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Towards the sustainability of the agricultural landscape The case of the watershed management and implication in the Rift Valley of Ethiopia

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May 2020

Abstract

Watershed deterioration in Ethiopia is significant in debilitating and modifying the agricultural landscape system, causing cumulative and synergetic effects on resources, climate and food security that deteriorate the ecological services and the socioeconomic conditions of the people who mainly depends on agriculture. On the other hand, practices and strategies of watershed management have also been conducted to avert mainly land degradation problem since the 1980s. The objective of the study was to assess the watershed management practices in averting the problems of watershed degradation and its implications in enhancing food security and fostering the mitigations and adoption of climate change in the southern Rift Valley. The study employed various methods of collecting data (satellite image, interviews, group discussion) and analysis (statistics, GIS). The results showed that the watershed marked by different forms land degradation among which the main ones are soil erosion, gully erosion, grazing land deterioration and deforestation which in turn affect the agricultural productivity of the area. A wide range of watershed management practices such as agronomy (crop rotation, crop diversification, improved seed, drought-resistant crop), irrigation, terrace, composting, agroforestry and mulching have been implemented. These practices resulted in the increase of forest areas, carbon sequestration, enhanced the soil fertility and reduction of soil erosion which all contributed to the enhancement of food security and climate change adoptions. However, the effective adoption and implementation of the watershed management practices are affected by a wide range of demographic, physical, economic and institutional factors. Among others, sex of household heads, education level of household heads, number of livestock holding, access to extension services and being a member of rural organizations affect adoption of composting positively and significantly. Also, farm distance affects composting practices negatively. The probability of applying agroforestry is positively and significantly associated with sex of household heads, farmers' field day participation and knowledge on environmental regulation. Besides farm distance affect the likelihood of agroforestry application negatively. The policy makers and planners should thus take into account the cumulative and synergy of the interactions of watershed management, climate change and food security for the planning of the sustainable development of agriculture.

Keywords: watershed, land degradation, forest, climate change, mitigation, sustainable development, Ethiopia

JEL classification: Q01, Q20

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Watershed deterioration in Ethiopia is significant in debilitating and modifying the agricultural landscape system, causing cumulative and synergetic effects on resources, climate and food security that deteriorate the ecological services and the socioeconomic conditions of the people who mainly depends on agriculture. On the other hand, practices and strategies of watershed management have also been conducted to avert mainly land degradation problem since the 1980s. The objective of the study was to assess the watershed management practices in averting the problems of watershed degradation and its implications in enhancing food security and fostering the mitigations and adoption of climate change in the southern Rift Valley. The study employed various methods of collecting data (satellite image, interviews, group discussion) and analysis (statistics, GIS). The results showed that the watershed marked by different forms land degradation among which the main ones are soil erosion, gully erosion, grazing land deterioration and deforestation which in turn affect the agricultural productivity of the area. A wide range of watershed management practices such as agronomy (crop rotation, crop diversification, improved seed, drought-resistant crop), irrigation, terrace, composting, agroforestry and mulching have been implemented. These practices resulted in the increase of forest areas, carbon sequestration, enhanced the soil fertility and reduction of soil erosion which all contributed to the enhancement of food security and climate change adoptions. However, the effective adoption and implementation of the watershed management practices are affected by a wide range of demographic, physical, economic and institutional factors. Among others, sex of household heads, education level of household heads, number of livestock holding, access to extension services and being a member of rural organizations affect adoption of composting positively and significantly. Also, farm distance affects composting practices negatively. The probability of applying agroforestry is positively and significantly associated with sex of household heads, farmers' field day participation and knowledge on environmental regulation. Besides farm distance affect the likelihood of agroforestry application negatively. The policy makers and planners should thus take into account the cumulative and synergy of the interactions of watershed management, climate change and food security for the planning of the sustainable development of agriculture.

Chapter One

Introduction

The main challenges of sustainability agriculture are the unprecedented land use, land cover and landscape changes, in particular, the agricultural landscape transformation. It is estimated at a continental scale that over 50% of the land in sub-Shara Africa, SSA, has been converted from forest to agricultural land use (crop and grazing), particularly over the last 50 years., as population have started to expand exponentially (Ramankutty, 2018). Similarly, the extent of available agricultural land in Ethiopia has enormously increased, particularly during the last hundred years. Since 1900 about 23 M ha of forest land was cleared, mainly driven by conversion to arable farmland (Assefa and Bork, 2014).

Moreover, soil degradation is a serious threat to agriculture and the environment in Ethiopia. The estimated annual soil loss in Ethiopia is 1.5 billion tons, of which 50% occurs in cropland. Soil loss by water may be as high as approximately 300 tons ha^{-1} $year^{-1}$ on steep slopes, and soil nutrient losses may be as high as 80 kilograms of nitrogen, phosphorus, and potassium per ha and year or more. In general, half of the Ethiopian highlands are moderate to severely eroded (Hurni 1993; Pender 2002)

These all resulted in forest loss and fragmentation, green gas emissions (GEG), biodiversity loss, soil loss and deterioration of water. These, in turn, lead to food insecurity, poverty and immense impacts on wellbeing and these impacts are expected to rise in the future (Ramankutty et al., 2018). These problems are emerged from the complex social and ecological interaction and currently exacerbated by population growth and climate change. Farmers in sub-Saharan Africa, compared to other parts of the world were highly affected by extreme heat events and increasing rainfall variabilities, that led to agricultural production decline over the past three decades (Cohn et al. 2017).

Thus in Ethiopia in general and in the study area in particular, mitigating the challenges of land degradation is crucial to the livelihood of a large number of population and at the same time to maintain and rehabilitate the environment. Sustainable use and maintenance of land use and land cover are therefore fundamental to human wellbeing. It is also vital for planning of the long-term sustainable use of the fragile environments Africa’s in general and Ethiopia’s in particular.

Sustainability, however, plays a central role in policies and strategies to address the current debates of economic development while maintaining biodiversity at global, regional, national and local levels (Griggs et al., 2013, Scoones, 2016). An overview of issues to be tackled by sustainable development, SD, has been pointed out in the UN General secretary High level Panel on global sustainability in the report "Resilient People, Resilient Planet: a future worth choosing". The global community adopted 17 Sustainable Development Goals, SDG, as an extension of the MDG, which is envisioned as the main developmental concept by the UN intended to catalyze transformation in the global, national and regional level. Moreover, massive initiatives and scientific assessment on sustainable development have also been undertaken by Intergovernmental Panel for Climate Change, Intergovernmental Platform for Biodiversity and Ecological Services, IPBES, International Assessment of Agricultural Knowledge and Science and Technology for Development.

Similarly, policies issued in Ethiopia over the past two decades strongly advocate Sustainable Development as defined in major international documents like the 1987 ‘Our Common Future’ and the 1992 ‘Agenda 21’. Ethiopia`s second Growth and Transformation Plan 2015 (GTPII) has also incorporated SDG, aiming to build 'climate resilient green economy' Moreover, a plethora of studies demonstrate that intensified agriculture in different parts of Ethiopia have maintained the ecology (edhaphic and water resources) and biodiversity proving the existence of sustainable and resilience agriculture for a long period of time.

The Sustainable Land Management Program (SLMP) is one of the instruments designed under the long-term Ethiopian Strategic Investment Framework (ESIF) for Sustainable Land Management adopted by the Government in September 2008. ESIF is the framework that underpins domestic and foreign support for addressing issues related to the pervasive challenges to land and water resources. Similarly, SLMP is being implemented by the Ethiopian Ministry of Agriculture (MoA) through its decentralised agencies at regional, zonal, woreda and kebele levels since October 2008.

Current funding for SLMP comes from the International Development Association (IDA-World Bank), Global Environment Facility (GEF), German Development Cooperation (GDC) implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and KfW Development Bank, Canadian Department of Foreign Affairs, Trade and Development (DAFTD), the European Union (EU), the Government of Finland, Royal Norwegian Embassy and the Government of the Federal Democratic Republic of Ethiopia (FDRE).

Watrershed management is one of the core component of the SLMP which has been practiced in the country. Ministry of Agriculture and the United Nations World Food Programme (WFP) staff developed participatory and community-based watershed planning guidelines known as the Local-Level Participatory Planning Approach (LLPPA). These guidelines were developed with a practical focus for the benefit of development agents. Their emphasis was upon integrated natural-resource management(NRM) interventions, productivity-intensification measures and small-scalecommunity infrastructures such as water ponds and feeder roads. During the same period, several non-government organisations (NGOs) and bilateral organizations also adopted participatory land use-planning approaches to their respective areas of intervention – always in close collaboration with government partners. For instance, GIZ2 followed a Participatory Land Use-Planning (PLUP) approach with some success in South Gonder Zone, North and West Shoa Zones of Oromia Region, and in some woredas of Tigray Regional State.

However, in the past formal planned development of watersheds in Ethiopia began in the 1980s. At that time a planning unit for developing large watersheds comprised 30- 40,000 hectares and held the primary purpose of implementing natural resource conservation. Large-scale efforts remained mostly unsatisfactory due to a lack of effective community participation, a limited sense of responsibility for assets created, and unmanageable planning units. The lessons learned from this experience encouraged the Ministry of Agriculture (MoA) and supporting agencies such as the Food and Agriculture Organization of the United Nations (FAO) to initiate pilot watershed planning approaches on a bottom-up basis, using smaller units and community-based approaches. As a result, minimum planning and sub-watershed approaches were introduced. This involved a shift from larger watersheds to smaller sub-watersheds. The new approach was piloted with FAO assistance under the MoA in 1988–91.

This research project was carried out in Hare-Kulfo watershed of the south Rift valley. Where smallholding agriculture production system is predominant, and where both areas are affected by a wide spread of land degradation. On the other hand, various types and forms of watershed management practices have been implemented over a long period of time. Moreover, there are no well established links of sustainable resource use and management with food security and climate change adoption and mitigation.

Objective

The main objective of the research project is to assess the interventions of the community to the agricultural landscape deteriorations through watershed management practices and appraise the impacts and determinants of the interventions.

The specific objectives of the study are:

- To assess the major watershed deterioration that affects the livelihood the community
- To examine the approaches, strategies, and practices of the watershed management interventions
- To assess the contribution of the watershed on enhancing food security and climate change adoptions
- To appraise the major determinants factor in the implementation of watershed management practices.

Chapter Two

Materials and Methods

2.1 Description of the study area

The study was carried out in Kulfo_Hare watershed (Arbaminch and Chencha) in the south Rift Valley of Ethiopia, which is situated in the south Nation, Nationality and People of Ethiopia (Figure 1). They are situated about 480 km southwest of Addis Ababa and are bounded on the east by Lake Abaya and Lake Chamo. The topography is characterized by a series of undulating and rugged landscapes, which include from east to west the Rift Valley Plain, the escarpment with incised valleys, and high plateaus, which are topped by hills and mountains. The Rift Valley escarpment and the upper slopes of the mountains are very steep and marked by undulating and rugged surface features. Mountaintops are mostly gentle to almost flat. The valleys of the rivers Kulfo and Hare, are steep in the upstream (highland) and midstream (escarpment) areas, and flat in the lakes. The lower part of the investigation area, lower Hare river, has a sufficient accommodation space that is used as a trap for sediments from the surrounding escarpments and highland. They are characterized by high altitude differences within short distances; about 2400 m of elevation difference within a 20km distance (Fig.3). However, despite their altitudinal differences, these areas are spatially highly interconnected. The disturbance of the natural environment of the highlands, for instance, affects runoff generation that in turn causes gully formation and development in the lowlands.

The mean annual rainfall of the investigation areas, based on meteorological records from Arbaminch (1,200 m a.s.l.) and Chencha (2,700 m a.s.l.) from 1970 to 2008, varies from 781mm (Arbaminch) to 1,392mm (Chencha). The elevation is the most important factor for the variation of the mean annual rainfall. Based on the records, two patterns of rainfall can be discerned; bimodal in Arbaminch and monomodal in Chencha. In the bimodal pattern, the main rain occurs during the period from March to June, and the peak is on average 148 mm in April. During this period, the weather becomes more unsettled, and the convergence of southeasterly winds originating from the Indian Ocean with a weakening northeasterly air stream causes heavy rainfall in this area. The minor rainy season (the second peak) is between August and November, during which the peak is in October and amounts to an average of 92 mm.

The population of Chencha totalled 134,531 and of Arbaminch 247,915 in 2005 (CSA, 2006). Population density is estimated at 368 and 205 persons per square kilometre in Chencha and Arbaminch respectively**.** Scientific investigations prove that the area has been settled at least since about 3360 years cal BP (Arthur et al., 2010). Olmstead (1972) estimated that 5,000 to 35,000 people lived in Chencha area at the end of the 19th century. The main economic activity of the area is subsistence agriculture.

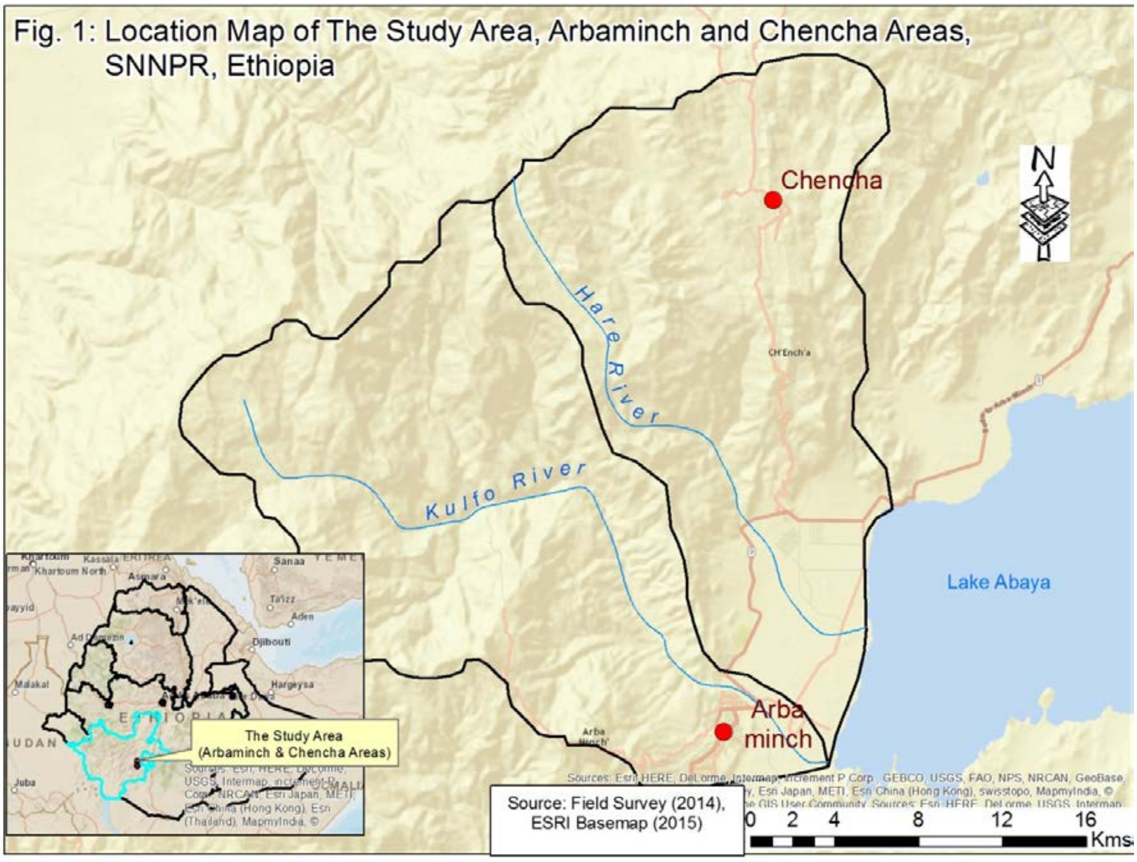


Fig. 1: Location Map of The Study Area, Arbaminch and Chencha Areas, SNNPR, Ethiopia

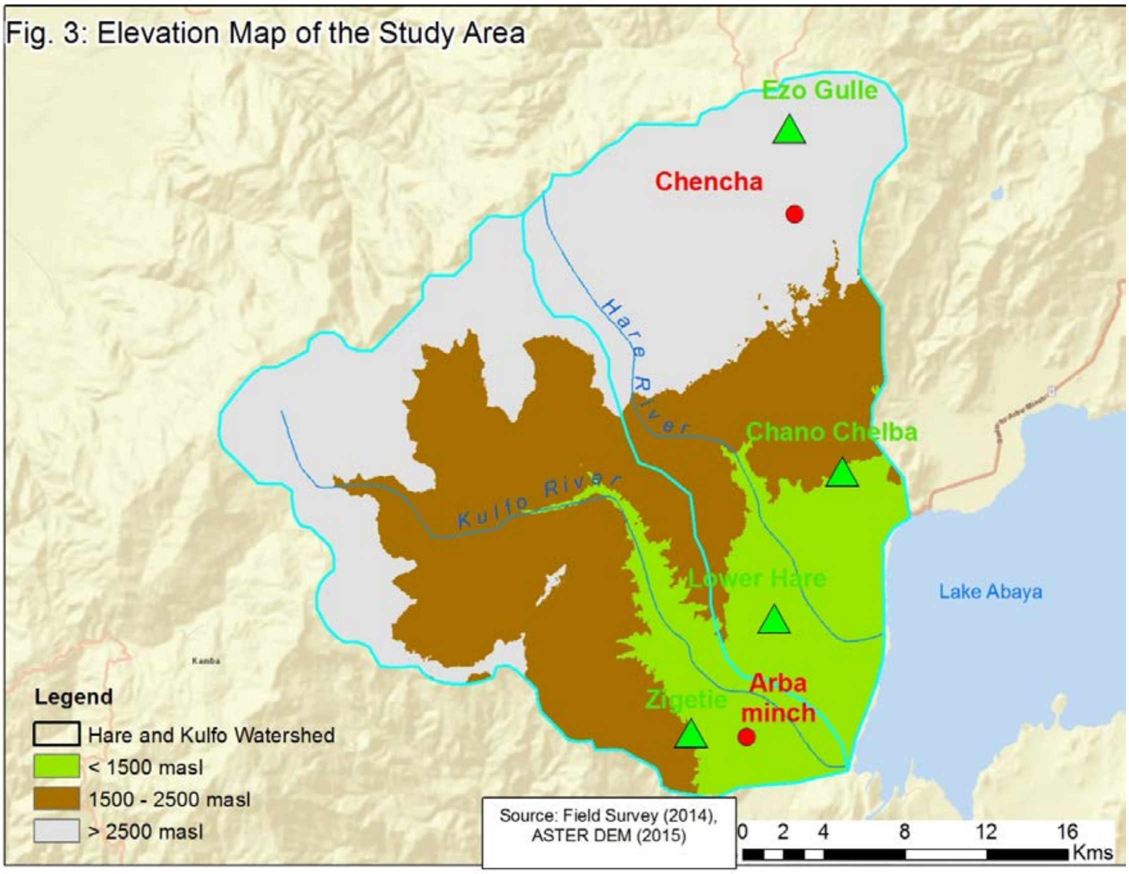


Fig. 3: Elevation Map of the Study Area

2 Methods

2.2 Satellite Data and GIS

Cartographic resources such as a topo map of the area, satellite images and Google Earth used to map out the Digital Elevation Model, DEM, and the trends of land use and land cover of the areas. A Digital Elevation Model extracted from ESRTI, which enabled us to derive slope map, elevation and other geomorphologic features.

Satellite Image Collection

Land use and land cover of the different periods of the study areas was generated using a time-series satellite image analysis. Remotely sensed Landsat images 30m pixel resolution taken in 1986, 2000 and 2017G.C was downloaded from the GLCF website and used for land use/cover mapping and change (detection) analysis. The image which was taken in 1986 was Landsat TM 7 whereas the images taken for 2000 and 2016 was Landsat 8 ETM+. .

Steps of image classification

Pre-processing

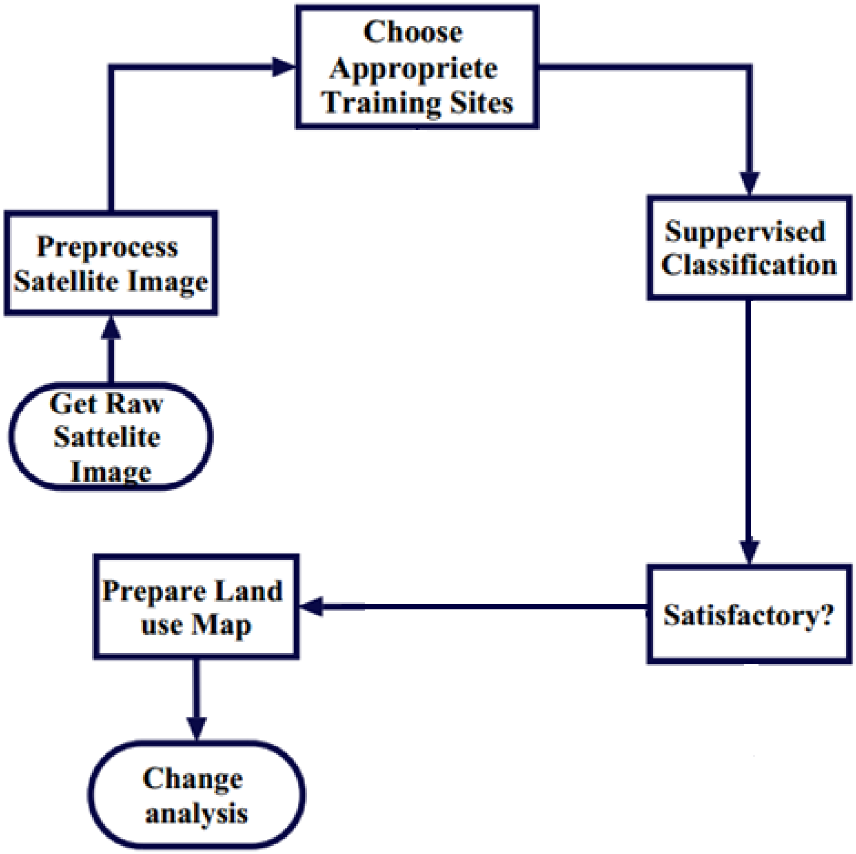
Image preprocessing is the process in which all works are done to make the satellite image ready for land use/land cover classification. The image preprocessing includes the process of making it free from errors like cloud cover, radiometric correction, and other related errors. Also, image preprocessing includes layer stacking and sub setting.

The first step in image classification is getting sufficient raw satellite image of the study area. Time series of the images should be available to proceed to the next step which is image pre-processing.

Supervised classification: The first step in a supervised image classification is creating training areas to capture all the spectral classes in the image used to capture the variability in those classes via the signature editor. First of all, GCP point shape files with their attributes should be overplayed on the image so that they can indicate the land use class types (e.g., water, forest, etc.) for signature editing. Finally, the classification process was performed using the maximum likelihood method of supervised image classification.

III. Spatio-temporal Distribution of Land use/covers

Different land uses such as forest, cultivated, grazing land and others were identified from the images by supervised classification method. Three maps of land use/cover which shows the spatial and temporal distribution of each land cover classes produced for the 1986, 2000 and 2016 Landsat images



2.3 Sampling and Sample Size

The population of the study consist of smallholder rural farmers who are living in the rural areas of the Arbaminch and Chancha. In order to represent the population with sufficient accuracy and to infer the sample results to the population, the target sample households were selected in a purposeful multistage stratified sampling process. In the first stage, 17 kebeles were stratified into three based sub-watershed units as (upper, middle and lower watershed). In the second stage, 3 kebele administrations (KAs) were purposefully selected among a three sub-watershed (based on socio economic, infrastructural accessibility, time, agro- ecology and other physical factors status of the kebeles to carry out watershed management practices. In the third stage, among the three ones, a total of 150 households were randomly selected for the household survey. This number of KAs in the study site was considered to be sufficient for statistical analysis and convenient to be surveyed with the available resources of finance, human and time.

2.4 Data collection instruments

Household survey

Questionnaires were distributed for 150 household farmers to the watershed who are living in four kebeles, in order to assess: the patterns and trends of watershed deterioration such as soil erosion, soil fertility decline, deforestation, and grazing land deterioration. Moreover, watershed management practices and their socio economic and food security impacts were also collected. The question items are both open ended and closed ended type. They originally prepared in English and latter translated to the local language which are the widely spoken languages of the sample kebeles. The survey was conducted by enumerators (one for each kebele) after being trained on data collecting procedure and content of the instrument by the researcher.

Focus group discussion (FGD)

The purpose of the focus group discussions was to generate in depth information on some of the survey findings and other issues that may not have been adequately captured by the structured questionnaire survey. FGD was employed to collect first hand information on development and dynamics of the land degradation problem and the nature, practices, challenges, and implementation of watershed practices. Besides, FGD was conducted to assess farmers perception of watershed practices. Focus group discussants were purposively selected in order to be representatives of different social groups and to get their long years of experience on agricultural practices of their kebeles. Accordingly, three focus group discussions which consist of 8 to 10 individuals were held across the sample kebeles.

2.5 Data Analysis

Geographic Information System used to map the land use and land cover map of the different period. The bio physical, socio economic and institutional data that was collected using questionnaires from the selected 150 household farmers were analysed by using descriptive statistical analysis including frequency distribution, percentage, mean and standard deviation (SD). Moreover, also, regression analysis using the logit model was employed to identify determinant factors that influence the adoption of CSA practices by rural famers using statistical package for social sciences (SPSS version 24.0). The qualitative data collected by employing open ended questions, FDG, key informant interviews and direct observation by transect walking were used along with quantitative data as a supplement to support and elaborate the findings.

2.6. Model Specification

The two computing models commonly used in the adoption studies are the probit and logit models. The models are popular statistical techniques in which the probability of a dichotomous outcome (such as practicing or non-practicing) is related to a set of explanatory variables that are expected to influence the outcome. However, the results obtained from the two models are very similar since the normal and logistic distributions from which the models are derived are very similar. There is no compelling reason to choose one over the other. In practice, many researchers choose the logit model because of its comparative mathematical simplicity (Gujarati and Porter, 2009). Logistic regression also referred to as logit model has no assumptions about the independent variables: they do not have to be normally distributed, linearly related or of equal variance within each group (Tabachnick, 2007). Due to its computational simplicity and other statistical advantage the logit model is employed in this research paper.

Following (Gujarati and porter, 2009) the logit model can be specified as:

$P_i = E(Y_i = 1/X_i) = F(\beta_0+\beta_i X_i)$ (1)

$$= \frac{1}{1 + e^{-(\beta_0+\beta_i x_i)}}$$

$= \frac{1}{1+e^{-z_i}}$, where $z_i = \beta_0 + \beta_i x_i$

$= \frac{e^{z_i}}{1+e^{z_i}}$ ……… is the cumulative logistic distribution function (2)

Where $P_i = P(Y= 1)$ is the probability that the farmers adopt CSA practices

X_i = are different factors that affect a farmer's adoption decision

β_0 = is the constant term.

β_i's = is the coefficient of parameters.

In the estimation of the model, the probability of non – adoption is given by:

$1 - P_i = \frac{1}{1+e^{z_i}}$ (3)

Moreover, the odd ratio which tells the ratio of the probability of the farmer will adopt CSA practices to the probability the farmer will not adopt the practices can be written as:

$$\frac{p_i}{1 - p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} \qquad (4)$$

Hence ,

$$L_i = \ln\left[\frac{p_i}{1 - p_i}\right] = Z_i = \beta_0 + \beta_i x_i$$, where, L_i is the log of the odd ratio. (5)

Also,

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i + e_i \qquad (6)$$

Taking the natural logarithms of the odds ratio of equation (4) will result in what is called the logit model as indicated below.

$$\ln\left[\frac{p_i}{1 - p_i}\right] = \ln\left[e^{\beta_0} + \sum_{i=1}^{n} \beta_i X_i\right] = Z_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + e_i \qquad (7)$$

(e_i is the error term with zero mean and constant variance.)

The model is expressed as follows:

$Y_i = \beta_0$ (±) $\beta_1$age (+) β_2 sex (+) β_3 family size (+) β_4 active labour force (+) β_5 education (+) β_6 farm size (-) β_7 number of parcels (-) β_8 average farm distance from homestead (-) β_9 average farm distance from the proxy market (-) β_{10} average farm distance from the main road + β_{11} degradation + β_{12} number of livestock + β_{13} access to credit + β_{14} radio + β_{15} access to weather forecasting + β_{16} Off-farm income + β_{17} knowledge on Environmental regulations + β_{18} extension service + β_{19} training + β_{20} Organization + β_{21} farmer's field day participation + ε_i (The signs in the bracket indicate the expected signs in the predicted model)

Chapter Three

Watershed Deterioration

Intensive agriculture such as cultivation of crops, raising of animals and forestry management have been practiced for a longer period in the study areas, which plays a pivotal role of the wellbeing and sustainable resource management. However, the sustainability of the resources and their capacity to perform functions central to supporting growing human wellbeing, is rapidly changing. Watershed deterioration is one of the wide spread phenomena of land degradation in the study area. The most common forms of watershed deterioration include soil erosion, soil fertility decline, deforestation and grazing land deterioration.

3.1 Soil erosion _ gully erosion

The large majority (68%) of respondents to the survey acknowledged the problem of soil erosion on their cultivated land, and among them, 51% rated the soil erosion as severe.

A large proportion of interviewed farmers (57%) acknowledge the problem of gullying. Among these respondents, 45% conveyed the severity of the problem (Table 1). The farmers were asked if they had noticed the rate of changes concerning the extension length, width and area of gully, particularly in the last forty years. Eighty one percent of the interviewed farmers stated that the magnitude of gully erosion over the last 30 years has increased and the problem has become severe.

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Table 1: Farmers´ views of the dynamics of gully erosion

Views of gully erosion	Upper watershed % of respondents	Middle watershed % of respondents	lower watershed % of respondents
How serious is gully erosion			
High	32	57	46
Medium	47	26	29
Low	21	17	25
Observed changes in the magnitude of gully erosion over the last 40 years			
Increase	80	72	92
Decrease	4	8	0
No change	16	20	8
If increase: How serious is the problem?			
High	50	62	63
Medium	33	28	25
Low	17	10	12

In our discussion with old people, they also pointed out that, in the past gullies were confined to along the escarpments. In the lowlands, in particular, there was no pronounced gullying before the 1960s. This is because the lowland area was not under cultivation before this time. At present, however, gullies are common across the investigated areas, and their different land use types, namely cultivation, grazing, bush land and intensively used woodland. Gullies have also been formed on different slope gradients and topographic positions. This trend of gully expansion continues unabated, large areas will be void of agriculture. Figure 4 and 5

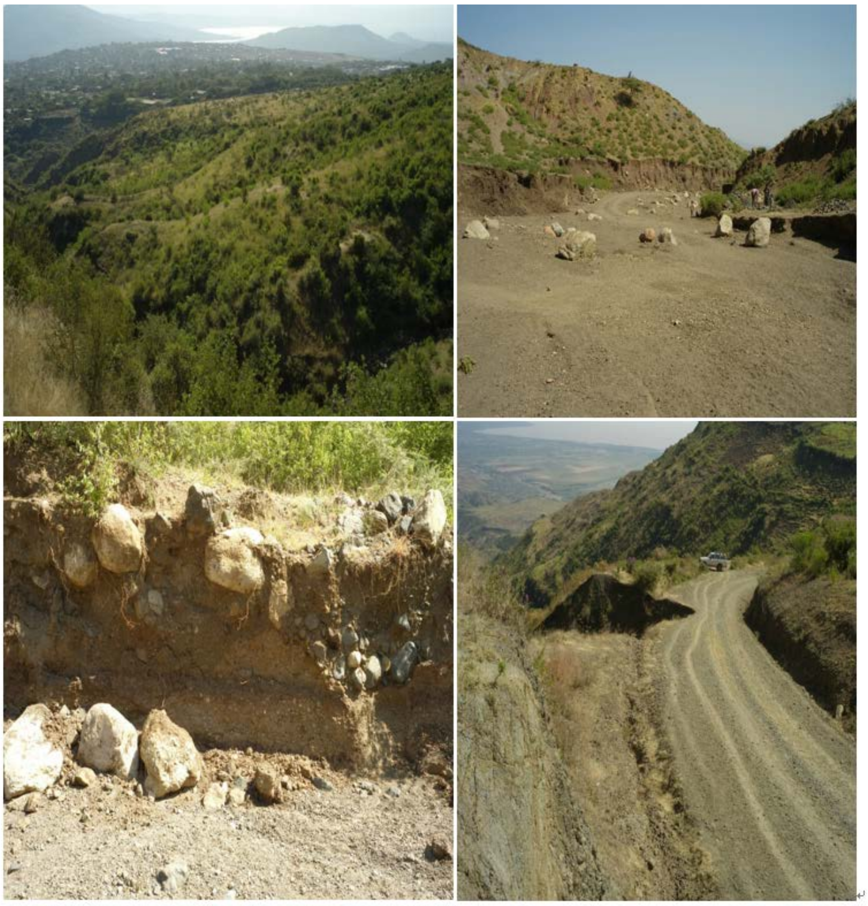


Figure 4: Gully erosion

Figure 5: Gully erosion

3.2 Soil fertility deterioration

Soil fertility decline was identified as one of the serious problems that have affected the agricultural land in the highlands, as expressed by the majority of respondents (Table 2). Almost all respondents confirmed that the fertility of their cultivated land was very low compared to the situation forty years previously. They have characterized the low soil fertility as resulting in low plant performance and low yields even during a good rainy season. Farmers have different farm plots and have also categorized the land among their holdings as fertile, moderate and not fertile. They have recognized that soil fertility often decreases with growing distance from their homesteads. They have also grown different types of crops, and they manage the land according to the fertility of the soils. The land around homesteads is fertile due to the application of large quantities of manure in order to grow enset there. Hence enset groves often surround the houses in the highlands. The farm plots which are found at the farthest distance from the houses are marked by poor soil fertility and are often used to grow wheat. Moreover, some farmers have also commented that in the past a small quantity of manure application enabled them to produce sufficient yields, while at present the amount of manure applied to the land should be high in order to get viable yields. The main reasons perceived by farmers for the decline of soil fertility were a shortage of manure and uninterrupted cultivation, leading to an abandonment of fallowing practices. Farmers stated that soil erosion was also a factor for the decline of soil fertility, as it caused removal of fertile surface soil. However, farmers were not aware of soil acidity, which is a serious problem that affects agricultural production in the area (Haile and Boke 2011).

Table 2: Farmers´ perceptions of soil fertility loss*

Perception of soil fertility loss % of respondents	Upper watershed % of respondents	Middle watershed % of respondents	Lower watershed % of respondents
Awareness of soil fertility as a problem			
Yes	87	78	32
No	13	22	68
If yes: How serious is the problem?			
High	95	87	18
Medium	5	17	33
Low	0	6	49
Soil fertility changes observed over the last 40 years			
Decreasing soil fertility	97	98	41
Increasing soil fertility	0	2	7
No significant change	3	0	52
Perceived indicators of soil fertility			
Reduced yield	96	98	82
Crop performance	91	89	53
Plant with yellowish colour	83	87	37
Mineral fertilizer is required	86	84	53
Perceived reasons for low soil fertility			
Soil erosion	77	52	31
Uninterrupted cultivation (no period of fallowing)	86	87	61
Low amount of manure application	92	91	56
Decline in crop rotation	74	80	22
Crops residues and dung for fuel	7	4	0

wood			

* Percentage does not add up to 100 because of multiple responses.

On the other hand, about 68 % of the respondents thought that there is no fertility problem in the lowlands. This is in line with the fertile nature of the prevailing soil, a Fluvisol. It is characterized by high nutrient status and high soil water retention capacities and is thus suitable for crop cultivation. Cultivation started in the lowlands during the 1960s, unlike in the highlands where it has been practiced for centuries. However, the dominant problem that deleteriously affects the soil quality of the area is salinization, as expressed by the farmers. This problem is mainly derived from ascending ground water in silty and clayey soils situated in the surroundings of the lakes and the floodplains of the lowlands, mainly as a result of the lack of effective drainage systems. However, the farmers did not note the causes of salinization.

3.3 Grazing land deterioration

Livestock tending is the main integral part of the agricultural system in the study area. There are several sources of cattle feed. The principal sources are common grazing land, which is mostly found on the summits of the mountains in the highlands and along the lakeshores in the lowlands, and pastures within woodlots and forest. Other pasture sources, such as fallow land, cultivated land after harvest, marshland, market places and the borders of roads and paths, are also important sources. Stall feeding is common for milk cows, for fattening and cattle prepared for sale or slaughter. Chopped enset leaves and grasses from marshland are mainly used for stall feed. The solid remains of local beer are used for sheep fattening.

The deterioration of grazing land was the most widespread problem as expressed by 93% of the respondents of the survey (Table 3). Among these respondents, 74% reported that the problem of grazing land deterioration was severe, while 15% stated the problem was moderate. Nearly all surveyed farmers recognized the dynamics and were aware of the increase in the problem over the last forty years. In the lowlands, however, the problem of a lack of grazing land was not significant compared with the highlands, as demonstrated by the interviewed farmers. 45 % of the respondents in the lowlands mentioned the severity of the problem, compared to 89 % in the highlands (high and middle attitudes).

Shortage of grazing land, inadequate feed supply, and poor quality of grass were the most often mentioned indicators for the deterioration of grazing land. Nearly all respondents claimed that a large proportion of grazing land was converted to cultivated land and consequently a grazing land shortage had occurred. In the past, almost every farmer had possessed his own grazing land to feed cattle. However, at present only a few farmers have private grazing land, and the majority of farmers converted their grazing land to cultivated land. Farmers could categorize the quality of the grazing land based on the color and height of the grass. They categorized green and tall grass sites as good quality land while short and brown grass sites were evaluated as poor quality land. As reported by farmers, the community grazing land has been the most deteriorated pasture land, especially during the dry season. However, farmers did not recognize soil degradation in the grazing land and the impacts of overstocking on herbaceous plants inside the forests. However, high livestock stocking, particularly of sheep, inside the forest, exerts tremendous pressure on soil deterioration and herbaceous plants.

The majority of respondents (87%) in the highlands stated that conversion of large grassland areas to cultivated land was the main cause of the shortage of cattle feed. Such a conversion at a large scale also occurred in the 1960s as reported by Jackson (1967). Currently, large areas of communal grazing land have also been converted to cultivated land in order to distribute the land to landless people. This is also reported by various studies that were conducted in the area (Ogato 2005). The principal reasons for the conversion of grazing land to agricultural land were population increase and the decline of agricultural production as expressed by the informants. Furthermore, large areas which were used for grazing in the past were afforested – another cause of the shortage of grazing land. The problem of grazing was exacerbated by forestland on steep slopes where exotic trees, predominantly eucalyptus, grow, which prohibits the growth of grass.

Table 3: Farmers' perceptions of grazing land deterioration*

Perceptions of grazing land deterioration	Highland (Doko Mesho) % of respondents	Mid altitude (Dorze Belle) % of respondents	Lowland (Chano Chelba) % of respondents
Awareness of grazing land deterioration			
Yes	96	98	85
No	3	2	5
If yes: How serious is the problem?			
High	87	90	45
Medium	9	9	53
Low	4	1	29

Changes observed in grazing land over the last 40 years			
Increased deterioration	99	100	98
Decreased deterioration	0	0	0
No significant change	1	0	2
Perceived indicators of grazing land deterioration			
Scarcity of grazing land	93	96	69
Overgrazing of pastures	87	92	78
Insufficient feed	88	89	53
Lack of alternative feed	85	78	46
Quality of feed	75	74	57
Grazing land degradation (soil erosion)	16	21	27
Perceived reasons for grazing land deterioration			
Conversion to agricultural land	75	69	74
Grazing land used for afforestation	53	65	32
Increased number of cattle	32	31	82
Drought	25	26	42
Increased human population	67	71	73
Poor management of community grazing land	41	53	62

* Percentage does not add up to 100 because of multiple responses.

The shortage of grazing land that resulted in feed shortage and the decline in the quality of feed has caused an intensive reduction of the number of cattle in the highlands. Besides, it resulted in an important change: people now raise sheep instead of cattle. Sheep browse all available leaves in the forest; their feed requirements are lower than those of cattle. However, sheep as a browser have negative impacts on biodiversity, which is not recognized by farmers. Despite the decline of the extent and the quality of grazing land, the number of livestock increased in the lowland due to the impact of animal health services (vaccinations and treatments), particularly the disappearance of trypanosomes. The availability of grazing land in the lowlands is better than the highlands.

3.4 Deforestation

The result of satellite image interpretation depicts that forest accounted for 35.8%, 32.8 and 27.7 % of the investigated area in the years 1986, 2006 and 2017. Table 4 and 5. Figure 4 and 5. While crop land increased from 21.1 % to 26.9%.

Table 4 Land use/Land cover Change in Chencha-Arba Minch Watershed during 1986 - 2017

VALUE	1986		2000		2017	
	Ha	%	Ha	%	Ha	%
Water body	279.7	0.4	279.7	0.4	279.8	0.4
Forestland/Plantation	26849.6	35.8	24598.9	32.8	20796.6	27.7
Grassland	24343.6	32.5	26687.7	35.6	21449.4	28.6
Bareland	7442.8	9.9	7576.6	10.1	10205.2	13.6
Cropland	15843.4	21.1	14825.3	22.0	20156.0	26.9
Builtu-area	244.5	0.3	1035.5	1.4	2093.7	2.8
Total	75003.7	100.0	75003.7	100.0	74980.6	100.0

Table 5 Land use/Land cover Change in Chencha-Arba Minch Watershed during 1986 - 2016

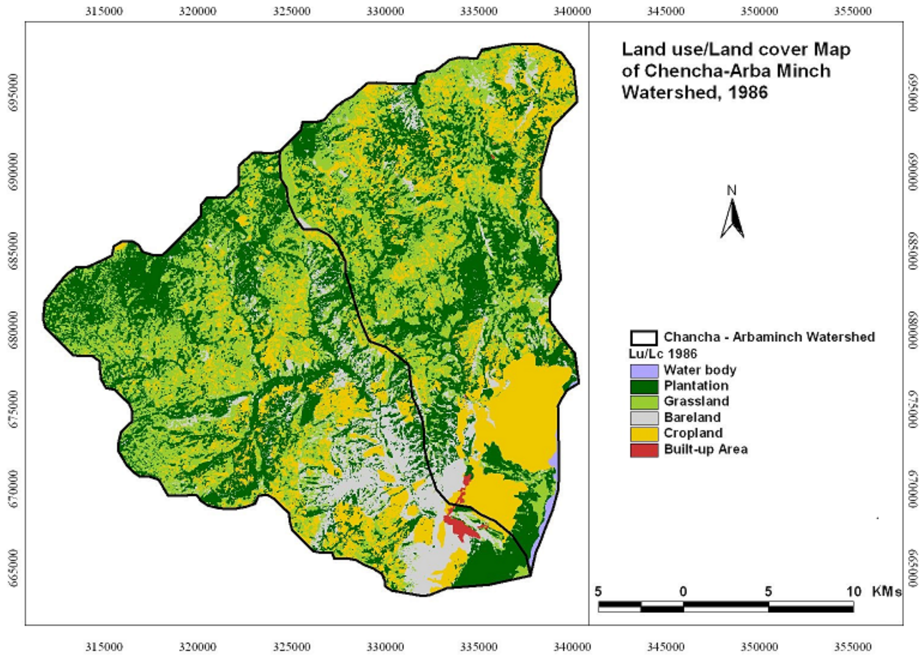
VALUE	1986 - 2000		2000 - 2017		1986 - 2017	
	Ha	%	Ha	%	Ha	%
Water body	0.0	0.0	0.1	0.0	0.1	0.0
Forestland/Plantation	-2250.7	-8.4	-3802.3	-15.5	-6053.1	-22.5
Grassland	2344.1	9.6	-5238.3	-19.6	-2894.2	-11.9
Bareland	133.7	1.8	2628.7	34.7	2762.4	37.1
Cropland	-1018.1	-6.4	5330.6	36.0	4312.5	27.2
Builtu-area	790.9	323.4	1058.2	102.2	1849.2	756.2
Total	0.0	0.0	-23.1	0.0	-23.1	0.0

The downward trend in forest cover is a widespread phenomenon in subsistence agriculture, characterized by an increase in the demand for cultivation land and fuel wood. This result is also in line with the reports of various studies which were undertaken in different parts of the country.

For example, Dessie and Carl (2008) have demonstrated a decline in forest extent in the Awassa region, southern Ethiopia, from 16 % to below 3 % from 1972 until 2000. Zeleke and Hurni (2000) have revealed a considerable decline of natural forest extent in Denbecha, Gojam region, from 27% in 1972 to below 1 % in 1997.

The above satellite image interpretation is also in line with the household survey. A large proportion of interviewed farmers (57%) acknowledge the problem of deforestation. Among these respondents, 64% conveyed the severity of the problem. The farmers were asked if they had noticed the rate of changes concerning the extension of forest clearance, particularly in the last forty years. In this period two regimes changed land-use and land tenure radically. 56 % of the respondents expressed that deforestation increased at a high rate. In our discussion with old people, they also pointed out that most of the land, especially the hilly mountain area, was covered by forest in the time of their parents. However, at present these areas have been brought under cultivation. Farmers are also aware of the increased plantation of forests and household tree plantation over the past three decades. They did not only recognize the changes in the size of forest cover, but they are also aware of existing forest deterioration. They described how sunshine could not be seen inside the forests, along with the lakeshores for example, in the past but today the sun may heat even the soil surface inside the forest, proving the severity of forest degradation. Furthermore, farmers recognized endangered tree species. They reported that *Cordia africana* and *Aeschynomene elaphroxylon* are tree species which are under threat of disappearance.

The decline of forest cover is a result of the significant changes in farming land expansion (as expressed by 97% of the respondents) along with increasing fuel demand (83% of the respondents) and settlements (56%). They mentioned that the main reasons for agricultural land expansion are low agricultural production and population increase. An increase in agricultural land at the expense of forestland, particularly during the last fifty years, was also a widespread phenomenon in different parts of Ethiopia, as reported by various studies (e.g. Zeleke and Hurni, 2000; Dessie and John, 2007). Moreover, fuel wood is the main source of energy for rural people and the surrounding urban population of Arbaminch and Chencha towns. These increasing demands have in turn led to a shortage of fuel wood; subsequently, the people have travelled over long distances to collect wood. In particular, women who are responsible for wood collection have to walk for hours to collect it. This is also another hardship for the people. During the last five decades, settlement and agricultural practices in the lowlands have also resulted in massive forest clearance.


Land use/Land cover Map
of Chencha-Arba Minch
Watershed, 1986
N
Chancha - Arbaminch Watershed
Lu/Lc 1986
Water body
Plantation
Grassland
Bareland
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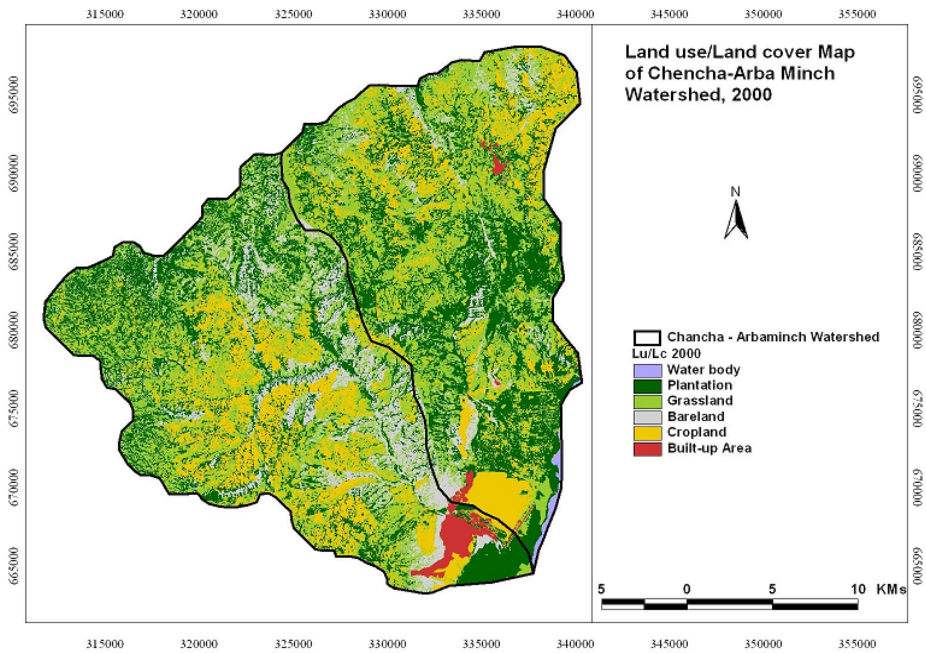
Land use/Land cover Map
of Chencha-Arba Minch
Watershed, 2000
N
Chancha - Arbaminch Watershed
Lu/Lc 2000
Water body
Plantation
Grassland
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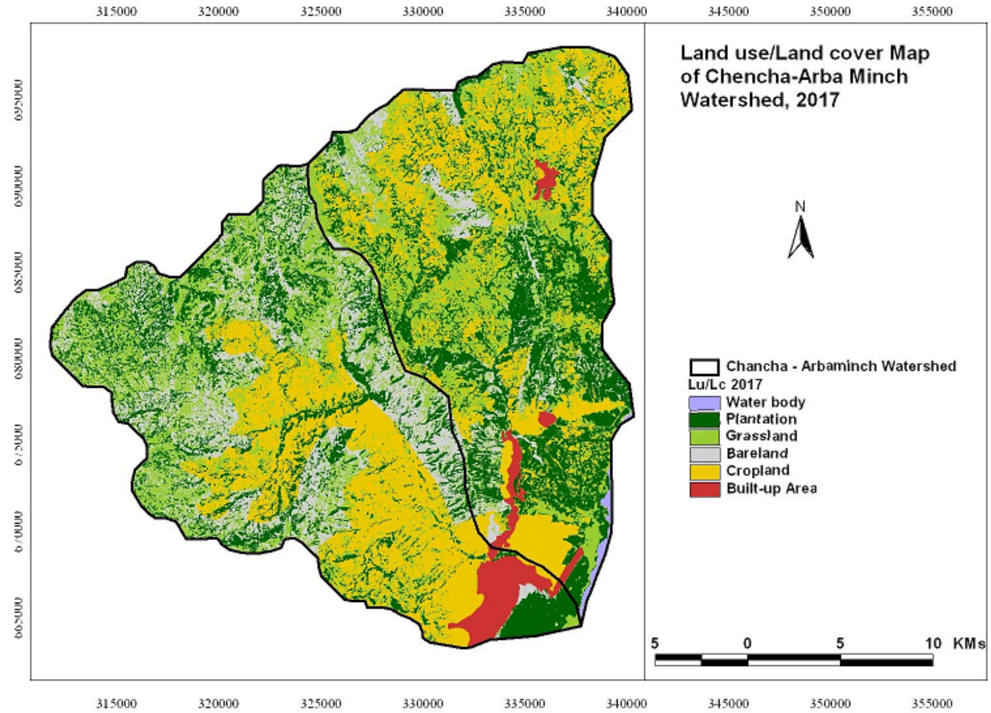
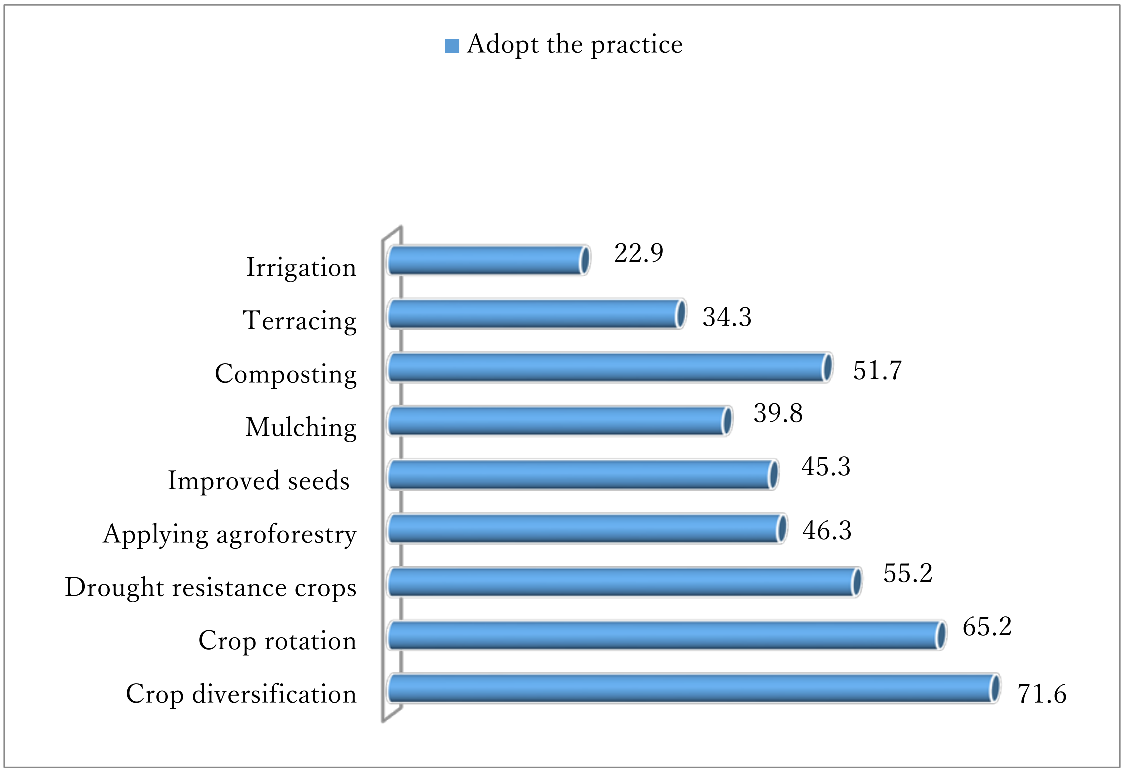


Chapter Four

Watershed Management Interventions

4.1 Types of watershed management practices

The most commonly practiced watershed management practices in the study area are portrayed in Figure 8. These major ones are terracing, composting, mulching, improved seeds, agroforestry, drought resistance crops, crop rotation, and crop diversification. Among the watershed practices, crop diversification received a high priority among rural farmers (71%). This was followed by other practices such as crop rotation (65.2%) and uses of drought resistance crops (55.2%). Irrigation received the lowest priority as 23 % of the respondents reported having adopted it. As it is revealed from key informant interviews, utilizing crop diversity ensure food security, resilience to climate change and minimize the adverse effect of mono-cropping, especially the build-up of pests and diseases. Nowadays, crop pests and diseases were critical challenges for rural subsistence farming. Therefore, crop diversification by popularizing of new crops and crop varieties is acknowledged for sharing of the total risk of crop failure.



4.2 Characteristics of watershed management practices

Agronomy practices

Drought resistant crop -Enset *(*Ensete ventricum)

Enset is the center of agricultural production in the study area. Sometime in the remote past, the enset plant was first domesticated and used as a staple food in Southern Ethiopia in general and in the study area in particular (Westphal, 1975; Cartledge, 1995). It also has cultural and social significance (Olmstead, 1975). Hence, the region is labelled as an enset culture area, and the farming system is also known for its enset planting complex (Amare, 1980).

An enset grove planted near homesteads is a widespread plantation pattern in the area. Enset grows with coffee and cabbage at an early stage. It requires fertile and deep soil. Garden land is usually set aside for enset cultivation as its fertility is maintained by applying large quantities of manure. Moreover, a house is positioned in such a way that the urine of the cattle, which are held in the house, drains directly into the surrounding home garden to enrich the fertility of the soil. Furthermore, home gardens are the areas least affected by soil erosion in comparison with fields outside the compound due to the presence of plant cover by enset and trees. Last but not least, growing enset in gardens close to houses is also significant for harvesting, processing and the timely transportation of the enset products with minimum labour. Enset harvesting can be carried out at any time of the year except during the rainy season, so people frequently harvest enset when others crops have been consumed. The roots of enset (which include the pseudo stem) is processed, wrapped in large leaves, and then put in pits near the farmhouses and buried in the garden soil. This is very important in order to reduce post-harvest loss, which is common for other crops across different areas of Ethiopia.

Enset provides a higher portion of foodstuffs per unit area than most cereals. Furthermore, enset is also known for its high starch content, yielding 20 million calories per hectare (Olmstead, 1975). High yields per unit area of enset also partially contribute to the support of a dense population in the southern region. The other salient feature of enset is its drought resistance as a result of its deep roots and its capacity to store water in tuberous roots and pseudo-stems. For this reason, it is known as a plant against drought (Shack, 1966) and the area is one of the least affected by drought in Ethiopia.

Enset is also widely used for other purposes (Olmstead, 1975). It is used as wrapping paper, washing detergent, and for the production of strings, umbrellas, seats, and hats. The leaves of enset are also an important animal fodder. Furthermore, enset plays a very significant role in maintaining high environmental quality. It prevents soil from erosion as the leaves capture moisture and the stems lower the run-off. The leaves and residues of enset are integrated into the soil to reach or to maintain high fertility. Enset also serves as a wind breaker and as a shade for other crops which are intercropped with enset.

However, the extension of the area devoted to enset is declining. In the 1960s, the area used to grow enset reached about 16% of the total cultivated land of the highlands (Jackson et al., 1969). At present, enset acreage comprises about 10% of total acreage. According to surveyed households, the main reasons for the decrease of enset cultivation are a decline of soil fertility due to low amounts of manure application, a scarcity of land which forced farmers to cultivate crops with short growth periods, and diseases. Other enset growing regions of Southern Ethiopia, including Sidama, Hadyia, and Wollayita, have also experienced a similar decline of enset cultivation due to land shortages and substitution of enset by cash crops (Tesegaye, 2002).

Crop diversification and intercropping

Growing several varieties of crops (crop diversification) was one of the salient features of the agriculture practices in the area over a long period. In the lowlands and at middle altitudes, Belachew (2002) identified about 133 different plant species of which 48 species are used as food for humans. Jackson et al. (1969) also reported a wide range of grains, cereals, root crops, vegetables, and stimulant crops that grow in different agro-ecological regions. The varieties of crop species are also high in the area, For instance, Samberg (2010) recognized about 65 varieties of barley while Olmstead (1975) observed about 34 varieties of enset. Local farmers also reported that some of the varieties of barley were locally domesticated. Enset is endemic to the area (Cartledge, 1995).

Farmers use various methods to grow these varieties of crops. Intercropping (growing of different crops on the same field in the same season) is one of the systems. For instance, farmers grow barley together with kolto, beans, and peas. They also grow enset with taro, coffee, and cabbages. Intercropping has been practiced in the area due to the various advantages that overweigh mono-cropping systems in small holding agriculture. The main benefit is that self-sufficiency can be achieved with farming different types of crops.
Moreover, it also reduces or avoids the spread of calamities, since some crops are more resistant to drought while others are less susceptible to the impacts of outbreaks of various pests and crops diseases. The practice of intercropping is also vital in order to grow various crops on sites with different topographies and climates that suit them, thereby maximizing the efficient use of available resources. Furthermore, different crops have different harvesting cycles. Therefore, the people on the land have been successful in feeding a dense population and in overcoming food shortages (Rahmato, 2009).

Crop rotation

Crop rotation is a temporal system of growing different crops sequentially on the same piece of land. Crop rotation has significant benefits for restoring and maintaining nitrogen since leguminous plants are included in the rotation. Legume plants store nitrogen-fixing bacteria in their nodules. They are also important for reducing erosion by covering the land surface and increasing the organic matter content of the soil. Ultimately, the productivity of the soil is enhanced.

Crop rotation is one of the methods used by a large number of farmers, about 44 % of the surveyed households, in the area to maintain soil fertility. It is characterized by the cultivation of barley and wheat in the first two or three years, and then afterwards peas and beans are grown. Besides crop rotation, the farmers also practice mixed cropping, for example, cereals (barley and wheat) grown together with beans and peas.

However, the frequency of crop rotation is decreasing because of the scarcity of cultivated land. People prefer to grow staple food crops such as barley, wheat, and enset. Also, they also want to maximize the benefits they get from the land by growing cash crops such as apple and banana. So they devote their piece of land to growing only these crops. They only mix or rotate with beans and peas when they feel the soil fertility has steeply declined and ceased to sustain plant growth.

Terraces

The traditional terrace, *kella*, was built over generations based on the farmers' perception of the problems, as well as their knowledge, skills, energy, and survival strategies. The main purpose of the traditional terraces is to keep the soil from erosion by water and to reduce the negative effects of surface runoff. Among the surveyed households, about 51 % reported that they have been employing *kella*. In particular, terraces are most widely practiced (by 82% of the surveyed farmers) in the middle altitude, *Belle* area, because of the dominant steep slopes and an abundance of stones. However, the soil was also used to construct terraces.

Kellas are very strong, and they last for a long period (a minimum of eight years or more without maintenance) as expressed by farmers. These terraces are maintained when they are broken or sometimes washed down by high amounts of runoff, which usually occurs in April and October. The maintenance is carried out by groups of people. Also, cattle deteriorate the terraces as they graze on the terrace fields after harvest (they are common property for cattle grazing after harvest). There are usually minor damages to terrace walls due to grazing activities, and thus the individual farmers take care of and maintain them during the ploughing time. Labor requirements in constructing and maintaining terraces are very high. There is sometimes a need to bring stones and boulders over long distances. This problem is exacerbated when labour shortages in the area occur due to the migration of persons to other places in search of different jobs. The old people said that their parents worked hard to maintain the terraces, harder than they have done. The old people also reported that the maintenance of terraces is a declining trend, owing to less effort and time devoted to them by the younger generations.

Moreover, the agricultural bureau of the *Wereda* also introduced terracing (conventional terraces) in the area in the early 1970s. However, these terraces are not popular among the farmers, as 75 % responded. Frequently cited reasons for the poor performance of these terraces are their labour intensive construction and maintenance, that space is taken away from agricultural production, the problems of ploughing narrow terraces, and rodents or other pests harboured by terrace walls. Additionally, the structural design problems of the conventional terraces and the top-down approaches to the design and implementation of the plans are other factors. Hence, the unpopularity of conventional terraces is expressed by not maintaining and eventually demolishing them. Some informants even reported that in one specific area the people had demolished seven times the conventional terraces constructed during the forty years of their use. Despite these problems, conventional terrace construction has continued to date instead of evaluating their performance and identifying the reasons for the failures. There is hardly any attempt by planners to evaluate the performance of conventional terraces. Mistakes in the adoption of terraces were also reported for different places in Ethiopia (e.g., Bewket 2007; Admassie 2000).

Agroforestry

Growing trees on farm land is an ancient skill for millennia. Farmers have nurtured trees on their farm, pasture lands and around their homes. This is why agroforestry is considered as ancient land-use farming practices around the world. It has been estimated to exist for more than 1300 years (Omarsherif and Daniel, 2017).

Trees are at the center of agricultural practices in the area and thus planting of trees has been a widespread practice for the majority of farmers over a long period. The community also acknowledges possession of large areas of trees as prestigious and a sign of wealth. Trees are planted on land designated for plantations, in the farm fields, and around homesteads

The predominant farmers have assigned small plots of land for the planting of trees. These lands are usually found on degraded steep slopes, which are marked by poorer soil quality. They are abandoned for cultivation and are no longer used to grow crops. Farmers also plant trees along the sides of paths and road borders, as well as along and inside the gullies.

According to the informants, the dominant types of planted trees are Eucalyptus (according to 98% of respondents) and Juniperus (according to 46% of respondents). The eucalyptus tree was introduced to the area around the middle of the twentieth century according to the informants. The members of a British Expedition, who travelled to the area in the 1960s, also observed eucalyptus at most farmers' homesteads and along the roads (Jackson et al. 1969).

At present, the area cover of eucalyptus has increased compared to the past, as expressed by the farmers. This is because of large-scale plantations of eucalyptus trees at the level of individual farms in the mid 1980s. At that time farmers were encouraged by the then government through the supply of free of charge eucalyptus seedlings. Moreover, the people have also been aware of the various benefits of eucalyptus compared to the indigenous trees; above all, the short period of harvest – eucalyptus are coppiced every third year at the earliest. Additionally, eucalyptus requires minimum care and grows in poor environments. At present, eucalyptus trees are also increasingly grown in areas where the land was abandoned due to poorer soil quality and soil erosion, particularly on steep slopes. Eucalyptus trees are thus an important source of wood for fuel, for construction of houses and sale. However, the people are also aware of the disadvantages of planting eucalyptus trees. Among others, they noticed the high water requirements, depleting soil nutrients and suppression of grass growth, which in turn is a limitation for cattle feed.

Long-lived trees are also common in the farm fields and around homesteads, showing that trees are not only growing on the abandoned farmland. Also, trees are also planted along borders to mark the boundaries of properties and also boundaries of farmland and grazing land. The most common tree species include *Juniperus procera*, *Erythrina abyssinica, Hagenia abyssinica, Croton macrostachyes, Euphorbia spp., Terminalia brownie, Olea africana, Ficus soria, Cordia africana, Sterculia africana*, and *Acacia abyssinica*. Also, *Moringa oleifera* and *Coffea arabica* are also planted in large numbers, mainly around homesteads.

Trees have various economic, environmental and social significances for the people. Namely, they are important for daily diets (e.g., moringa), as sources of cash crops (e.g., coffee) and also they provide fuel wood. Trees are also important for beekeeping (apiculture). These trees are also a source of income during crop failures; cash from the sale of wood is used as insurance. Along with their use as fodder for livestock, trees also serve as shade during the high sun period when the land is used for pasture. The people are also aware of the environmental significances of trees, such as maintaining soil fertility (e.g., Erythrina, Hagenia, and Croton) and as barriers against surface runoff and soil erosion.

Furthermore, trees have traditional religious significances, namely they are a place of spirit dwelling and sacrifice (Cartledge 1995). Juniperus is considered as important for rituals and wooden statues. This all clearly implies that trees are at the center of agriculture with additional wider social significances.

Chapter Five

Impacts of Watershed Management on environment and food Security

5.1. Effects of Watershed Management Practices on Environment - Farmers' perspectives

As it is indicated in Figure 9, the study revealed that 92% of smallholder farmers are positively perceived as WSM practices can overcome several environmental problems such as soil degradation, water resource deterioration, climate change, and variability. Survey results and FGD outcomes in all the study kebeles indicated that most farmers were willing to adopt the WSM practices. Those who were willing to adopt the practices indicated that increasing yield and soil fertility improvement as the main driving force for their adoption demand. Such results indicate the importance of an understanding the need of the rural farmers and their perception before the implementation of WSM interventions. Such results are in line with other studies (Gwambene et al.,2015; Eric, 2012). The studies suggested the importance and needs for considering local community perceptions in planning for intervention. According to these studies, local communities have knowledge developed for a long time in their surroundings through experience and practices which are important in developing adaptation and mitigation strategies. Consideration of their knowledge and experience is important for up and out scaling and sustainability of the interventions.

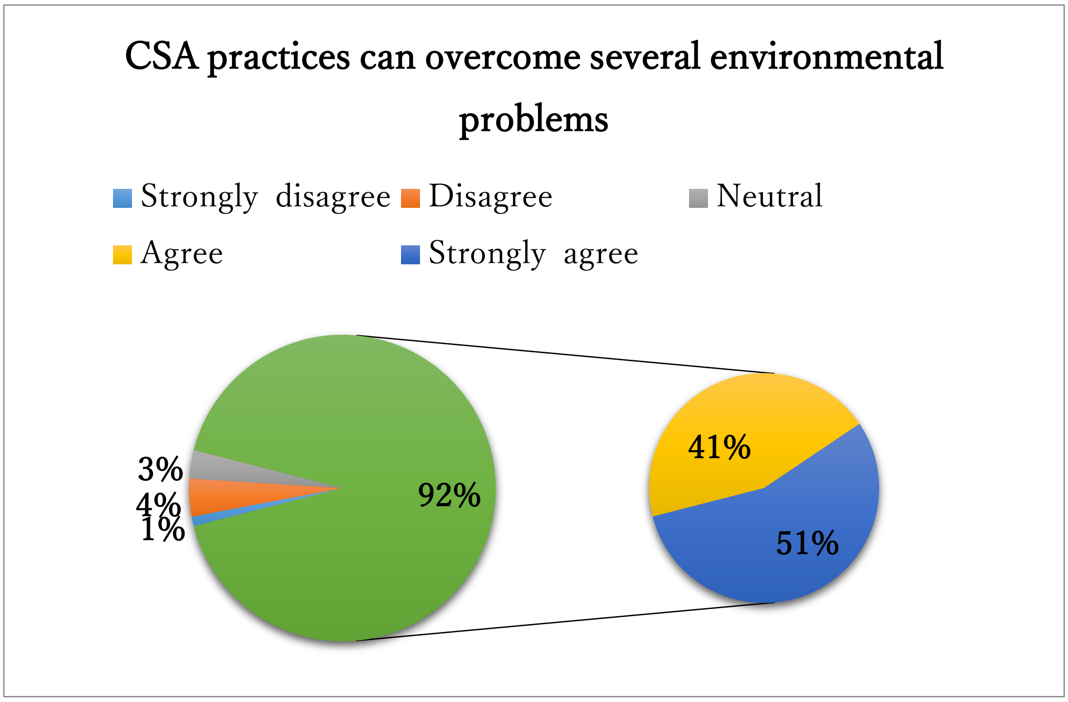


Figure 6. Perception results on WSM practices

Environmental concern for the next generation and application of compost received the highest consideration among smallholder farmers (Table 10). Farmers perceive application of compost as the best soil management practice which improves soil fertility. The respondents perceived that natural resources should be protected both for the present use and for future generations even if it leads to farmers incurring cost in the short run. Cultivation of legume crops and crop diversification was ranked third and considered as one of the best soil erosion protection practices. The results are consistent with that of Erich (2012). Minimum tillage was ranked fourth as a practice that helps to reduce soil erosion disturbance and exposure. In the case of Ethiopia, land preparation is mainly carried out with a view of getting rid of weeds, but it also helps in breaking compacted soils and improves moisture infiltration. However, moisture infiltration is much better in soils that are less tilled but not compacted by the effect of overgrazing.

Contrary to Gwambene et al. (2015) and Eric (2012), crop rotation was perceived being least compare to other soil and water management practices. Most of the time farmers prefer to plant high value crops continuously. Poor farmers do not incline to rotate by low market value crops.

Table 10. Farmers' view towards watershed management practices

Statement	Mean	Std. Deviation	Rank
Natural resources must **be protected** for the next generations	4.66	.652	1
Soil fertility can be improved by application of compost	4.66	.476	2
Leguminous species and crop diversification can protect soil from erosion	4.55	.556	3
Minimum tillage reduces soil erosion, disturbance and exposure	4.53	.700	4
Growing multipurpose trees and shrubs in steeper slope land can reduce soil erosion and improve soil fertility	4.50	.657	5
I have to protect natural resources even if it will lead to incurring losses in the short run	4.49	.530	6
Mulching or Retaining crop residues reduce weed growth, reduce moisture loss and reduce erosion by water and wind	4.38	.726	7
By storing water, farming operation can be done during the dry season	4.36	.808	8
Soil fertility can be improved by the application of green manure	4.33	.810	9
Boundary planting and windbreaks can protect soil erosion and improve water retention of the soil	4.31	.725	10
Growing trees in association with crop production generate additional income and able to improve my livelihood	4.30	.923	11
Drought resistance crops are selected in low rain fall season	4.26	1.031	12
Terraces can improve the water retention capacity of the soil	4.23	.860	13
Slope stabilization improve the water availability in the soil	4.23	1.009	14
Intercropping can improve soil fertility	4.21	.962	15
Alley cropping provides nutrients specially nitrogen to the soil	4.20	.764	16
Crop rotation reduces soil degradation	4.04	.964	17

(Source: computed from field data)

5. 2. Food security effects of the adoption of WSM practices - synthesis

In the mid 1970s and 1974s world food conference was held to solve the problem of world food crises and major famines around the world. Food security and insecurity are the terms used to describe whether or not households have access to sufficient quality and quantity of food. With progress in time and severity of the problem, food security issues gained prominence and great attention at the global, national, household and individual levels. Such progressive work by scientists led to redefining the scope and depth of the food security concept.

Food security is a concept that has evolved considerably over time, and its definitions developed and diversified by different researchers, scholars, and organizations. There are approximately 200 definitions and 450 indicators of food security. Food security is such a complex notion that it is virtually impossible to measure it directly, and a variety of proxy measures have been suggested. Consumption and expenditure, nutritional status, coping strategies are the most frequently used measures of food security.

Without much change in the basic concepts, different institutions and organizations define food security in different ways. According to [FAO, 2010] food security is a situation that achieved at the individual, household, national, regional and global levels when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets

Based on the above FAO definition [2010] of food security, it was developed four main ***dimensions*** of food security which are food availability, food accessibility, food utilization, and stability.

The major benefits of the WSM, as witnessed by different literature, are resulting in making higher and more stable crop yields and subsequently enhanced livelihoods and food security. In this section, we summarize on some of the practices of the WSM on crop yield as follows:

Agroforestry

Agroforestry encompasses a wide range of land use practices (e.g., farming with trees on contours, bush and tree fallows, establishing shelter belts, and riparian zones/buffer strips with woody species) in which woody perennials are deliberately integrated with crops, varying from very simple and sparse to very complex and dense systems. This improves land productivity by providing a favorable microclimate, permanent cover, improved soil structure and organic carbon content, increased infiltration, reduced erosion, and enhanced soil fertility ((Lal, 2004, Schroth and Sinclair 2003; Garrity 2004).

Cover crops

Continuous cover crops can reduce on-farm erosion nutrient leaching and grain losses due to pest attacks and build soil organic matter and improve the water balance, leading to higher yields (Lal 2008; Olson et al. 2010). For example, Kaumbutho and Kienzle (2008) showed that maize yield increased from 1.2 to 1.8–2.0 t/ha in Kenya with the use of a mucuna (Velvet Bean) cover crop using case studies conducted from 2004 to 2007. Pretty and Hine (2001) also found that farmers who adopted mucuna cover cropping benefited from higher yields of maize with less labor input for weeding (maize following mucuna yields 3-4 t/ha without application of nitrogen fertilizer, similar to yields normally obtained with recommended levels of fertilization at 130 kg N/ha) based on 208 projects conducted between 1998 to 2001.

Crop rotations and intercropping with nitrogen-fixing crops, such as groundnuts, beans, and cowpeas will enhance soil fertility and enrich nutrient supply to subsequent crops, leading to increased crop yields (Woodfine 2009). For example, Hine and Pretty (2008) showed that in the North Rift and western regions of Kenya maize yields increased by 71 % and bean yields by 158 % in 2005/

Organic fertilization (Compost)

Adopting organic fertilization (compost, animal, and green manure) is widely found to have positive effects on the yields. For example, Hine and Pretty (2008) showed that maize yields increased by 100 % (from 2 to 4 t/ha) in Kenya in 2005; Parrot and Marsden (2002) showed that millet yields increased by 75-195 % (from 0.3 to 0.6–1 t/ha), and groundnut by 100–200 % (from 0.3 to 0.6–0.9 t/ha) in Senegal in 2001; and Scialabba and Hattam (2002) showed that potato yields increased by 250–375 % (from 4 to 10- 15 t/ha) in Bolivia between the early 1980s and 2000s. Edwards (2000) showed that in the Tigray province of Ethiopia, composting led to yield increases compared with chemically fertilized plots: barley (+9 %), wheat (+20 %), maize (+7 %), teff (+107 %), and finger millet (+3 %) based on projects conducted between 1996 and 2000.

Chapter Six

Watershed Implications on the enhancement of the climate changes

6.1 Introduction

The impacts of climate change on agriculture are expected to be widespread across the globe, although studies suggest that African agriculture is likely to be most affected due to heavy reliance on low-input rain-fed agriculture and due to its low adaptive capacity (NMA, 200). It was also stated that Sub-Saharan Africa is expected to be affected worst, given that temperature is generally already high, and most of the region’s inhabitants depend for their livelihoods on rain-fed agriculture.

The National Metrological Agency (2007) revealed that in Ethiopia climate variability and change in the country is mainly manifested through the variability and a decreasing trend in rainfall and increasing trend in temperature. Besides, rainfall and temperature patterns show large regional differences. For the IPCC mid-range emission scenario, the mean annual temperature will increase in the range of 0.9 -1.1 °C by 2030, in the range of 1.7 - 2.1 °C by 2050 and in the range of 2.7-3.4 °C by 2080 over Ethiopia compared to 1961-1990 normal. A small increase in annual precipitation is expected over the country. Other sources of data have also substantiated the variability of climate and its trends in a somewhat similar way. Historical climate analysis for Ethiopia indicates that mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade. The increase in temperature in Ethiopia has been most rapid in June, August, and September at a rate of 0.32°C per decade. Rainfall is historically highly variable, and there is no clear trend in the amount of rainfall over time. Mean annual temperature is projected to increase by 1.1 to 3.1°C in the 2060s, and 1.5 to 5.1°C in the 2090s. Under a single emissions scenario, the projected changes from different models span a range of up to 2.1°C (McSweeney et al., 2008).

The significant range between these climatic condition highlights the uncertainty in future projections for climate change in Ethiopia. Clearly, Ethiopia is highly vulnerable to current variability, and there are also indications that climate change will increase rainfall variability which will likely increase losses from rain-fed agriculture. The ecosystems of the country, as well as its community, are highly exposed to climatic variability. Ethiopia is vulnerable to climatic variability owing to its low adaptive capacity accountable to the low level of socioeconomic development, high population growth, inadequate infrastructure, lack of institutional capacity and high dependence on climate sensitive natural resource-based activities (Belay, 2016).

Case studies indicate that Ethiopian agriculture is highly vulnerable (with large spatial and temporal variation) to the impacts of climate change because of high exposure and sensitivity of the sector to climate variability and change. It is also because of the low adaptive capacity of smallholder farmers. The vulnerability of the agriculture sectors to impacts of climate change is exacerbated by non-climatic drivers such as inappropriate land use and land degradation, population pressure, subsistence farming, low technological innovation, and application and poverty (Nathnael, 2017).

While agriculture is the sector most vulnerable to climate change, it is also a major cause of climate change, directly accounting for about 14 percent of global greenhouse gas (GHG) emissions, and indirectly much more as agriculture is also the main driver of deforestation and land-use change responsible for Another 17 percent of global emissions. Even if emissions in all other sectors were eliminated by 2050, growth in agricultural emissions in a business-as-usual world with a near doubling in food production would Perpetuate climate change (FAO, 2013).

According to FAO (2016), Ethiopia's annual greenhouse gas (GHG) emissions were estimated at 150 Mt CO2 e in 2010, with 50 percent and 37 percent of these emissions resulting from the agricultural and forestry sectors respectively. In agriculture, livestock production accounted for more than 40 percent of the emissions, while in forestry the main culprit was deforestation for expansion of agricultural percent of forestry related emissions, followed by fuel wood consumption at 46 percent of forestry-related emissions. The major sources of GHG emissions within the agriculture sector of Ethiopia. The largest proportion of emissions results from enteric fermentation, followed by manure left on pasture, both of which are related to livestock production

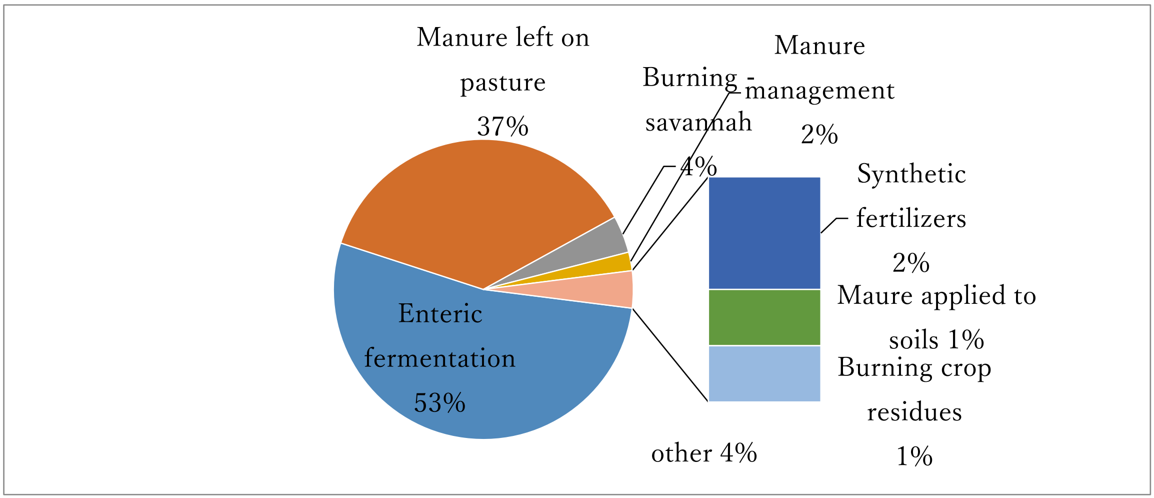


Figure 1. GHG emission source in Ethiopia (Adapted from FAO, 2016)

6.2 Climat Change Mitigation and Agriculture

Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Mitigation, together with adaptation to climate change, contributes to the objective expressed in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC):

Ethiopia's per capita emission of less than 2 ton CO_2 Dioxide equivalent) is low compared to more than 10 ton in the EU and more than 20 ton in the US and Australia. The country's total emissions of around 150 Mt CO_2 e represent less than 0.3% of global emissions. The agriculture sector is one of the major contributors of GHG (Green House Gas) emissions in Ethiopia through the crop, livestock and natural resources carbon footprints (like as a result of soil degradation and land use change from forest land to agricultural land). For instance, there are 50% and 38% GHG emissions from the agriculture and forestry sectors, respectively (FDRE, 2011). Ethiopia intends to limit its net GHG emissions in 2030 to 145 Mt CO_2e or lower. This would constitute a 255 MtCO $_{two}$ e or 64% reduction from the Business As Usual (BAU) emissions in 2030, which would otherwise become 400 Mt CO_2 e with BAU in the same year (Belay, 2016; Nathnael, 2017).

GHG emission has impacted the agriculture sector in a way that rainfall variability and associated yield reductions are estimated to cost Ethiopia around 38% of its potential growth rate and increase poverty by 25% (World Bank, 2006). Since the country's main-stay and/or economy are based on agriculture, climate change could negatively affect agriculture. Thus, it will ultimately reduce GDP by 3-10% by 2025 (Nathnael, 2017). Results show that warmer temperature is beneficial to livestock agriculture, while it is harmful to the Ethiopian economy from the crop agriculture point of view. Moreover, increasing/decreasing rainfall associated with climate change is damaging to both (crop and livestock) agricultural activities.

According to different studies, a variety of mitigation strategies to the immune level of emissions particularly from the agriculture sector (i.e., from the crop, mainly livestock and natural resources) are drawn. Some of the identified mitigation strategies are: reducing expansion of cultivated land through agricultural intensification (increasing productivity by reducing Green House Gas (GHG) emission: conservation agriculture, compost, wise use of inorganic fertilizers, proper crop management); improving animal productivity through breeding; feedlots practice by smallholder farmers; improving feed and feeding management; diversification toward lower emitting animal species (small ruminants); mechanization; manure management; afforestation/reforestation; agroforestry; soil and water conservation and land rehabilitation; and reducing rate of desertification. (Belay, 2016; Nathnael, 2017).

Climate Change Adaptation and Agriculture

Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).

Studies in Ethiopia indicate that, the dominant adaptation methods practised by Ethiopian crop producing farmers include: use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation adoption of mixed crop and livestock farming systems and changing planting dates (Temesgen et al. 2009; Temesgen, 2014; Nathnael, 2017).

Effects of WSM on the mitigation of the CC

Watershed management practices (sustainable land management) deliver significant mitigation co-benefits in the form of removal of atmospheric carbon dioxide by plants and storage of fixed carbon as soil organic matter. Sustainable land management increases and stabilizes soil organic carbon density in the soil, improving its depth distribution and encapsulating it within stable microaggregates so that carbon is protected from microbial processes (Lavelle 2000; Lal 2004).

LULC Change impacts

Converting agricultural land to a more natural or restorative land use essentially reverses some of the effects responsible for soil organic carbon losses that occurred upon conversion of natural to managed ecosystems (Lal 2004).

Agronomy

Improved agronomic practices enhance soil quality and biodiversity, reduce erosion, and increase biomass production. Healthy soil is teeming with life and comprises highly diverse soil biota. The activity of these animals has a strong influence on the soil's physical and biological qualities especially with regards to its structure, porosity, aeration, water infiltration, drainage, nutrient cycling, organic matter pool and fluxes, and improving the soil

organic carbon pool (Lavelle 1997; Lal 2004). Rotations and intercropping with nitrogen-fixing crops enhance biodiversity, the quality of residue input and the soil organic carbon pool. It is well established that, all other factors being equal, ecosystems with high biodiversity absorb and sequester more carbon in soil and biota than those with low or reduced biodiversity (Lal 2004).

Organic fertilization: (Compost)

Judicious nutrient management is crucial to humification of carbon in the residues and soil organic carbon sequestration. Soils under low-input and subsistence agricultural practices have low soil organic content which can be improved using organic amendments and strengthening nutrient recycling mechanisms (Lal and Bruce 1999). This can also lead to decreased nitrous oxide emissions by reducing leaching and volatile losses and improve nitrogen use efficiency (Lal 2004). Manure management can improve soil fertility and enhance carbon storage by increasing biomass and improving soil equilibrium. In general, the use of organic manures and compost enhances the soil organic arbon pool more than the application of the same amount of nutrients as inorganic fertilizers.

Agroforestry

In agroforestry systems, the standing stock of carbon above ground is usually higher than the equivalent land use without trees. Planting trees and bushes increase the carbon sequestered above ground. Agroforestry may also reduce soil carbon losses stemming from erosion, thus improving the soil's organic carbon pool (Lal and Bruce 1999; Lal 2004)

Chapter Seven

Determinants of Farmers' Adoption of Watershed Management Practices

7.1 Introduction

In general, compared to a high positive perception or willingness to adopt CSA practices with actual adoption status, farmers of the study area were by far low adopters. Majority of CSA practices conducted in the study area were practiced by less than half of the rural farmers. Adoption is a mental process that begins when a farmer learns of innovation and ends at the final adoption stage (Rogers, 2003). The behaviour process and effect of an agent depends on the intensity of its perception and attitude. However, positive perception or attitude alone is not sufficient for adoption decision. Other factors should also be considered. The low adoption status of smart climate agriculture was associated with socio-economic, bio-physical, cultural and institutional factors. Basing on key informant interviews and FGD, rural farmers have a number of constraints to adopt and expand appropriate and feasible climate-smart and climate-resilient agriculture practices. Shortage of water and lack of labour to prepare compost, lack of animal feed and fuel wood to apply to mulch, lack of seedlings to promote agroforestry and lack of water, lack of access to credit and lack of training to adopt small scale irrigation are some of the prominent bottlenecks.

Among the watershed practices, adoption of the agroforestry and composting will be affected by a number of physical, institutional and social factors. Studies identified: gender of farmers, land size, level of education, farmers' experience, farmers' association, contact with research and extension, land tenure, agro-ecological zone, distance to nearest center, and farmer's income as influencing factors in adopting agroforestry practices by rural farmers (Gitonga and Mukoya , 2016; Tanga and Amare , 2016).

According to a research conducted at Fogera district of north-western Ethiopia, Age, attitude land tenure security, erosion and training in natural resource management and/ or agriculture affects agroforestry practices significantly. Except for Age, the remaining four factors are affecting the practice positively (Tanga and Amare, 2016). A research conducted by Geremew (2016), at Mecha rural district of Amhara regional state revealed that, being male-headed household, have a positive effect on cash tree adoption.

Similarly, composting is a labour intensive in transportation and application. As a result, the adoption of the composting is mostly based on labour endowments and income levels of the farmers. (Wassie, 2016; Mengistu and Bauer, 2011). Labour availability can be measured as the proportion of household members who contribute to farm work. Using a binary logit, Odendo et al. (2009) found that the proportion of household members available to provide labour positively influenced the adoption of soil fertility management practices.

According to Kilcher (2007), the greatest constraints faced by poor farmers on the road to organic soil management practices such as composting are lack of knowledge, access to markets, certification, agricultural inputs and lack of organization. According to FAO (2013), the global experience depicted that the main constraints of composting adoption are; Cost, limited access to technology and information. However, the specific barriers to adoption of compost and extent of adoption of compost production and usages vary from location to locations (Kassie et al., 2009) due to variation in agroecology, climate, socioeconomic condition, level of training and extension service provided to famers etc. For instance, Kassie et al. (2009) studied the determinants of adoption of compost in semi-arid Tigray region of Ethiopia and reported both plot level and socioeconomic, characteristics are important in adoption decision. According to the authors' young people, households that have access to extension service (aware), availability of sufficient labor in the household, being literate and having enough livestock positively impact the adoption of compost in the study area which is consistent to other results (Wassie, 2016).

Consistent with results from (FAO, 2013; Eric G.,2012; Kassie et al. 2009; Kilcher, 2007), according to Wassie (2016), the most widely recognized and crucial barriers to the adoption of compost by Ethiopian farmers are lack of skills, shortage of ingredients and lack of labour force for compost preparations. Compost production requires some kind of skills and knowledge on methods of compost production techniques which most famers are lacking it. A few farmers are not willing to adopt composting because of offending foul smell released from the oxidation process. In some places, farmers complain that volatile acids and gases released during turning of composts cause a variety of health problems.

This section presents factors that affect farmers' decision to adopt two watershed management practices in Hare-Kulfo Wateshed. South rift valley. The two regressed dependent variables are: composting and agroforestry (Table 11).

Table 11. Descriptive Statistics for the logistic regression model (n=201).

Variable	Mean	Std. Deviation
Adoption of compost	.52	.501
Adoption of agroforestry	.46	.500
Age	47.36	12.086
Sex	.88	.325
Labour force proportion	58.34	22.045
Family size	5.43	1.751
Education	.43	.496
Number of parcels	2.87	.929

Farm size	2.04	.981
Home distance from farm plot	27.89	16.85
Degradation	.35	.478
Home market distance	85.77	29.66
Home main road distance	40.67	31.70
live stock number	3.18	3.83
Off farm income	.40	.492
Extension service	.79	.411
Training	.83	.380
Radio	.49	.501
Weather forecasting	.47	.500
Farmers' field days	.65	.479
Member of organization	.59	.493
Access to credit	.42	.494
Environmental regulation	.67	.473

(Source: computed from field data)

7.2 Analysis of Determinants: Logit Model Regression Results

1 Composing

This section identified the most important hypothesized independent variables that influence farmers' decision to adopt composting in the study area. The dependent variable was either adopting or not adopting of composting. In this case, a farmer who carried out composting practice was considered to be "an adopter". In model diagnostics, the Hosmer and Lemeshow test is used to estimate the good-fit model, and if the p-value is above 0.05 (statistically non-significant) the estimated model has adequate fit, and if the p-value is below 0.05 (statistically significant) the estimated model does not adequately fit the data. In this research, the P-value was 0.983, and the model fit very well (Table 12). The rate of correct model prediction was up to 90.5%. From all sample farmers, the correctly predicted adopters and correctly predicted non adopters of the model were 90.4% and 90.7 %, respectively. In the logistic regression model summary, over all model evaluation (likelihood ratio), statistical tests of individual predictors (Wald statistics), goodness of-fit statistics (R^2) are presented. In standard regression, the co-efficient of determination (R^2) value indicates how much variation in Y is explained by the model. This cannot be calculated for logistic regression, but the model summary table showed the values for two pseudo R^2 (Cox & Snell R Square and Nagelkerke R Square (pseudo R^2)) which try to measure something similar. In the estimated model, pseudo R^2 is 83.7%. It indicates that, of the total variation in the dependent variable, 83.7% was explained by the independent variables.

Out of 21 explanatory variables that were hypothesized to affect farmers' decision to practice composting or not, only 8 of them were found statistically significant (Table 12). These significant explanatory variables include: sex of the household head (DSEX), labour force proportion (LABOR), education level of the household head (DEDUC), average farm distance from home (FRMDIST), number of livestock (DLIVSTOK), extension service contact per year (DEXTSERV), access to weather forecasting (DWEATHER) and being member of rural organizations (DORGANZ). A number of farm plots, average market distance from home, main road average distance from home, having radio and participation in farmers' field day were found to have a positive effect on composting practicing but not statistically significant. On the other hand, age, family size, degradation, training, access to credit and knowledge on environmental regulation were negatively related with composting practicing, but the relation was statistically insignificant.

Table 12. Determinants of compost adoption in Gerar Jarso woreda

Variables	Estimated coefficient (B)	Std.error (S.E.)	Wald Statistics (Wald)	p-value	Odds ratio of adopting Exp(B)
DAGE	-.015	.026	.341	.559	.985
DSEX**	5.156	2.045	6.360	.012	173.487
LABOR**	.041	.017	5.666	.017	1.041
FAMSIZE	-.125	.173	.525	.469	.882
DEDUC*	3.401	.815	17.405	.000	29.994
PLOTNR	.103	.430	.057	.811	1.109
FRMSIZE	-.047	.376	.016	.901	.954
FRMDIST**	-.048	.023	4.459	.035	.953
DDEGRAD	-1.183	.863	1.880	.170	.306
MKTDIST	.019	.015	1.676	.195	1.019
RDDIST	.001	.013	.006	.936	1.001
DLIVSTOK*	1.260	.268	22.046	.000	3.526
DOFFARM	.797	.772	1.065	.302	2.218
DEXTSERV***	1.653	.995	2.758	.097	5.222
DTRAING	-.566	1.290	.192	.661	.568
DRADIO	1.354	.863	2.458	.117	3.871
DWEATHER*	-3.596	1.169	9.455	.002	.027
DFIELDAY	.404	.901	.201	.654	1.498
DORGANZ*	2.622	.920	8.130	.004	13.763
DCREDIET	-.870	.792	1.208	.272	.419
DENVREGU	-.503	.763	.435	.510	.605
Constant	-11.449	3.414	11.245	.001	.000
Number of obs.	201				
Hosmer and Lemeshow Test	.983				
-2 Log likelihood	79.920				
Cox & Snell R Square	.627				
Nagelkerke R^2	.837				
Prediction statistic	90.5				

* Significance level at $p < 0.01$, **Significance level at $p < 0.05$, ***Significance level at $p < 0.1$
(source : Model estimation output)

2. Agroforestry practices.

This section identified the most important hypothesized independent variables that influence farmers' decision to adopt agroforestry practices in the study area. The dependent variable was either adopting or not adopting agroforestry. In this case, a farmer who carried out agroforestry practice was considered to be "an adopter". In model diagnostics, the Hosmer and Lemeshow test is used to estimate the good-fit model, and if the p-value is above 0.05 (statistically non-significant) the estimated model has adequate fit, and if the p-value is below 0.05 (statistically significant) the estimated model does not adequately fit the data. In this research, the P-value was .740, and the model fit very well (Table 13). The rate of correct model prediction was up to 79.6%. From all sample farmers, the correctly predicted adopters and correctly predicted non adopters of the model were 76.3% and 82.4 %, respectively. In the logistic regression model summary, over all model evaluation (likelihood ratio), statistical tests of individual predictors (Wald statistics), goodness of-fit statistics (R^2) are presented. In standard regression, the co-efficient of determination (R^2) value indicates how much variation in Y is explained by the model. This cannot be calculated for logistic regression, but the model summary table showed the values for two pseudo R^2 (Cox & Snell R Square and Nagelkerke R Square (pseudo R^2)) which try to measure something similar. In the estimated model, the pseudo R^2 is 55%. It indicates that, of the total variation in the dependent variable, 55% was explained by the independent variables.

Out of 20 explanatory variables that were hypothesized to affect farmers' decision to practice agroforestry or not, only 7 of them were found statistically significant (Table 13). These significant explanatory variables include: sex of the household head (DSEX), labour force proportion (LABOR), , average farm distance from home (FRMDIST), average market distance from home (MKTDIST), access to weather forecasting (DWEATHER), participation in farmers' field day (DFIELDAY) and knowledge on environmental regulation (DENVREGU). Family size, education level, number of farm plots, farm size, degradation, off-farm income, extension service, main road average distance from home, having radio and training were found to have a positive effect on agroforestry practicing but not statistically significant. On the other hand, age, member of organization and access to credit were negatively related with agroforestry practicing, but the relation was statistically insignificant.

Table 13. Determinants of agroforestry adoption

variables	Estimated coefficient (B)	Std. error (S.E.)	Wald Statistics (Wald)	p-value	Odds ratio of adopting Exp(B)
DAGE	-.002	.018	.008	.927	.998
DSEX*	2.163	.834	6.729	.009	8.699
LABOR*	.037	.011	11.911	.001	1.038
FAMSIZE	.100	.116	.747	.387	1.105
DEDUC	.418	.450	.863	.353	1.519
PLOTNR	.114	.258	.195	.659	1.120
FRMSIZE	.080	.264	.093	.761	1.084
FRMDIST**	-.030	.015	4.320	.038	.970
DDEGRAD	.019	.460	.002	.967	1.019
MKTDIST*	.026	.009	9.453	.002	1.027
RDDIST	.007	.007	.935	.334	1.007

DOFFARM	.414	.442	.880	.348	1.514
DEXTSERV	.220	.531	.172	.679	1.246
DTRAING	.552	.621	.790	.374	1.736
DRADIO	.813	.531	2.344	.126	2.254
DWEATHER**	-1.254	.627	4.006	.045	.285
DFIELDAY**	1.388	.583	5.675	.017	4.009
DORGANZ	-.071	.535	.017	.895	.932
DCREDIET	-.231	.459	.254	.614	.793
DENVREGU*	1.517	.495	9.387	.002	4.558
Constant	-9.586	2.121	20.432	.000	.000
Number of obs.	201				
Hosmer and Lemeshow Test	.740				
-2 Log likelihood	170.800				
Cox & Snell R Square	.412				
Nagelkerke R^2	.550				
Prediction statistic	79.6				

* Significance level at $p < 0.01$, **Significance level at $p < 0.05$ (source : Model estimation output)

7.3 Discussion: Factors affecting the adoption of WSM practise

1. Demographic factors

The most statistically influential demographic factors that hypothesized as independent variables to affect the probability of adopting composting, agroforestry and mulching practices are sex, labour force proportion, family size, and education level.

Sex of the household heads is positively correlated with the adoption of composting and agroforestry practices at statistically significance level (B=5.156; p- value= .012) (Table 12) and (B= 2.163; p- value = .009) respectively (Table 13). The Wald statistics 6.36 for composting and 6.729 for agroforestry also indicated that sex has a strong association with the adoption of the practices. Moreover, the coefficients and odds ratio of these explanatory variables were by far larger than other variables. This showed that being a male-headed farm household will intensify the probability of adopting compost and agroforestry on farmlands than being female-headed. The odds ratio of logistic regression showed that male household heads are more likely to adopt composting by the factor of 173.487 and agroforestry by 8.699 than female headed households. This appears to be reasonable in that most female-headed households did not plough their own farm plots. Most of the women households employed different mechanisms of getting returns from their farm lands. Renting farmlands either in the form of money or crop was common in the study area. This is because female headed households lack labour to cultivate and conserve their farmlands. Also, females are involved in taking care of their children and other related tasks at home.

Moreover, all female household heads are widowed or divorced and do not have support other than their children. Their socio-economic marginality, compared to males in different parameters, therefore, retards them back to adopt the practices which demand time, energy, capital, and social networks. The result of this study is consistent with (Daniel and Mulugeta, 2017; Germew, 2016 and Abay et al., 2016) which were conducted in rural Ethiopia.

Labour force proportion (the percentage of household members age between 15 to 64) had a positive correlation at statistically significance level with insignificant impact (composting: B=0.041, p-value =0.017; agroforestry: B= 0.037; p-value =0.001and mulching: B=0.050; p-value =0.000) on the adoption of the practices. The results were affirmed by the wald statistics of 5.666 , 11.911 and 19.840 for composting, agroforestry and mulching respectively (Table 12,13 and 14). As it is predicted in the model, if a farm household has more active labour force in the family, the odds of adopting composting practices increased 1.041 times, agroforestry practices increased 1.038 times and mulching practices increased 1.052 times than a family endowed with a high age dependency ratio. This explains that a farm household family consists of higher active work age members could affect the probability of CSA adoption positively. Practically, the practices are labour intensive. The quantitative result was verified by transect walking how the practices demand much labour. Unexpectedly, however, active labour force endowments are not significant in affecting the probability of using compost unlike the case in other studies (Mengistu and Bauer, 2011). The reason for this is not clear, and it might imply that the availability of adult labour in the family was less important for the adoption decision.

The logit model predicted that education level of farm household head variable influences composting practicing positively and significantly at 1% significance level (Table 12). This showed that relatively better educated farmers are engaged in the adoption of composting practices. The odds ratio of the variable indicates that all other factors being the same, farmers whose education level is elementary and above practiced composting 29.994 times more likely than non-educated (illiterate) farmers. The result revealed that better exposure to education increases farmers' better understanding of the benefits and constraints of adopting the practice. A positive impact of education on technology acquisition is generally expected as it enhances farmer's ability to acquire and analyze new ideas, and provides specific or general skills that contribute to farm productivity (Workneh, 2015).

Similar to the finding of this study, (Daniel and Muluget, 2017; Workneh, 2015; Eric, 2012,) reported that education gives farmers the ability to perceive, interpret and respond to new information much faster than farmers with lower education level (non-educated). Thus, those household heads with better education level have a higher probability of adopting best practices.

In the case of mulching, the regressed binary logistic model revealed that an increase in the family size of the household leads to a rise in the likelihood of adopting mulching practices on the farmlands. The study result showed that, when the family size increased by one number, the likelihood of mulching adoption increased 1.332 times (Table 14). Labour is the main concern in the decision to adopt labour intensive technologies. Hence, large family size is a source of labour for adopting agricultural practices in rural Ethiopia.

2. Physical factors

Among the physical farm factors employed in the logistic regression model, average farm distance from home is captured as an influential predictor of composting, agroforestry and mulching practices. The models revealed that farm plot distance from home had a negative and insignificant impact on farmers' adoption decision (composting: B = -0.048, p-value = 0.035; agroforestry: B = -0.030; p-value = 0.038 and mulching: B= -0.46; p- value = 0.006) (Table). The negative sign shows that as the farm plot distance increases, the probability to adopt CSA practices decreases (Table 13 and 14). The result is consistent with prior prediction. In the study area, the average time taken to reach a farm plot is almost 28 minutes (Table 11). This showed that transporting CSA practices materials to farm plots highly discouraged farmers to adopt the practices. In the study area, compost has been preparing around the homestead especially in the house garden area for follow up the bio chemical process and security. The odds ratio indicated that being other variables constant, a one minute increase in distance of farmland from a farmer's home decreases adoption of composting by a factor of 0.953, agroforestry by a factor of 0.970 and mulching by a factor of 0.955 (Table 14). This revealed that greater distance of a plot from homestead might have discouraged farmers from giving the necessary care and maintenance for the plot. Because less time and energy are consumed for maintaining the soil fertility of near farmlands than far farmlands. In line with this, Daniel and Mulugeta (2017); Robera (2013); Eric (2012); Mengistu and Bauer (2011): Kessler (2006) and Birhanu and Swinton (2003) also found that, distant farmlands discouraged adoption of any soil and water conservation practices. It is more tedious to carry compost manure and mulching materials from the homestead to the farm and this may require employing more labour and capital. This leads to raise cost of production which hinders farmers' to adopt the practices.

In the case of agroforestry, contrary to the stated hypothesis, market distance from farmers' homestead had a positive impact on adoption at 1% significance level (Table 13). The reason for this might be farmers' adopt agroforestry type other than high value trees which couldn't be marketable and generate income. But study conducted by Germew (2016) at Mecha district of western Gojam, in agreement with the stated hypothesis, showed that, as the distance of the farm household from the proximal market areas increased by one percent (one minute), the probability of agroforestry adoption would be declined by 21% units. This is because of the demand for fuel wood, andwood construction materials might induce the proximate farm-households to adopt agroforestry on their farmlands.

3. Economic factors

The number of livestock holding by farm household head had a significantly positive impact on the adoption of composting practices, which supports the hypotheses of the model. This explanatory variable is highly influential at 1% significance level with estimated coefficient and odds ratio of adopting 1.260 and 3.526 respectively (Table 12). The odds ratio result from the estimated model depicted that, as the number of livestock increases by one tropical livestock unit (having one extra ox or two donkeys or ten sheep, etc.), adoption of compost increases by a factor of 3.526. Since, livestock are important providers of manure for compost preparation, as farmers' hold more livestock; by far they are encouraged to prepare and apply compost in their farmlands. Also, livestock holding in rural Ethiopia in general and in the study area, in particular, is considered as indicator of income level and hence wealth status of the households. It shows farmers financial ability to buy even commercial composts for their farmlands.

On the other hand, some of the livestock type like donkey and horse are still an important means of transports for goods and human being in the study area. So, a farm household having a number of livestock is not challenged in applying compost to their farmlands which are even takes more than 28 minutes from the homestead. So, a large number of livestock presences in rural family minimize time, energy and costs of practicing composting. The result is agreed with that of Workneh (2015) and Mengistu and Bauer (2011).

Farm income other than agricultural activities (Off-farm income) is the most influential factor that affects farmers' decision to adopt mulching. The result of the regressed model depicted that off-farm income has a positive correlation at statistically significant level (B = 1.204; p-value =0 .008) with the adoption of mulching practices (Table 14). The odds ratio of the binary logistic regression result revealed that household heads who are engaged in off-farm activity adopt mulching practices 3.333 times greater than those who are not engaged in the off-farm activity. Because income from off-farm activity increases the financial capacity of farmers which in turn encourages investment in soil and water conservation practices.

Contrary to this, Daniel and Mulugeta (2017) reported that off-farm activity is correlated negatively at a statistically significant level with the adoption of soil and water conservation practices. They argued that there is labor competition between off- farm activity and soil and water conservation practices which restrain farmers from involving in implementing and maintaining conservation practices on their farmlands.

As expected, the other economic factor, farm size was found to be positively associated with mulching adoption (B= 0.499; p- value = 0.068). From the predicted model result (Table 14), it was found that, if farm plot increases by one hectare, adoption of mulching increases by a factor of 1.647. The positive coefficient of the variable implies that farmers with larger farm size are more likely to adopt mulching compared with those with small farm size. Farmers with large farm size can afford to devote part of their plots (sometimes the less productive parts) to try out high yield giving technologies, and this may influence adoption decision.

In line with this (Robera, 2013; Rafael, 2005) argued that relatively larger farm size had a higher risk of adopting improved agricultural practices. This can be attributed to the fact that fertility enhancement occupies part of the scarce productive land and, therefore, farmers with larger farm size can afford it compared to those with relatively lower farm size.

Institutional factors

Not surprisingly, farm household heads who have access to agricultural extension service and who are members of rural organizations like rural cooperatives and other forms of associations are more likely to adopt composting. Access to extension service more than three times per one cropping season had a positive correlation at statistically significance level (B = 1.653; p-value = 0.097) with the adoption of composting. The other institutional factor, being a member of rural organizations, also positively and significantly affects the likelihood of using compost at B = 2.622 and p-value = 0.004 (Table 12). The odds ratio of extension service was 5.222; if extension service increased by one service contact, the probability of adopting compost increases 5.222 times. Similarly, the odds ratio of a member of organizations was 13.763, denoted that farmers being a member of organizations were 13.763 times more likely to adopt composting practices than that of being non members.

This showed that extension service and rural organizations are important sources of information and knowledge for rural farmers. Based on the innovation diffusion theory, farmers who have contacts to extension services tend to be more progressive and receptive to innovation. However, some farmers may strategically delay adoption of a new practice until they build confidence through watching and learning from fellow farmers. In FGD and key informant interview contacts, farmers said that they also got information about compost preparation and application from other farmers. Nowadays, farm organizations like rural cooperatives, Youth associations, women associations and rural kebele administrations are the best places to acquire training and experience sharing opportunities. Even, indigenous institutions like *Idir* and *Maheber* are still played an important role in agricultural technologies information exchanges. These indicate that formal and non-formal institutions are key for farmer-to-farmer information exchange for technology adoption.

Rural organizations expose farmers to a wide range of ideas and sometimes give farmers the opportunity to have better access to information on innovations. Group membership also enables farmers to have collective bargaining power when selling their product as well as purchasing farm inputs (Eric, 2012).

The findings of the influence of extension service and rural organizations on compost adoption in this research are consistent with those of Daniel and Mulugeta (2017) and Workneh (2015) who analyzed the adoption of soil and water conservation techniques and composting in south wollo zone of Amhara region and Beseku district of Oromia region repectively. Also, Wang et al. (2016); Eric (2012) and Somada et al. (2002) reported similar findings on composting technology adoption in China, Kenya, and Burkina Faso respectively.

Farmers' field day participation influences agroforestry practicing positively and significantly. This implies that the variable is one of the motivating factors for practicing agroforestry. The coefficient and odds ratio of this variable were 1.388 and 4.009 respectively (Table 13). Keeping other factors constant, when farm household heads get an opportunity of extra one day participation in farmers' field day, they could be 4.009 times more likely to practice agroforestry. Research results by Gitonga and Mukoya (2016) showed that adoption of agroforestry practices could be strengthened by promoting regular farmers-to-farmers dialogue. From the practice, it is observed that farmers are the prime agents of change in their respective communities. One of the rural institutional set ups that create exposure to farmers-to-farmers dialogue on their success stories is farmers' field day. It is a practical experience sharing arrangement among farmers' to promote the adoption of high beneficial agricultural practices like agroforestry. In most cases, rural farmers delay adoption of a new practice until they build confidence through watching and learning from fellow farmers. Therefore, the best time to build confidence and learn by watching is farmers' field day.

The other institutional factor, knowledge on environmental regulation had positively correlated with the adoption of agroforestry practices at statistically significance level (B= 1.517; p- value = .002). The Wald statistics (9.387) also indicated that the variable has a strong association with the adoption of agroforestry practices (Table 13). If a farmer is knowledgeable about environmental regulations, the likelihood of adopting agroforestry practices increases 4.558 times. The results are consistent with that of Wang (2016).

When farmers' get some knowledge and highlights on Ethiopia's environmental regulations such as the environmental policy of Ethiopia, agriculture sector programme of the plan on adaptation to climate change and climate resilient green economy strategy, they could develop a better attitude towards eco friendly agricultural practices. The policies and regulations mainly address the mechanisms of how environmental degradation and climate change adverse impacts could be manageable. So, the issue of environment influences the attitude of farmers' in the study area who are mainly living in degraded environment.

A study by Tanga and Amare (2016) reported that farmers' awareness about land degradation and their attitude towards land management practices leads farmers' to have positive attitude towards land management practices including agroforestry.

Although from FGD and key informant interview, it is verified that, environmental regulation statements are boldly written on farmers land use certificate. The entitlement card enforces them to conserve their environment. However, some farmers even indicated that they had never heard of the environmental regulations, which indicates that the popularization of the regulations is not enough and that the laws also do not perform their role of advising, regulating and supervising.

Contrary to the stated hypothesis, information to weather forecasting had a negative and significant impact on compost adoption at 1% significance level and agroforestry adoption at 5% significance level (Table12 and13). The reason for this might be the absence of the timely available weather information and high probability of weather prediction accuracy. If so, the variable was less important for the adoption decision.
Radio is assumed to give information about climate smart agricultural practices to farmers and hence it is expected to affect adoption decision positively. However, Contrary to the stated hypothesis, radio had a negative and significant impact on mulching adoption at 5% significance level (Table 14). The reason for this might be the absence of sufficient and well organized radio programmes concerning farming activities that influence the adoption decision of farmers.

Conclusion and Recommendation

The general, he objective of the study, was to assess the watershed management practices in averting the problems of watershed degradation and its implications in enhancing food security and fostering the mitigations and adoption of climate change in the southern Rift Valley. The main watershed deterioration that affects the sustainability of agriculture includes soil erosion mainly gully, soil fertility decline, grazing land degradation and deforestation.

The satellite image interpretation shows that over 50% of the forest land of the areas was converted to the faming land in the past four decades, land in has been converted from forest to agricultural land use (crop and grazing), particularly over the last 50 years. The extent of available agricultural land in the study area has enormously increased, particularly during the same period,-from 1986 .to2016. It was also assessed as the soil erosion particular gully erosion is becoming a serious problem occurring in the different land use and landscape that affect the agricultural productivity of the areas.

In response to the challenges of land degradation, various watershed measures have been taken. These include soil and water conservation, minimum tillage, composting, and agroforestry. These practices increased forest areas, carbon sequestration, enhanced the soil fertility and reduction of soil erosion. In addition to the rehabilitation and maintenance of the environment, the WSM intervention has also enabled the increment of agricultural productivity and consequently. They have contributed to the enhancement of food security and climate change adoptions.

However, the effective adoption and implementation of the watershed management practices are affected by a wide range of demographic, physical, economic and institutional factors. Among others, sex of household heads, education level of household heads, number of livestock holding, access to extension services and being a member of rural organizations affect adoption of composting positively and significantly. Also, farm distance affect composting practices negatively. The probability of applying agroforestry is positively and significantly associated with sex of household heads, farmers' field day participation and knowledge on environmental regulation. Besides farm distance affect the likelihood of agroforestry application negatively.

This study argues that the sustainable use and maintenance of agricultural landscape are thus fundamental to human wellbeing and planning for the long-term sustainable use of the south rift valley's environments and requires flexible, adaptive strategies. The policy makers and planners should thus take into account the cumulative and synergy of the interactions of watershed management, climate change and food security for the planning of the sustainable development of agriculture. In this regard commitment of every stakeholder is required in fostering the use of the practices through supporting those who already implemented and increasing awareness among non-users to encourage them to adopt the practices. The policy makers and planners should thus take into account the cumulative and synergy of the interactions of watershed management, climate change and food security for the planning of the sustainable development of agriculture.

Finally, given the limitations of this study, there are some implications that do deserve further research. These include:

- The necessity to consider the broader aspect of the environment beyond farm land conservation including livestock production, conservation of water, wetlands, forest, and biodiversity in different units of the watershed and the respective mechanisms should also be devised.
- The need to have time series information for assessing the dynamic nature of adoption by the variables considered in this study ;
- The need to appraise the strength and weak links of each specific watershed management practice in a specific watershed unit.
- Finally, the impacts of the food security and climate adoption and mitigation on the watershed environment should also be evaluated.

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