	Diba Mariet	DM_P2	N=10.518467 E=037.535367	2100	Dikerens zaf	*Acacia decurrens*	10
A/Yewubesh	Diba Mariet	DM_P2	N=10.518467 E=037.535367	2100	Yehabesha grar	*Acacia Abyssinica*	67
A/Yewubesh	Diba Mariet	DM_P2	N=10.518467 E=037.535367	2100	Kega	*Rosa abyssinica*	15
A/Yewubesh	Diba Mariet	DM_P2	N=10.518467 E=037.535367	2100	Gorgo	*Erythrina abyssinica*	2
A/Yewubesh	Diba Mariet	DM_P3	N=10.517267 E=037.534050	2103	Agam	*Carissa edulis*	6
A/Yewubesh	Diba Mariet	DM_P3	N=10.517267 E=037.534050	2103	Sasbania	*Sesbania sesban*	9
A/Yewubesh	Diba Mariet	DM_P3	N=10.517267 E=037.534050	2103	Nechbaher zaf	*Eucalyptus globulus*	3
A/Yewubesh	Diba Mariet	DM_P3	N=10.517267 E=037.534050	2103	Yehabesha grar	*Acacia abyssinica*	4
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Dikerens zaf	*Acacia decurrens*	20
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Agam	*Carissa edulis*	19
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Kega	*Rosa abyssinica*	3
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Yehabesha grar	*Acacia Abyssinica*	3
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Enjori	*Rubus steunberi*	4
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Saligna	*Acacia saligna*	2
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Atat	*Maytenus arbutifolia*	32

A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Abalo	*Brucea antidysenterica*	3
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Qacamo	*Myrinse africana*	76
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Limich	*Causena anisata*	7
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Fiyelfej	*Cutia abyssinica*	5
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Dingayseber/ Misar gaftir	*Ilex mitis*	3
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Sasbania/ Girangire	*Sesbania sesban*	3
A/Yewubesh	Meskalimo	MK_P1	N=10.483883 E=037.547367	2402	Anfar/Nechilo	*Budeleia polystachya*	2
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Agam	*Carissa edulis*	9
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Atat	*Maytenus arbutifolia*	53
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Fiyelfej	*Cutia abyssinica*	5
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Gangarita	*Vernonia oriculifona*	2
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Sasbania	*Sesbania sesban*	6
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Anfar/Nechilo	*Budeleia polystachya*	4
A/Yewubesh	Meskalimo	MK_P2	N=10.483933 E=037.545300	2386	Chifrig	*Sida tenuicarpa*	10
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Yeferanj tid	*Cupressus lusitanica*	10
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Atat	*Maytenus arbutifolia*	280
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Koshim	*Dovyalis abyssinica*	1
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Abalo	*Brucea antidysenterica*	5
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Djigitta	*Euclea schimperi*	5
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Gangarita	*Vernonia oriculifona*	5
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Qacamo	*Myrinse africana*	20
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Limich	*Clausena anisata*	8
A/Yewubesh	Meskalimo	MK_P3	N=10.485067	2359	Fiyelfej	*Cutia abyssinica*	8

			E=037.544583				
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Dingayseber/ Misar gaftir	*Ilex mitis*	8
A/Yewubesh	Meskalimo	MK_P3	N=10.485067 E=037.544583	2359	Anfar/Nechilo	*Budeleia polystachya*	9
L/Damot	Genamemcha	GM_P1	N=10.515483 E=037.560033	2169	0	*0*	0
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Saligna	*Acacia saligna*	2
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Dikerens zaf	*Acacia decurrens*	29
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Yehabesha grar	*Acacia Abyssinica*	3
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Gravilla	*Grevillea robusta*	3
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Yeferanj tid	*Cupressus lusitanica*	3
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Azamir	*Bersama abyssinica*	3
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Abalo	*Brucea antidysenterica*	2
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Sasbania	Sesbania sesban	4
D/Kelamu	Shola Amba	SA_P1	N=10.520083 E=037.628550	2515	Anfar/Nechilo	Budeleia polystachya	11
G. Total							**863**

Appendix 5: Survey Questionnaire

Addis Ababa University

College of development studies

Center for Environment and sustainable development

<u>Questionnaire for participant and non-participant respondents on degraded communal land plantation</u>

Dear Respondent,

This questionnaire is prepared by a post graduate student of Addis Ababa University for MA Thesis as partial fulfillment of master's degree in the field of Environment and sustainable development. The aim of this questionnaire is to collect data about the state of community participation in degraded land restoration as well as communities attitudes towards restoration activities and factors affecting community participation in four villages of Machakel district Amhara region, Ethiopia. The information you provide is believed to have a great value for the success of this research. I confirm you that all data will be used only for academic purpose and will be analyzed anonymously. In advance I highly appreciate your kind cooperation in providing the necessary information.

General instruction: You are not supposed to write your name.

: Mark symbol "X" for your response or encircle.

: Write your response to open ended questions and additional explanations.

Date of interview: __________ Time: _____________ Interviewer name: _________________

Respondent ID_______________ Region _____________Zone_____________ District_______

Village _____________________ Sub village (Got) ________________________

Agro-ecology: 1. High land 2. Mid land 3. Low land 4. Other _____________________

Supervisor name and signature ___________________________ date _____________________

Part 1: Respondent socio-economic information's

1. What is your Age: ____
2. Sex: Male ☐ Female ☐
3. What is your educational status: ______________________________________
4. What is your main occupation?

   Student ☐ Self-employed ☐ Government employed ☐

   Private/NGO employed ☐ Non employed ☐ Farmer ☐ Others specify_____
5. What is your marital status:

   Married ☐ unmarried ☐ divorced ☐ Widowed ☐
6. Household type: Male headed ☐ 2. Female headed ☐ 3. Other_____________
7. How many family members do you have? __________ Male_______ Female _______
8. What is the net yearly income of your family (birr)? ___________________________
9. For how long you have been living in the village and/or got (sub-village)? ____________

Part 2: The state of community participation in restoration activities.

10. Did you participate in degraded communal land plantation program of your locality during the last four year? 1. Yes 2. No

    10.1. If yes, what kinds of tree species were planted?

    1. Indigenous 2. Exotic 3. Both

    10.2. If yes, for what purpose/s plantation carried out and to what extents?

Purposes of plantation	Extent				
	Highly agree	Agree	Indifferent	Disagree	Highly disagree
Biodiversity conservation					
Environmental protection					
Commercial (economic benefit)					
Commercial & envnt’l protection					
Commercial & biodiversity Conservation					
Biodiversity conservation and envnt’l protection					
Other…..					

10.2. If yes, in which stages of tree plantation project did you participated and to what extents?

Participation stages	Extent of participation					Remark
	Very high	High	medium	low	very low	V.high= >80% of activities
Communities need assessment						Performed and/or
Project planning						# of days used
Implementation						High = 60-80 % “
Monitoring						Medium = 50-60% “
Evaluation						Low = 30-50% “ V.low = <30%. “

10.3. If yes, what was/were your specific level of involvement in degraded communal land plantation of your locality during the last four year?

Specific participation areas	Extent of participation					Remark
	Very high	High	Medium	Low	Very low	V.high= >80% of the
Information and experience sharing						activities Performed
Restoration site selection and delineation						and/or # of days used.
Decision making on land for restoration						
Food and cash contribution						High = 60-80 % “

Local material contribution(wood pole)						
Labor contribution for: ✓ Plantation site preparation						Medium = 50-60% “
✓ Tree seedlings transportation						Low = 30-50% “
✓ Tree plantation						V.low = <30%. “
✓ Restoration site fencing						
✓ Restoration site guarding						

10.4. If Yes, What was the main reason/s for your involvement in degraded communal land plantation during the last four year and to what extent?

Reasons for participation	Extent				
	Very high	High	Medium	Low	Very low
Recognized problem of land degradation					
Social obligations through; Idir, Ekub and etc.					
To make own & community life better of expected restoration benefits					
Remuneration in cash of work access					
Other….					

11. Once tree plantation carried out on degraded communal land, what is your post plantation responsibility and to what extent you are engaging?

11.1. Plantation site committee: enforcing bylaws and following up overall activities.

1. Very highly 2. Highly 3. Fairly 4. Few 5. Very few

11.2. Restoration sites protection (guarding) from human and animal interference

1. Very highly 2. Highly 3. Fairly 4. Few 5. Very few

11.3. Silvicultural management (like; Weeding, hoeing, thinning) and maintenance plantation

1. Very highly 2. Highly 3. Fairly 4. Few 5. Very few

Part 3: Factors determining community's participation in communal land plantation

12. If you are non-participant of tree planting on degraded communal land of your locality, what was the reason/s for not participated and to what extent you agree with?

Possible reasons	Extent				
	Very high	High	Somewhat	Little	Very little
Prefer the land for grazing.					
Tree plantation has no advantage.					
Don't have alternative land for grazing					
Don't want to contribute labor and local materials as others did.					
Forest attracts wild animals which affects farm and home animals.					
The land is under boundary and/or ownership conflict					
Don't want to plant Indigenous trees of low growth rate as others did.					
Need only fast growing trees species to plant.					
Other…					

- **Communities knowledge towards land degradation and benefits of tree planting**

13. Do you have any knowledge about land degradation and its causes? 1. Yes 2. No.

11.1. If yes, how was the role of formal learning at school to your knowledge?

1. Very high 2. High 3. Fair 4. Few 5. Very few

11.2. If yes, how was the role of formal training to your knowledge?

1. Very high 2. High 3. Fair 4. Few 5. Very few

11.3. If yes, how was the role of mass media to your knowledge?

1. Very high 2. High 3. Fair 4. Few 5. Very few

11.4. If yes, how was the role of awareness raising/short orientations workshops to your knowledge?

1. Very high 2. High 3. Fair 4. Few 5. Very few

11.5. If yes, how was the role of your own physical experience to your knowledge?

1. Very high 2. High 3. Fair 4. Few 5. Very few

12. How is the current land degradation condition of your locality?

1. Very Sevier 2. Sevier 3. Moderate 4. Low 5. Very low.

12.1. To what level do you agree that population growth and intensive land use are the potential causes of land degradation in your locality?

1. Very high 2. High 3. Somewhat 4. Little 5. Very little

12.2. To what level do you agree that overgrazing is the potential causes of land degradation in your locality?

1. Very high 2. High 3. Somewhat 4. Little 5. Very little

12.3. To what level do you agree that Soil and water erosion is the potential causes of land degradation in your locality?

1. Very high 2. High 3. Somewhat 4. Little 5. Very little

12.4. To what level do you agree that short term farmers' perspective is the potential causes of land degradation in your locality?

1. Very high 2. High 3. Somewhat 4. Little 5. Very little

12.5. To what level do you agree that deforestation is the potential causes of land degradation in your locality?

1. Very high 2. High 3. Somewhat 4. Little 5. Very little

13. Do you have any knowledge about biomass and carbon stocks in the forest? 1. Yes 2. No

13.1. If yes, how was the role of government training and awareness raising to your knowledge?

1. Very high 2. High 3. Somewhat 4. Few 5. Very few

13.2. If yes, how was the role of training and awareness given by NGO's/agencies?

1. Very high 2. High 3. Somewhat 4. Few 5. Very few

13.3. If yes, how was the role of training and awareness provided by tree planting project on degraded communal land (Weforest) to your knowledge?

1. Very high 2. High 3. Somewhat 4. Few 5. Very few

13.4. If yes, how was the role of formal School learning to your knowledge?

1. Very high 2. High 3. Somewhat 4. Few 5. Very few

13.5. If yes, how was the role of Medias and others to your knowledge?

1. Very high 2. High 3. Somewhat 4. Few 5. Very few

14. To what extent do you understand about planting trees enhances forest carbon stock?

1. Very well 2. Well 3. Somewhat 4. Few 5. Very few

15. To what extent do you understand about atmospheric carbon sequestration in trees reduces the effect of global climate change?

1. Very well 2. Well 3. Somewhat 4. Few 5. Very few

- **Community's attitude and perceptions towards degraded land restorations and participatory tree planting**

16. Do you think that degraded land restoration through tree planting is the Solution for degrading communal lands in your locality? 1. Yes 2. No

17. To what level do you think planting trees on degraded communal land is important?
    1. Very important 2. Important 3. Somewhat 4. Don't know 5. Not important

18. How do you think about the forest cover of your locality before the last four years?

    1. Highly degraded 2. Degraded 3. Remain the same 4. Dense 5. Highly dense

19. How do you think about the forest cover of your locality after the last four years?

    1. Highly increasing 2. Increasing 3. No change 4. Decreasing 5. Highly decreasing

20. Who do you think is responsible to plant and manage forests on degraded communal lands for its environmental services and economic benefits?

20.1. The local communities:
    1. strongly agree 2. Agree 3. Don't know 4. Disagree 5. Strongly disagree

20.2. The government:

    1. Strongly agree 2. Agree 3. Don't know 4. Disagree 5. Strongly disagree

20.3. Non-governmental organizations and other institutions/agencies.

    1. Strongly agree 2. Agree 3. Don't know 4. Disagree 5. Strongly disagree

21. Do you think that community participation in tree plantation is vital for sustainable land and forest management? 1. Yes 2. No

21.1. If yes, to what level do you agree that it gives authority to the community to control over the resources?

    1. Strongly agree 2. Agree 3. Somewhat agree 4. Disagree 5. Strongly disagree

21.2. If yes, to what level do you agree that it builds communities capacity to manage their resources?

    1. Strongly agree 2. Agree 3. Somewhat agree 4. Disagree 5. Strongly disagree

21.3. If yes, to what level do you agree that it creates communities sense of ownership and insures sustainability

1. Strongly agree 2. Agree 3. Somewhat agree 4. Disagree 5. Strongly disagree

21.4. If yes, to what level do you agree that it reduces communal land degradation and environmental depletions?

1. Strongly agree 2. Agree 3. Somewhat agree 4. Disagree 5. Strongly disagree

22. Do you agree that participatory tree planting is vital to enhance degraded land carbon stocks and solution for global climate change?

1. Strongly agree 2. Agree 3. Somewhat agree 4. Disagree 5. Strongly disagree

23. To what extent do you satisfied with planted trees on degraded communal land of your locality during the last four year?

1. Very satisfied 2. Satisfied 3. Somewhat 4. No sense 5. Not satisfied

24. Will you participate in planting trees on degraded communal lands of your locality?

1. Yes always 2. Some times 3. Still not decided 4. I don't think 5. Not at all

25. Will you plant trees on your own woodlots?

1. Yes always 2. Some times 3. Still not decided 4. I don't think 5. Not at all

- **Community's practices and customs towards tree planting**

26. Did you ever plant trees on your own land and/or communal land? 1. Yes 2. No,

26.1. If yes, what kinds of tree species? 1. Native 2. Exotic 3. Both

26.2. If yes, for what purposes?

1. Biodiversity conservation 2. Environmental protection 3. Commercial

4. Commercial & envnt'l protection 4. Commercial & biodiversity conservation

27. What are the cultural values of the community towards planting trees on communal lands and to what extent it affects your participation?

27.1.The community Prefers planting native tree species for biodiversity conservation

1. Highly affects 2. Affects 3. Somewhat affects 4. Indifferent 5. Not affect

27.2.The community had been Planting fast growing exotic trees species for commercial

1. Highly affects 2. Affects 3. Somewhat affects 4. Indifferent 5. Not affect

27.3.The community Prefer using land for grazing and/or Agriculture activities than forestry

1. Highly affects 2. Affects 3. Somewhat affects 4. Indifferent 5. Not affect

27.4.The community has no relationship with forest.

1. Highly affects 2. Affects 3. Somewhat affects 4. Indifferent 5. Not affect

- **Participation incentives**

28. Did you get any incentives to participate on degraded communal land plantation during the last four year? 1. Yes 2. No.

28.1. If yes, what incentive/s did you received and to what extent it motivated you?

Incentives	Extent of motivation				
	Very highly	Highly	Somewhat	A few	Very few
Training and awareness					
Fruit and multipurpose agroforestry tree seedlings					
Other livelihood packages					

Appendix 6: Checklist questions for focus group discussions (FGD)

- **FGD check list questions to participant community members:**

1. What was the main reason/s for your involvement in degraded communal land plantation?
2. Did you get any incentive/s to participate in restoration activities? What?
3. Which tree species did you planted and for what purposes?
4. At which stages of the restoration project did you participated and how?
5. To which specific restoration activities did you participated and how?
6. Do you have any post plantation social duties regarding restoration? & What?
7. What do you fill about trees planted in the past to which you were involved?
8. Did you ever planted trees before the restoration project? Which species? For what purpose/s?
9. What do you know about land degradation? How it's going on in your locality currently? What causes it? What do you think is the solution?
10. Do you know any about biomass and carbon stocks in the forest? And How?
11. How is the forest cover of your locality before and after restoration project intervention?
12. Why communities' collective action is important in degraded communal land plantation?
13. Do trees have any contribution in reducing the effect of global climate change and how?
14. Who do you think is responsible to restore degraded communal lands and manage forests? and Why?

- **FGD check list questions to non-participant community members:**

1. Why you did you not participated in degraded communal land plantation?
2. Did you get any incentive/s to participate in restoration activities? What?
3. Did you ever plant trees? Which tree species? For what purpose/s?
4. What do you fill about trees planted in the past around your locality?
5. What do you know about land degradation? How it's going on in your locality? What causes it? What do you think is the solution?
6. Do you know any about biomass and carbon stocks in the forest? And How?
7. How is the forest cover of your locality before and after restoration project intervention?
8. Why communities' collective action is important in degraded communal land plantation?
9. Do trees have any contribution in reducing the effect of global climate change and how?
10. Who do you think is responsible to restore degraded communal lands and manage forests? Why?

Appendix 7: Woody vegetation's data collection formats

1. Woody vegetation information (20 × 20 m Plot for trees and shrubs with DBH > 5cm)

Village________________ Site name___________________ Plot ID________ land use type _______________ Age of land use_______

GPS Record: latitude(y) ______________ longitude(x) _________________ Altitude _______________

Data collector: _____________________________ Date: _________________________

Plant ID	Species local name	Scientific name	Life forms (T/ S)	Tree DBH at 1.3 m	height(m)	# of stems	Species nativity	Remarks
1								
2								
3								
4								
5								
6								
7								

Note: Life form: Tree (T); Shrub (S) and Species nativity: Indigenous (I) and Exotic (E)

2. Woody vegetation information (5 × 5 m Plot for trees and shrubs with a DSH 2cm to 10.1cm or (DBH ≤5)).

Plant ID	Species local name	Scientific name	DSH at 0.3m	Height (m)	# of stems	Species nativity	Remarks
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Note:

Species nativity: Indigenous (I); Exotic (E)

Species nativity: Indigenous (I); Exotic (E)

3. Woody species seedling regeneration count (5 × 5 m Plot)

Plot No ____________________________ Date _______________________

S/No	Species local name	Scientific name	Total ≠	Seedling propagated through 1= Seed 2= Vegetative	Remark
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					