COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR FOOD SECURITY STUDIES

CONTRIBUTION OF NATURAL RESOURCE MANAGEMENT TO FOOD SECURITY IN LEMAN WATERSHED, DEGEM WOREDA, OROMIA NATIONAL REGIONAL STATE.

By: Zerihun Mekuria

June 2019

Addis Ababa, Ethiopia.

Contribution of Natural Resource Management to Food Security in Leman Watershed, Degem woreda, Oromia National Regional state.

By: Zerihun Mekuria

Supervisor: Degefa Tolossa (PhD)

A Thesis Presented to the School of Graduate studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Food Security and Development Studies

Addis Ababa University

Addis Ababa

June 2019

Declaration

I declared this thesis is my original work and it was done in collaboration with my advisors. All sources of materials that used for this thesis have been dully acknowledged.

Zerihun Mekuria

Signature_________________

Date_____________________

As thesis advisor, I hereby confirm that this thesis is the output of research undertaken by Zerihun Mekuria under my supervision and that it be submitted for the M.Sc. degree award.

Confirmed by Advisor: Degefa Tolossa (PhD)

Signature: ___________________________

Date: _______________________

Addis Ababa University

Addis Ababa, Ethiopia.

July 2019.

Addis Ababa University

School of Graduate Studies

This is to certify that the thesis prepared by Zerihun Mekuria, entitled: ***Contribution of Natural Resource Management to Food Security in Leman Watershed, Degem woreda, Oromia Region.***

and submitted in partial fulfillment of the requirements for the degree of Master of Science (Food Security and Development Studies) compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by Examining Committee

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External Examiner____________________________ Signature____________ Date______________

Internal Examiner___________________________ Signature _____________ Date_______________

Advisor___________________________________ Signature _____________ Date ______________

Abstract

The overriding objective of this study is to explore the of participation of households in different soil and water conservation practices in enhancing their production and food security and examine their production efficiency Thus, this study analyzes farmer's choice of single and combination choice of SWC practices (i.e. stone bund, soil bund, stone bund and soil bund, soil bund with plantation and all conservation practices) and evaluates the impact of these technologies on households food security and also assess their production efficiency and determinants of inefficiency. The necessary data were generated principally from primary and to some extent secondary sources to answer the research question. Thus, household survey involving 290 households was done using questionnaires. Multinomial logit and endogenous switching regression models were employed to achieve the above objectives. In addition, the study employed one stage approach in which both technical efficiency and factors of inefficiency are analyzed simultaneously. The result of endogenous switching model reveals that adoption of SWC practices have a positive and significant impact on household's food security. Moreover, the result of the study also shows that households adopting all conservation practices are more food secure than other alternative adopters. Failure to adopt SWC practices leads to lower food security status. According to the multinomial logit result, technology adoption is positively related with education/ training, soil fertility, access to extension services, land size and livestock holding. But adoption of agriculture technologies has negative and significant relation with non-marriage status, and distance to the input and out market. On the other hand, study revealed nearly half of households produce with only 50% percent efficiency and there is a room to improve production efficiency. Slope of farmland, livestock possession, agricultural tools ownership and SWC participation are factors that significantly determine efficiency. Increased effort on physical SW conservation activities along with biological, investing more education and training, improving infrastructure/access to services are key recommendation in improving production efficiency and food security are stemmed out of the study.

Key Words: Food security, Multinomial endogenous, Soil and water conservation, Switching regression, Technical efficiency,

Acknowledgement

First and foremost, I thank the Almighty God for giving me the wisdom, strength and power throughout my MSc studies in general and preparation of my thesis work in particular.

My honest and deepest gratitude to my advisor **Dr. Degefa Tolossa** for sharing his invaluable comments, suggestions and advices. I really appreciate his commitment in carefully reviewing my drafts and his ability to point out detail gaps within the thesis and suggestions for improvement. Each moment I sit down with him I get a great deal of knowledge and critical advices which I used it not only for enhancing this thesis but found them extremely useful for my individual and academic personalities.

Special thanks to my wife **Abaynesh Tegene** and children; **Dibora Zerihun, Samuel Zerihun** and **Eyana Zerihun** for the energy and enthusiasm I obtained with their understanding of time I spent on my study and encouragement.

My sincere thanks to **Dr. Solomon Tsehay** who encouraged me to attempt a research on this theme and gave me pieces of advices on some technical matters on the paper. Thanks to FEWS NET colleague, **Mandefro Mekete** for unreserved support with his advises and used his access to subscribed references to provide me necessary materials. Thank you, **Getachew Abate** for your GIS inputs, on this thesis. I am grateful to **Ambassador Kassa Teklebrehan** and **Zewditu Tegene** for their critical and useful intervention that enabled me to maintain my study.

I take this moment to extend my gratitude to FEWS NET SMT for encouragement, positive attitude for my master’s study and finance support for the courses of the study. Last but not least, I would like to thank staff members of Degem Woreda Agriculture Office in particular **Dereje and Eshetu Hunde** for their continuous moral support in my research work.

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Acronyms

ATT	Average Treatment Effect of Treated
ATU	Average Treatment Effect of Untreated
CSA	Central Statistical Agency
DA	Development Agents
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
ERS	Endogenous Regime Switching
ETB	Ethiopian Birr (Currency)
FAD	Food Availability Decline
FAO	Food and Agriculture Organization
FANTA	Food and Nutrition Technical Assistance
FCS	Food consumption Score
FDRE	Federal Democratic Republic of Ethiopia
FED	Food Entitlement Decline
FGD	Focus Group Discussion
GDP	Gross domestic Product
GIZ	German Society for International Cooperation, Ltd
GTP	Growth and Transformation Plan
HDDS	Households Dietary Diversity Score
HEA	Households Economy Approach
HFBM	Households Food Balance Model
HFIAS	Households Food Insecurity Access Scale
HH	Households Heads
IFPRI	International Food Policy and Research Institute
MESR	Multinomial Endogenous Switching Regression
MLE	Maximum Likelihood Estimates
MoARD	Ministry of Agriculture and Rural Development
NDRMC	National Disaster Risk Management Commission
OLS	Ordinary Least Square
PASDEP	Plan for Accelerated and Sustainable Development to End Poverty
PIM	Programme Implementation Manual
PSNP	Productive Safety Net Programme
SFA	Stochastic Frontier Analysis
SIDA	Swedish International Development Agency
SLMP	Sustainable Land Management Programme
SNNP	Southern Nations and Nationalities People
SNRM	Sustainable Natural Resource Management
SSA	Sub-Saharan Africa
SWC	Soil and Water Conservation
TE	Technical Efficiency
TLU	Tropical Livestock Unit
WFP	World Food Programme
USAID	United States of America International Development

Glossary

Belg	Short rains between February and May, in southern, north-eastern, eastern and north central parts of the country; also used to describe the secondary agricultural season
Kebele	‘Locality’: the smallest administrative unit, rural or urban
Kiremt	The long rains between June and September throughout the cropping areas of the country
Region	Admirative unit in Ethiopia that is above zone and below National
Teff	A very fine-sized grain (Eragrostis tef) with a grass-like stem, unique to Ethiopia as a staple
Woreda	Lower administrative unit in Ethiopia that is above the kebele and below zone
Zone	Administrative unit in Ethiopia that is above woreda and below Region

Chapter 1 Introduction

1.1 Background of the Study

Food is one and most important basic needs of human beings. Food security is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, Rome,1996). Food insecurity has long been stayed as challenge of households of Ethiopia. The drought and hunger in 1974 were the first wider scale episode which occurred mainly in Wello (north eastern Ethiopia). The ghastly famine of 1972-74 broke out in all its devastating consequences. It had been estimated that 200,000 people perished (Girma, 2014).

The 1984/85 drought is the most serious one by affecting over eight million people and causing the death of one million Ethiopian's (Abduselam, 2017) and (Giirma, 2014). Very recently, In Ethiopia, El Nino triggered drought and shortage of production made more than 27 million people became food insecure and total population of 18.1 million people require food assistance which either induced by chronic and acute factors in 2016 (Abduselam, 2014).

A lot has been said about the immediate and underlining causes of global food insecurity in general and problem of food security in Ethiopia in particular. Several studies highlighted food and livelihood security are highly linked with exploitation and conservation of natural resources (land, water and forest). Extreme degradation of natural resources in the country pose a major threat on the ecosystem, biodiversity and low agricultural production. As Degefa (2005) cited in Meskerem (2011) reported that the cause of failure of Sub-Saharan Africa to feed its alarmingly increasing population by and large is attributed to climatic problems like drought, resource degradation, inefficient policies, widespread epidemics, technology stagnation, continuous civil strife and conflicts, and the like.

Ethiopia understands environmental degradation is a major stumble block in alleviating poverty and ensuring food security. Environmental degradation threatens physical and economic survival. It reduces the environment's ability to produce biomass for food, feed and household energy. It undermines prospects for fighting poverty and achieving sustainable development (PASDEP, 2006).

The Global Mechanism (2007) estimated that over 85 % of the land in Ethiopia is moderately to very severely degraded, and about 75 % is affected by desertification (Samuel *et al.*,2015). In Oromia Region, the average erosion rate for agricultural land has been estimated at about 40 t/ha but there is wide variation between different parts of the region and between production systems (Bizuayehu *et al.*, 2002). Empirical studies highlighted the importance of natural resource conservation for enhanced income and food security. As noted by Environment for Development (2009) study, '…the impact of stone bunds on agricultural productivity ranges between Ethiopian Birr (ETB) 299 to 412 per hectare.

As response to the aforementioned challenges of environmental degradation, the FDRE designed strategies to combat the consequences of environmental degradation. PASDEP (2006) underlines promotion of a participatory and problem-solving livelihood improvement framework for gender equity, environmental protection and the sustainable use of environmental resource as one of the key strategies for environmental protection or rehabilitation.

To that end, several efforts underway and the Sustainable Land Management Programme (SLMP) is the one among others[1]. In this study, linkage of food security with natural resource development is examined. Although, many studies were done in the area with an aim to see how production and productivity were impacted by the natural resource activities, this more focused on the different physical and biological soil and water conservation measures and attempted to show how production and food security is different among different soil and water conservation practices. The study also provides answer on what are the added benefits of adopting different types of soil and water conservation practices by comparing with the counterfactual situation/ impact on food security which represents households food security status, if they hadn't implemented. The research also contributes in filling the knowledge gap providing knowledge to the academic world.

1.2 Statement of the Problem

[1] Read more on the SLMP in Chapter 3 of this thesis.

Among many factors, in Ethiopia, land degradation continues to undermine agricultural production and has become a key driver of productivity decline and household's food insecurity and poverty. Historical documents show that forest and woodlands covered over 40% of the total area of the country only a century ago (Badege , 2005). Presently, this figure is estimated to be less than 10% Bane, *et. al*. (2008). As FAO (1986, 1999) cited in Woldeamlak (2009), the country's annual deforestation rate is estimated to be about 62,000 hectares, attributed primarily to the increased demand for farmland, fuelwood, and settlement sites (Messay and Tsegachew, 2013).

According to Bizuayehu *et al*. (2002), the average erosion rate for agricultural land has been estimated at about 40 t/ha but there is wide variation between different parts of the region and between production system. Recent estimates suggest that the rate of deforestation is about 3.1% per annum.

In addition to the depth of extent environmental degradation, its impact goes far beyond. It involves an adverse impact ranging from disrupting the ecology to the level it hinders agricultural production and productivity thereby undermining food and livelihoods security of households.

At macro level, estimated other losses on an annual basis include $23 million a year on forest losses due to deforestation and $10 million a year due to loss of livestock capacity the equivalent of almost 1 million livestock units. This total loss of $139 million annually is almost 4% of agricultural GDP (Berry,2003). As IFPRI (2005) is cited in Temesge *et al*. (2014) cited as land degradation is one of the major causes of low and in many places declining agricultural productivity and continuing food insecurity and rural poverty in Ethiopia. Shibiru (2010) reported that the loss of soil productivity in Limo Woreda leads to reduced farm income and food insecurity, particularly among the rural poor and thus continuing or worsening poverty.

Evidence on Leman watershed inform that lack of adequate food is a concern for inhabitants of the watershed. As per (FDRE SLMP , 2012), average crop production within the watershed per household was 6400 kg. This is well below the requirement of household size of six which is 12000kg per annum. This is partly caused by minimal production which is highly constrained by low productivity due to land degradation.

The fact that natural resource degradation leading to multifaceted human and other biophysical sufferings and damages, the government of Ethiopia with development partners designed and implemented measures that help to protect and rehabilitate natural resource. The ultimate goal of these efforts is improving production efficiency of natural resources and contribute to poverty reduction and ensure food security. The conservation and management of natural resources calls for the integrated development and utilization of the resource bases (land, soil, water and forest) to enable the transition to improved livelihoods, and to protect these resources for future generations (PASDEP, 2006).

Ethiopia respond to land degradation problem in an attempt to improve production and food security. The SLMP is one of the most important efforts in the country. In an attempt to measure the contribution of these efforts, there has been several studies and impact assessments done. Despite these efforts, the linkage of these efforts with food security remains unassessed. Study limitations are worse when one looks for information describing the contribution of specific conservation to production and food security. Thus far, there are several tailored SWC technologies implemented to improve the degradation status of communal and farmlands of households. However, there is a paucity of information in examining the outcome of the application of these technologies.

Shibiru (2010) studied farmers perception on land degradation and their traditional control measures vis-à-vis impacts on improving production and productivity. Berry (2003) did an in-depth study on the cost of land degradation but not on the impacts of natural resource conservation on households and community as well as the environment. On another study Taddele (2016) examined the contribution of land management practices in improving livelihoods of farmers and land resources conservation in the area. Etsehiwot (2018) attempted to study impact of the technology adoption which involves adoption of improved seed, row planting and fertilizer on teff production.

It is, therefore, imperative for one to explore if adoption and application of natural resource conservation practices and its impacts on food security. This study intends to assess the natural resource conservation and food security nexus with special emphasis to Leman watershed management which is implemented under the SLM programme. It also examines the determinants of the decision behavior of households to different soil and water conservation practices. While attempting to explore the impact of natural resource conservation, the study is also designed to investigate resource utilization efficiency of households in the course of agricultural production. Meanwhile, as the study is targeted on watershed management projects, it will have significant contribution in taking findings and knowledge drawn from the study and roll-out to other similar efforts across the Region and the country.

1.3 Research Objective

1.3.1 General Objective

The overriding objective of this study is to examine the contribution of natural resource conservation practices to household's efficient food security with special emphasis to efforts under Leman watershed management projects in Degem woreda.

1.3.2 Specific Objectives

The specific objectives of the study are to:-

- Examine the contribution of SWC practices on productivity and food security .
- Measure the actual and counterfactual impact of different combination of soil and water conservation practices on household's food security.
- Identify the key factors that determine adoption of different soil and water conservation practices.
- Assess the technical efficiency of farmers and identify the major determinants of inefficiency.

1.4 Research Questions

The research intends to answer the following key questions

- What are the contributions of natural resource conservation to households food security?
- What are major socio-economic, cultural, demographic and policy factors that determine households adoption of different types of natural resource conservation practices?
- Do households efficient enough in terms of resource utilization in their effort to intensify production while adapting of different natural resource conservation practices?

1.5 Significance of the Study

The study will provide a multiple benefit for the different agents including programme benefiting households, the SLMP and government at different administrative levels. The study will fill the knowledge gap and help researchers and development practitioners in their respective efforts. The study attempt to explore which soil conservation practice, or a combination of practices are with an increased likelihood of adoption and suggest households which households or institutional attributes are important for them to determine decision behavior and make a condition for further exploration on why some household, institutional and plot attributes hindered the adoption of important technologies.

The study also informs the programme and beneficiaries of the programme about the efficiency of their production process. In other words, it helps to examine if the combination of inputs investment produced an efficient output. The study investigates on how technology adoption has profound importance in enhancing food security and also explore if food security is achieved with an optimum efficiency or not.

In sum, beneficiaries of the SLM, households in the Leman watershed, government at large is expected to draw lesson from the findings of this study which serve as input for program design, identify themes for further research and if necessary.

1.6 Scope of the Study

The general intent of this study is to investigate the contribution of natural resource conservation on food security of households who benefit from the SLM programme which is implemented across the country in selected woredas and water shades. This study is undertaken in one of the watersheds, in Degem woreda, North Shewa zone of Oromia Region.

While understanding the food security linkage of the watershed management is the primary focus of the study, the study will make use of the information from primary data collection in examining the factors that determines the natural resource conservation technology adoption of farmers in the study area. Meanwhile there has been an attempt to know the production efficiency of households who invested a resource on their land and in return benefitted from direct and indirect outcome of their investment.

1.7 Ethical Consideration

Ethics are the norms or standards for conduct that distinguish between right and wrong. They help to determine the difference between acceptable and unacceptable behaviors. ethical standards prevent against the fabrication or falsifying of data and therefore, promote the pursuit of knowledge and truth which is the primary goal of research.

In light with this, the enumerators and supervisors were instructed to abide with honesty, objectivity, respect for intellectual property, social responsibility, confidentiality, non-discrimination. This was checked during the field data collection if they adhered with these principles and there were no occasions, they violated these core ethical norms.

While data analysis and reporting are needed to attain the required moral and technical standards. Manipulation of data for an intended result is breach of ethical codes. Hence, at most effort has been made to respect these values during data entry and analysis.

1.8 Limitations of the Study

To the best of the researcher capacity, efforts were made to achieve the optimum quality of the study from the planning stage through data collection, analysis and drafting report. However, I also believe that the study is not free from limitation.

Limited access/availability to reference materials on multinomial endogenous regression model application restricted the opportunity of more reading in the area. The data collection had to be made by SLM programme community mobilizers, although the plan was to use DA and DAs were occupied with series of meeting during the data collection. There was data quality problem by two enumerators, which required extra effort as it was obligatory to undertake second time data collection. The analysis of technical efficiency was challenged by too many missing values, and the researcher had to rely on the existing valid observation for generating results and interpretation.

1.9 Organization of the Thesis

This research thesis is divided into seven chapters. The first chapter introduces the background, the statement of the problem, objectives, justification, significance and limitations of the study as well as scope of the study and ethical consideration. The second chapter covered review of related literature that discuses review of concepts, definitions and theories on food security, land degradation and production efficiency. The analytical framework work of the study also discussed in this chapter. This is followed by methodology of the study which is chapter three of the thesis. Chapter four begins with discussing results particularly on factors influencing technology adoption by applying multinomial logit model. In chapter five impact of adoption of SWC practices adoption on households food security status which used the multinomial endogenous regression model for the analysis. Chapter four is about analysis of production efficiency. Lastly, chapter seven briefly presented summary, conclusion and recommendation of the thesis.

Chapter 2 Literature Review

2.1 Review of Conceptual Literatures

2.1.1 Land Degradation

2.1.1.1 What is Land degradation

Land degradation includes all process that diminishes the capacity of land resources to perform essential functions and services in ecosystems (Hurni *et al*., 2010) are caused by two interlocking complex systems: the natural ecosystem and the human social system (Temesge *et al*.,2014). Land degradation manifests itself in many ways: vegetation becomes increasingly scarce, water courses dry up, thorny weeds predominate in once rich pastures, footpaths grow into gullies, and soils become thin and stony. All these manifestations have potentially severe impacts on the environment, for land users and for people who rely for their living on the products from a healthy landscape (Berry,2003).

Land degradation can be triggered by various processes that lower potential productivity leading to long-term, sometimes irreversible, deterioration of land. These processes are numerous but for the purposes of this paper, primary focus is given to soil erosion and biological, chemical and physical degradation as forms of land degradation in the Oromiya region (Bizuayehu *et al*.,2002).

Land and water degradation threaten food security for many of the poorest and most food insecure living in Asia, Africa and Latin America. It also contributes to persistent poverty, and results in decreasing ecosystem resilience and provision of environmental services (Bossio *et al*., 2004). In addition, environmental decline due to land degradation adversely affects the health, well-being and livelihood opportunities of the individuals (Temesge *et al*.,2014).

2.1.1.2 Land Degradation and Food Security

There is a vicious cycle of natural resource degradation and food insecurity driven by absolute poverty and population growth in Ethiopia. The country is caught up in a ‘poverty – environmental degradation and food insecurity circle (Sisay and Tesfaye, 2003).

As noted by Jhon and Salem (2011) food security is directly linked to our concept framework for SNRM, most significantly by the application of science and technology together with continued investment in research, development and innovation. When Frank and Alexander (2013) discusses about linkage of natural resource conservation with increased productivity explains as

> *"if adequate food production globally is to rely on productivity increases and we are witnessing degradation of soil and water resources in a significant sized area, then improved management of natural resources in agricultural landscapes is of paramount importance"*

Land and water degradation threaten food security for many of the poorest and most food insecure living in Asia, Africa and Latin America. It also contributes to persistent poverty, and results in decreasing ecosystem resilience and provision of environmental services (Temesgen *et al*, 2017) . A study made by (EFPRI,2005) reaffirm, land degradation is one of the major causes of low and in many places declining agricultural productivity and continuing food insecurity and rural poverty in Ethiopia

In agrarian community, the contribution of natural resource conservation to enhanced food security is mainly through improving agricultural production. Alemu and Kidane (2014) designed a framework that describe how the integration of physical and biological SWC measures reduces flood risk, sediment load and nutrient loss (Figure 1). As a result, it improves the availability of water for irrigation, power generation and increased agricultural productivity. Hence, reservoirs and dams have longer performance because different SWC practices protect them from siltation effect.

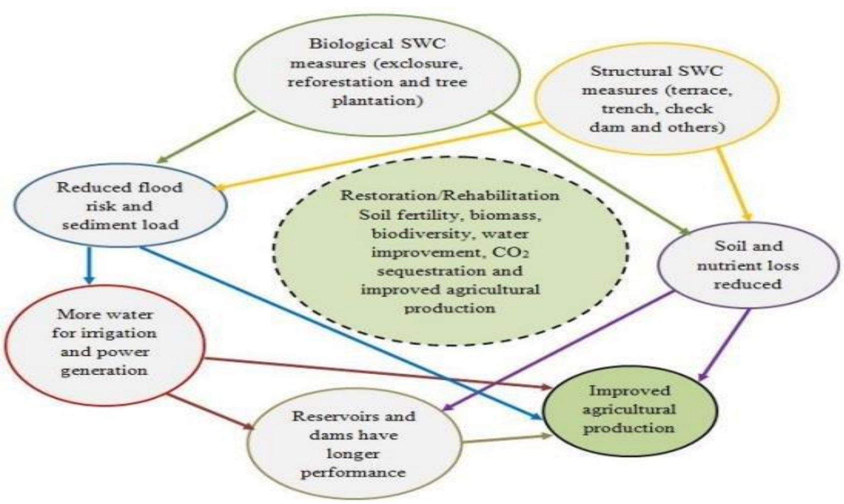

Figure 1: Conceptual framework demonstrating implication of SWC measures in degraded land rehabilitation (Alemu and Kidane, 2014)

2.1.1.3 Sustainable Land Management

A study area selection is based on where the SLM has been operational and adequate conservation practices took place to measure the impact on food security. Hence, it is imperative to briefly discuss about the SLM programme in Ethiopia.

Sustainable Land Management (SLM) has been defined by (TerrAfrica, 2005) as 'the adoption of land use systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources. SLM includes management of soil, water, vegetation and animal resources (FAO, 2011).

The same edition of FAO describes the SLM as an effort to deal with land degradation. Thus, SLM must address water scarcity, soil fertility, organic matter and biodiversity. SLM seeks to increase production through both traditional and innovative systems, and to improve resilience to the various environmental threats. The main principles of SLM as discusses by (FAO,2011) are; Increased land productivity, Improved livelihoods, Improved ecosystem, Adoption and decision support for upscaling best practices, Decision support – upscaling SLM.

In Ethiopia, SLM is a vital programme and receives emphasis in the country's development agenda, which aims to reverse land degradation, improve agricultural productivity and achieve food security through implementing soil and water conservation practices at a large scale. In this regard, many development projects and programs have been initiated and implemented by successive Ethiopian governments in collaboration with several consortia of donors since the 1970s. Between 1995 and 2009, the Ethiopian government incorporated SLM practices into agricultural extension packages/programs for individual farm-households. Recently, SLM practices have been promoted and implemented through community mass mobilization at a watershed level, as part of Ethiopia's Growth and Transformation Plans (GTP I and II) (Meskerem and Degefa, 2015).

2.1.1.4 Watershed Management

A watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. The word watershed is sometimes used interchangeably with drainage basin or catchment. Ridges and hills that separate two watersheds are called the drainage divide. The watershed consists of surface water--lakes, streams, reservoirs, and wetlands--and all the underlying ground water (USGS, 2016).

Watershed management is the process of organizing and guiding land, water, and other natural resources used in a watershed to provide the appropriate goods and services while mitigating the impact on the soil and watershed resources. It involves socio-economic, human-institutional, and biophysical inter-relationships among soil, water, and land use and the connection between upland and downstream areas (Guangy *et al*., 2016).

In Ethiopia, planning the development of watersheds has started in the 1980's. It was concentrated on selected large watersheds located mainly in the highly degraded parts of the highlands of Ethiopia (Gete,2006). The purpose was mostly for implementing natural resource conservation and development programs (Lakew *et al*., 2005). The major part of the initiative was supported by the World Food Programme (WFP) through its Food-for-Work land rehabilitation project (Temesgen, 2015).

2.1.1.5 Soil and Water Conservation Practices

Soil Conservation The prevention of erosion on cultivated land and other areas depends essentially on the reduction of soil detachment and runoff on the maintenance of adequate vegetation ground cover. Soil conservation involves the various methods used to reduce soil erosion to prevent depletion of soil nutrients and soil moisture and to enrich the nutrients status of the soil. The conservation techniques include terracing and other (Semu, 2018).

Water Conservation:- Due to regular and limited rainfall, water is one of the scarce resource while it is years round necessity for people, livestock and plant (vegetation). It is availability influences the nature and extent of human settlement and grazing patterns as well as plant production. The ever-increasing demand for water and the high cost of the water development is main constraint to agricultural development (Semu, 2018).

Typically, there are two types of soil and water conservation structures. These are physical and biological.

A physical soil conservation practice is applicable of soil management using knowledge or art with the goal protection of soil resource form exploitation. In addition, among those different applications, different structure applied in different farmlands . However, these conservation applications depend on climate, soil type, vegetation cover and level of economy (Belele and Stein, 2005).

Biological soil conservation practices are vegetation strips, protective tree stands, natural drainage way and rotated by permanent grass cover and afforestation (Mitiku, *et al*., 2006).

2.1.2 Food Security

2.1.2.1 Concepts and Theories of Food Security

Food security is a concept that has evolved considerably over time and its definitions developed and diversified by different researchers, scholars and organizations. As Devereux and Maxwell (2001) cited in Furgassa and Degefa (2016) indicated that the concept of food security became a prominent issue on the development debate in 1970s. Since then, its definition has considerably evolved over time and its concern has also rarely been out of scene. There are approximately 200 definitions and 450 indicators of food security (Abduselam,2017).

Food security was first defined in the proceedings of the 1974 World Food Summit as: ‘ availability at all times of adequate world food supplies of basic food stuffs to sustain a steady expansion of food consumption...and to offset fluctuations in production and prices’ (Messay , 2010) . The comprehensively accepted version of definition is the one formulated in the First World Food Summit. It is defined as the situation when all people at all times have physical, economic and social access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life as (FAO, 1996) referenced in (Furgassa and Degefa , 2016) .

To develop a definition of food security which is more tailored to Ethiopia, (Degefa, 2007:4) mentioned in (Messay, 2011) as

> *'Household can be described as food secure when its livelihood activities allow to meet its food requirements and other basic needs, either through its own productions i.e. crop cultivation and/or livestock rearing, through having opportunities to run own non-farm ventures or to work with somebody else, or getting access to food through transfers'.*

In particular, food insecurity includes low food intake, variable access to food, and vulnerability-livelihood strategy that generates adequate food in good times but is not resilient against shocks. These outcomes correspond broadly to chronic, cyclical or seasonal, and transitory food insecurity, and all are endemic in Ethiopia (Devereux , 2000).

Chronic food insecurity is long-term or persistent in that it can be considered to be an almost continuous state of affairs. It is a continuously inadequate diet caused by the inability to acquire food. It affects households that persistently lack the ability either to buy enough food or to produce food by their own food production system (Abdulselam, 2017).

Seasonal or cyclical food insecurity may be evident when there is a recurring pattern of inadequate access to food such as prior to the harvest period (the “hungry season‟) when household and national food supplies are scarce or the prices higher than during the initial post-harvest period. It is generally considered to be more easily predicted than temporary food insecurity as it is a known and regular occurrence (Hart,2009).

Transitory food insecurity on the other hand, is usually sudden in onset, short-term or temporary and refers to short periods of extreme scarcity of food availability and access. Such situations can be brought about by climatic shocks, natural disasters, economic crises or conflict. Experiences of transitory food insecurity may arise through smaller shocks at the household level, for example, loss of income and crop failure while not the normal state of affairs shocks can be severe and unpredictable (Hart,2009).

Based on the definition of FAO (1996) there are four dimensions of food security; availability, food accessibility, food utilization and stability (Figure 2).

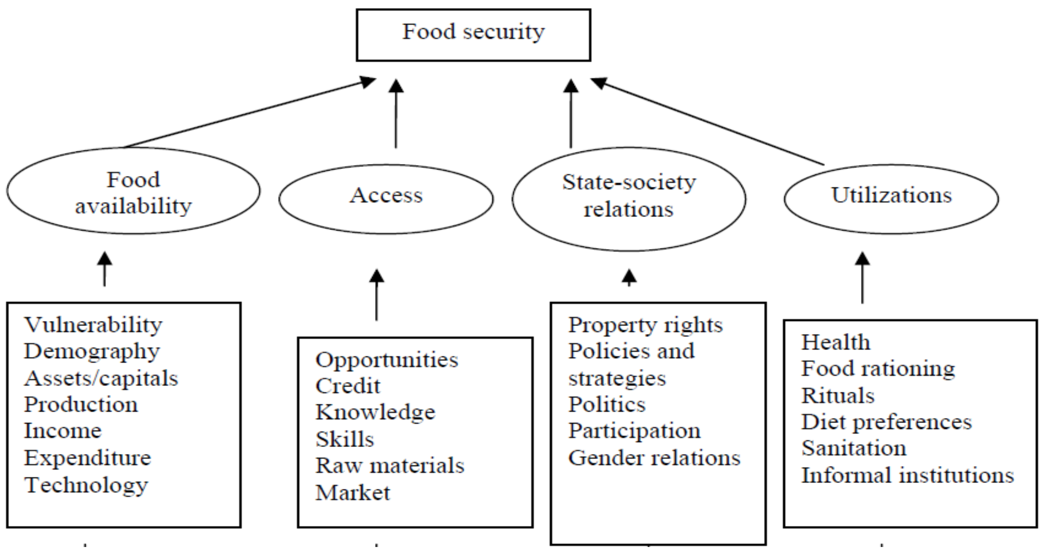

Figure 2: Household food security: research design (Degefa, 2005)

Food availability: refers to the presence of food at global, national, household and individual level, example when "sufficient quantities of appropriate, necessary types of food from domestic production, commercial imports, commercial aid programs, or food stocks are consistently available to individuals or nations." Hence, food availability is largely a function of macroeconomic factors.

Food Access: refers to the resources that households have to obtain foods, either through own production or through purchase. So, individuals need to have assets or incomes to produce, purchase in order to obtain foods needed to maintain their consumption. Hence, food access is largely related to household income and own production (USAID,2015).

Food Utilization: The World Food Summit's definition of utilization (the third element of food security) is "safe and nutritious food which meets their dietary needs". The availability of and access to food on their own are not enough, people have to be assured of "safe and nutritious food". (Pasquale and Matteo,2011).

Food Stability: refers to the stability of all other dimensions of food security over time. Even if your food intake is adequate today, you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of their nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status. Therefore, food security to be insured at global, regional, national, household, and individual level food stability should be maintained (FAO,2008).

2.1.2.2 Causes of Food Insecurity

Several causes have so far been explored to have impacted the food access by either undermining agricultural production or limiting social, physical and economical access of households. The principal factors attributed to the failure in Africa to adequately feed its population include: i) climatic hazards; ii) severe environmental degradation; iii) rapid population growth outstripping agricultural growth; iv) unstable macroeconomic environment and inappropriate government policies in some nations; v) low purchasing power of the people (poverty); vi) the absence of food security policies at national or regional levels; vii) lack of storage facilities; viii) limited access to infrastructure and basic services; ix) civil war; x) inappropriate incentives; and xi) low productivity of agriculture resulting from insufficient fertilizer use and poor control of weeds (Degefa, 2002).

As Hart (2009) and Tsegaye (2012) referenced in Messay and Shishay (2014) to inform that food insecurity is an aggregate of environmental tribulations, crude population growth, governance issue, poorly conceived policies, unstable food prices, natural calamities, instability of institutions, prevalence of diseases, and other socio-economic factors which deteriorate household food security situation coupled with weak household capacity.

Many studies agree that the damage of the biophysical elements in the environment have a significant role in determining food availability and access of households. This is part of the reason which led to initiation of idea of this study

2.1.2.3 Food Security Analysis

Food security analysis is mainly approached with complementarities of the two models known as Food Availability Decline (FAD) and Food Entitlement Decline. The models highlight the need for adequate food to be available and the households must have the capacity to acquire it. Food Availability Decline (FAD) which dates back to the writings of Adam Smith (1723-1790) and Thomas Malthus (1766-1834), proposes that famines are principally caused by a sudden decline in food availability. It refers to the per capita food availability decline attributed to various interrelated adverse environmental and socio-economic factors. The FAD model also argues that '…anything which disrupts food production…can cause famine [food insecurity] (Messay, 2016).

FED model is pioneered by Amartya Sen (1981) as an alternative method for food insecurity analysis which suggests that food availability in the economy does not necessarily entitle a person to consume it, and famine can occur without aggregate food availability decline. This means access to food plays a crucial role in securing command over food which is, in turn, determined by production among the other factors (Furgassa and Degefa , 2016).

2.1.2.4 Measuring food Security

Having in mind how food security frameworks developed to enable to understand the conceptual and theoretical aspects, a growing need and innovations evolved in devising techniques to measure/assess food security/insecurity. Food security has four components - availability, access, utilization and stability. Utilization, in the context of food security, refers to the individual's biological capacity to make use of food for a productive life. Consensus on the measurement of the utilization component has centered on various measures of nutritional status (anthropometric measurement) of children (FANTA III, 2006).

In many studies, attempts have been made to measure the access component of households food security. Household food access is defined as the ability to acquire sufficient quality and quantity of food to meet all household members' nutritional requirements for productive lives (FANTA III,2006).

There are plenty of techniques used to measure households food security/ insecurity where access is the key dimension to measure. Some of the most common techniques used and this study proposed to apply is the Food Consumption Score (FCS).

2.2.3 Production Efficiency

Productivity and efficiency are both measures of production performance. However, there is slight difference between them. One can improve the state of technology by inventing new ploughs, pesticides, etc. This is commonly referred to as technological change and can be represented by an upward shift in the production frontier. Alternatively, one can improve farmers` education, extension service, etc. This in turn will improve production efficiency of farmers and will be represented by farmers operating closer to the existing frontier. Hence generally, productivity growth may be achieved through either technological progress or efficiency improvement (Coelli, 1998). The simplest way to differentiate production and technical efficiency is to think of productive efficiency in terms of cost minimization by adjusting the mix of inputs, whereas TE is output maximization from a given mix of inputs (Palmer and Torgerson, 1999).

2.2.4 Approaches of Production Efficiency

The concept of efficiency can be explained more easily using input or output-oriented approaches the input -oriented (input overuse approach) measure of efficiency addresses the question "by how much can input quantities be proportionally reduced without changing the output quantities produced?" . The output-oriented approach (output shortfall approach which is the main focus of this study) measure of efficiency addresses the question "by how much can output be increased without increasing the amount of input use by utilizing the given inputs more efficiently?" (Coelli *et al.*, 1998)

As depicted in Figure 8 and Figure 9 in the Appendix, suppose a farmer is producing his output depicted by isoquant SS' with input combination level of (X1 and X2). Production at input combination at point P is not technically efficient because the level of inputs needed to produce the same quantity is Q on isoquant SS'. In other words, the farmer can produce at any point on SS' with fewer inputs (X1 and X2), in this case at Q in an input-input space. The degree of TE of such a farm is measured as OQ OP, which is proportional in all inputs that could theoretically be achieved without reducing the output.

On the other hand, In the output-oriented perspective, efficiency is evaluated keeping inputs constant. According to Farrell (1957), output oriented measures can be illustrated by considering the case where production involves two outputs (Y1 and Y2) and a single input (L). If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve in two dimensions as follows:

The production possibility curve is represented by the curve ZZ' in Figure 2, which represents technically efficient combinations of production of outputs Y1/X and Y2/X. Given same level of input (X), it is not efficient to produce at point A. Considering a firm situated at point A, the TE can be calculated as OA/OB.

As it is used by Shumet, (2011) and made a citation on Tewodros (2001) and Zenebe et.al (2005) given we are under traditional agricultural settings the concern is rather not that inputs are over-used but output short-fall. As such, this study is done using the out-put oriented approach.

2.2 Review of Empirical Literature

2.2.2 Extent of Land Degradation

It is evident from different studies that land degradation is a serious problem in globally in general and in Africa and Ethiopia in particular. Although the extent of global land degradation is open for debate, (Adams and Eswaran, 2000) estimate that it impacts 2.6 billion people in more than a hundred countries, covering over 33 per cent of the earth's land surface. Around 73 per cent of rangelands in drylands are currently being degraded, together with 47 per cent of marginal rainfed croplands and a significant percentage of irrigated croplands (Gisladotir and Stoking, 2004).

Africa accounts for 65 % of the total extensive cropland degradation of the world (Thiombiano and Tourino, 2007). According to the World Bank, at least 485 million Africans are affected by land degradation, and Africa is burdened with a US$9.3 billion annual cost due to this phenomenon (Thiombiano and Tourino, 2007).

In Ethiopia, historical documents show that forest and woodlands covered over 40% of the total area of the country only a century ago (Badege, 2005). Presently, this figure is estimated to be less than 10% (Bane, *et. al.*, 2008). As FAO (1986, 1999) cited in Woldeamlak (2009) cited, the country's annual deforestation rate is estimated to be about 62,000 hectares, attributed primarily to the increased demand for farmland, fuelwood, and settlement sites (Messay and Tsegachew, 2013).

Deforestation in one of the manifestations of land degradation which caused sizable damage in the Ethiopia and the following table is used by (Berry, 2003) to show the extent and dynamics of the damage.

Table 1: Forest Reduction in Ethiopia between 1950 to 2000

	Original Extent of Forest	1950's	1990	2000
Ethiopia	65%	16%	2.70%	2.20%
Highlands	90%	20%	?%	5.60%

Source : Berry, 2003

In Oromia Region, the average erosion rate for agricultural land has been estimated at about 40 t/ha but there is wide variation between different parts of the region and between production systems (Bizuayehu *et al*., 2002). In Degem woreda, where this study is conducted land degradation which manifested by increased deforestation is highly prevalent (Degem SLM Plan, 2012). One can understand how the land degradation has been crucial by looking at the change in the land use below compared to what has been 40 years ago.

Table 2: Change in Land Use Pattern in Degem Woreda

Main land use type	Proportion Before 40 yrs	Current Proportion
Farmland	34	51
Homestead	11	15
Grazing	31	7
Forest	23	1
Degraded Hillside		23
Others	1	3

Source: Leman Watershed Development Plan, 2012

2.2.3 Impact of Land degradation

Land degradation results in sizable cost associated with it by bringing about an immense damage on the ecology, social and economic arena. Due to the presence of land degradation, Africa as a whole has become a net food importer since the mid-1980s. However, the economic implications of land degradation are particularly severe in Sub-Saharan Africa because 65% of the population is rural and the main livelihood of about 90% of the population is agriculture (Temesgen *et al*., 2014)

Securing food and livelihood is inextricably linked to the exploitation of the natural resources base (land, water and forest) in Ethiopia, where over 85 percent of the population lives in rural areas and depend on smallholder agriculture. The pressure of intense human activity and improper farming and management practices pose serious threats to the sustainability of the natural resources and maintaining ecological balance (FAO, 2003).

There are evidences that show soil and water conservation measures bring a meaningful impact on income and improved household level of food consumption. As noted by FAO (2003) where examples mentioned using controlled and stationary scenarios explained as "under the "Stationary" scenario (no soil conservation and no change in technology and no migration), agricultural production will be reduced to 30 percent by 2030, and per capita per annum will decrease from $372 in 2000 to $162 in 2030, while food availability per capita will plunge from 1971 kcal per day to 685 kcal per day in 2030. In the “Control” scenario (soil conservation is practiced) productivity will improve by 9 percent in 2030, per capita income will decrease to $260 in 2030 while food per capita will improve from 685 kcal to 1085 kcal per day. Thus, a development path without soil conservation would be disastrous and clearly not an option.

Temesgen *et al*. (2014) highlights that environmental degradation have both socio-economic and ecological impact. The resultant ecological impacts of land degradation in Ethiopia include loss in the chemical, physical and/or biological properties of soil which directly affects the type of plant that are grown on the area, reduced availability of potable water, lessened volumes of surface water, depletion of aquifers due to lack of recharge, and biodiversity loss (Berry,2003). Land degradation reduced livestock productivity as a result of reduced grazing resources, loss of nutritious plants and grass species (Temesgen *et al*., 2014)

2.2.4 Adoption of SWC practices

Several efforts have been designed and implemented in an effort to combat the impacts of land degradation on the environment, society and economy. SLM is one of the approaches which is being extensively adopted and practiced in the globe in general and in Ethiopia in particular.

There are difficulties in quantifying the impact of SLM at community and households’ level. Nevertheless, some studies and reviews attempted to understand the level of importance of activities implemented under this approach. The (World Bank, 2006) revealed SLM projects had a high rate of success in achieving the intended project outcomes. The economic rate of return (ERR) estimated for all project expenditures ranged between 6.7 and 34 percent, averaging 21.8 percent

Paswal and Chiristopher (2006) studied on the determinants of households’ involvement in the natural resource management. As per the study, the size of the farm owned by a household, the value of its livestock, off-farm income, family labor supply, and the educational attainment and gender of the household head all had a significant positive effect on the likelihood of adoption. Similar factors were found to be statistically significant in discouraging abandonment of the practices under study. There, it seems to exist reinforcing feedback between investments in soil fertility management and household wealth, as measured by asset endowments.

Albert (2004) also reiterated that the acquisition of information about resources management technology is influenced by age of farmers and actions of official extension services; the adoption decision is influenced by prior utilization, the bundle of land property rights owned, and the level of financial liquidity; and the intensity of adoption is influenced by the percentage of the farm that is degraded.

2.2.5 Food Insecurity in Ethiopia

As indicated by Africa Food Security and Hunger Multiple Indicator Scorecard, Ethiopia ranked first in having the highest number of people in state of undernourishment which is 32.1 million people in 2014 (Abduselam, 2017). Ethiopia has been structurally food deficit since at least 1980. The food gap rose from 0.75 million tons in 1979/80 to 5 million tons in 1993/94, falling to 2.6 million tons in 1995/96 despite a record harvest (Befekadu and Berhanu, 2000:176). Even in that year, 240,000 tons of food aid were delivered, suggesting that chronic food insecurity afflicts millions of Ethiopians in the absence of transitory production shocks (Devereux, 2000).

As noted by Abduselam (2017) the 2015 El Niño drought is one of the strongest droughts that have been recorded in Ethiopian history were more than 27 million people became food insecure and total population of 18.1 million people require food assistance in 2016. Ethiopia experiences both chronic and transitory types of food insecurity. The country currently identified and support over 7.8 million with in over 300 woredas chronically food insecure population across the country (Table 1). Factors driving food insecurity includes; increased population, environmental degradation and limited livelihood options (MoARD, 2010).

Table 3: PSNP plan for 2009 by Region, Ethiopia

No	Region	No.of woredas	Bene.by resource type			Tot.NO.Benef
			Food only	Cash only	Food+Cash	
1	TIGRAY	31	8000	399,036	1,046,671	1,453,707

2	AMHARA	64	1,091,335	409,801	1,018,693	2,519,829
3	OROMIYA	78	229486	375651	834,627	1,439,764
4	SNNP	78	0	0	1,456,953	1,456,953
5	AFAR	32	0	472,229	0	472,229
6	SOMALIYA	15	0	409,771	0	409,771
7	HARARI	1	0	0	16,136	16,136
8	DIREDAWA	1	0	52,614	0	52,614
9	FFSCD	-	0	0	0	0
	TOTAL	**300**	**1,328,821**	**2,119,102**	**4,373,080**	**7,821,003**

Source: Ministry of Agriculture and Rural Development (MoARD)

As evidenced from the recently released NDRMC (2019), around 8.3 million people are in need of emergency food assistance with conflict and weather adversities are accounted as major drivers of seasonal food insecurity. Food insecurity in Ethiopia display variation within seasons across a year and among households of different social groups. This show food insecurity exists in areas commonly regarded as food self-sufficient and this draws an attention for food security to be studied and explored in various geographic and socio-economic contexts. Degefa (2002) found out that 40% of the households (out of 220 sampled households) faced seasonal food shortage. The proportion of farmers practicing double cropping who reported to have faced seasonal food deficit was 29%, while the proportion among single harvesters was 52%.

In Oromia region, where this study is undertaken, food insecurity is prevalent with the eastern parts of the region facing more severe problem than the west. The MoARD (2009) indicated over 1.4 million as chronically food insecure and the (NDRMC, 2019) revealed over 4.2 million people required emergency food assistance.

2.2.6 Production Efficiency

Under this session literatures on production efficiency that deals with the context of Ethiopia or elsewhere are reviewed, and more focus is given to those literatures that discusses more about technical efficiency. Different researchers did a study on production efficiency using either one or two stage approaches.

Byiringiro and Reardon (1996) using data from a sample of small-scale farms in Rwanda, first estimated a production function and then regressed the derived marginal value productivities for land and labour on the level of implementation of soil conservation practices, among other variables. These authors found a significant positive effect of soil conservation on land productivity, but they did not account for the fact that the adoption of these kinds of practices is arguably an endogenous variable.

A study in the South West Nigeria by (Kehinde and Awoyemi, 2009) cross-sectional data was obtained from 170 sawnwood producers using a two-stage sampling procedure. Results indicate that the mean technical, allocative and economic efficiencies of sawnwood producers in Ondo and Osun states are 68%, 81% and 54% and 79%, 83% and 67%, respectively. Furthermore, sawmillers' level of efficiency can be improved if sawlog, electricity and capital are effectively used in Ondo state while the same can be achieved if sawlog is efficiently used in Osun state. Managerial type, capital base and capacity utilization deserve attention in order to improve the present efficiency level of sawmillers.

Shumet (2011) cited in Solomon (2014)) a study that used a survey data collected by Tigray Microfinance in the year 2009 to estimate small holder farmers' TE and its principal determinants. He used both descriptive and econometric methods of analysis. In his study, he has tested the functional form, existence of inefficiency, and the joint statistical significance of inefficiency effects. The maximum likelihood parameter estimates showed that except labor all input variables have positive and significant effect on production. According to the study, the mean TE of farmers was 60.38 percent implying that output in the study area can be enhanced by 39.62 percent using same level of input and the current technology. The estimated stochastic frontier production function revealed that education of household heads, family literacy, family size, share cropping, credit access, crop diversification, and land fertility were found to have a positive and significant effect on efficiency. In contrast, Households' age, dependency ratio, livestock size, and off-farm activity affect efficiency negatively and significantly.

2.3 Analytical Framework

The study attempts to explore the food security status of households in light of how soil and water conservation and practices and other soil fertility improvement efforts within the watershed management project contributed to enhanced food security of households. Hence, the study is framed on the basis of understanding conceptual, theoretical and empirical narratives explains the relationship between natural resource conservation and food security.

Conceptually, FAO (2008) explains 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 their dietary needs and food preferences for an active and healthy life.

Availability, access, utilization and stability are generally recognized as the dimensions to include and analyze in any index of food security (Pasquale and Matteo,2011). Food availability addresses the household adequate supply of food and is determined by the level of home production, purchase in the market or food transfer (Meskerem, 2011). Food availability is a necessary but not sufficient condition for food access, which is, in turn, a necessary but not sufficient condition for food utilization (Dula and Degefa, 2017). In this regard, (Amartya Sen, 1981) argues, ensuring access to food, not merely increasing food supplies, should be regarded as critical component of food security.

Food access consists of three elements, which are physical (situation where food is being produced in one part of a country, but an inefficient or non-existent transport infrastructure means that food cannot be delivered to another part suffering from a lack of food.), economic/financial (when people can afford to buy sufficient food) and socio-cultural (Social conflict and civil strife can seriously disrupt food access) (Pasquale and Matteo, 2011). This study designed to examine food security status of households in the study area through applying food security measurement techniques that examines households food access towards adequate quantity and quality of food consumption. As such, the Food consumption score (FCS) is chosen as main and most appropriate food security measurement (Figure 3).

The Food Consumption Score (FCS) is an index that was developed by the World Food Programme (WFP) in 1996. The FCS aggregates household-level data on the diversity and frequency of food groups consumed over the previous seven days, which is then weighted according to the relative nutritional value of the consumed food groups.

In an attempt to ensure food security of households, natural resource play a central role as they determine food availability through agricultural production and enhance households financial/economic capacity. Land degradation is the common environmental problem in Ethiopia. It is one of the major causes of low and declining agricultural productivity and continuing food insecurity and rural poverty (Temesgen *et al*., 2017). Land degradation results in number of immediate and underling effects on soil properties. As per Bizuayehu *et al* (2000) soil degradation through erosion, nutrient loss and other processes results in undesirable physico-chemical soil properties and thereby considerably depresses crop yields. It also underlines the immediate impact of land degradation has reduced crop yield and productivity and makes an evidence on a study where barley yield was found to have declined by 72% over a 15-year period due to erosion.

Land degradation has also multiple effects which leads to poverty, increased vulnerability and food insecurity. Land degradation reduced livestock productivity as a result of reduced grazing resources, loss of nutritious plants and grass species. Due to land degradation, increased runoff and reduced infiltration contributes to flooding problem Temesgen *et al* (2017). In a bid to devise mechanisms to combat land degradation and impact of land degradation it is imperative for some to look at its broader perspectives and underlining causes (Figure 3). Fitsum *et al* (1996) lists down; population pressure, poverty, high cost and limited access to agricultural inputs and credit, low profitability of agricultural production and many conservation practices, high risks facing farmers, fragmented land holdings and insecure land tenure, short time horizons of farmers, and farmers' lack of information about appropriate alternative technologies as some of the underlining factors casing land degradation.

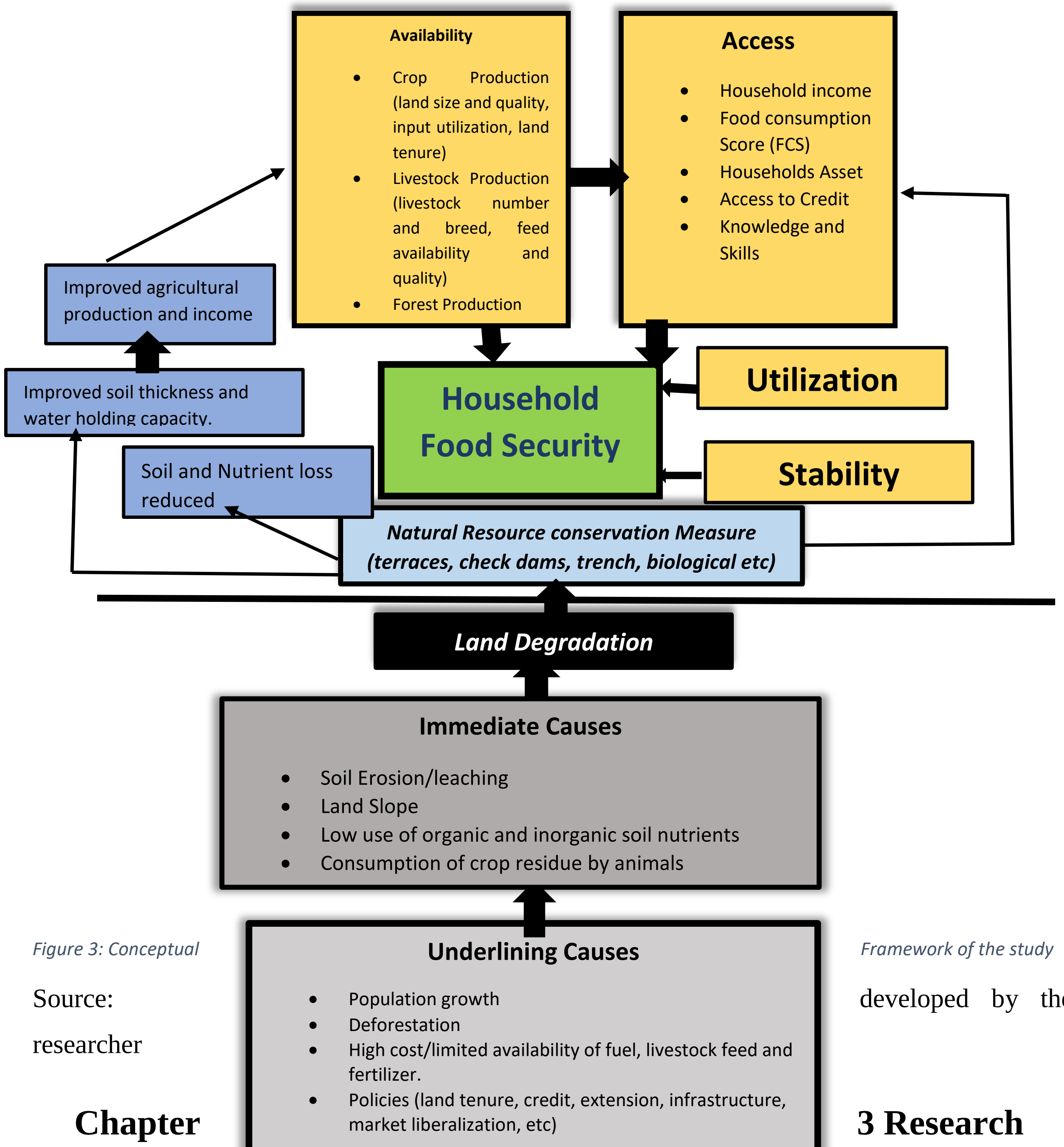

Figure 3: Conceptual Framework of the study

Source: developed by the researcher

Chapter 3 Research Methodology

3.1 Description of the Study Area

3.1.1 Geographic Location

This study is undertaken in Leman watershed situated in Degem woreda in North Shewa zone of Oromia Region. Degem woreda is located at 11^{0}04’30”-11^{0}05’latitude and 36^{0}52’ 36^{0}54’longitudes (Figure 4). Its capital town Hambiso is one of 16 woreda towns in North Shoa Administrative Zone located approximately 13km Northwest of Fitche, the capital town of North Shoa Zone and about 125km North West of Addis Ababa. Degem is bordered on the south by the

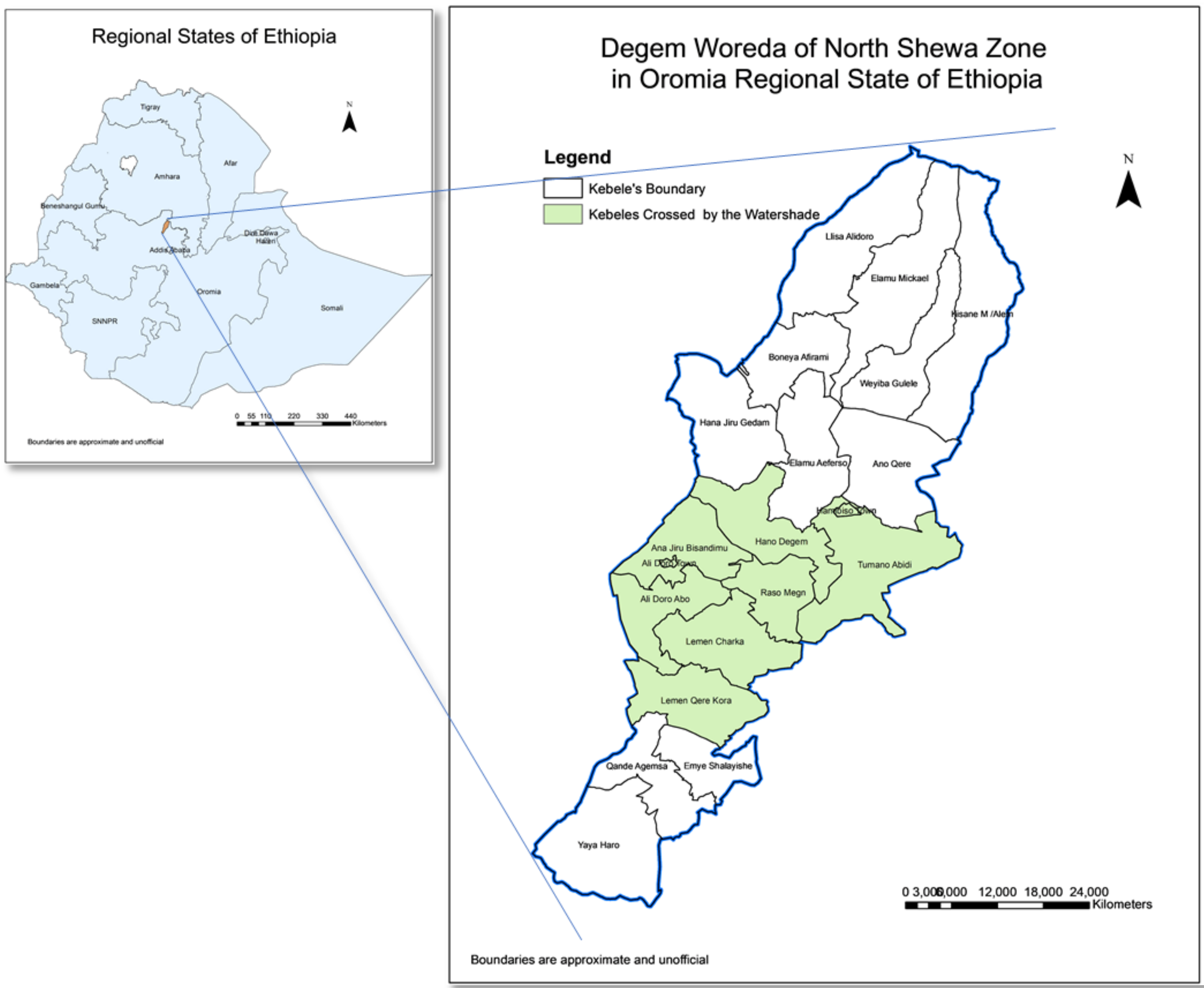

Figure 4: Map of the Study area; Degem woreda

Mugger River which separates it from the Eastern wolega zone, on the west by Kuyu, on the northwest by Hidabu Abote, on the north by Jemma River, which separates it from the Amhara Region, on the northeast by Girar Jarso,and on the east by Yaya Gulele and Debre Liban Woreda (Eshetu, 2011)

There is a total of 18 kebeles in Degem woreda. The Leman watershed which is also called as major watershed is situated across 6 kebeles with in the woreda. It stretches up to 15 km far from Degem town, capital of Woreda and 27 Km from Fitche, Zonal town. Geographically, it is located between 9^{0}41'33"-9^{0}47'44"N Latitude and 38^{0}30'29"-38^{0}39'14"E Longitude (FDRE-SLMP, Leman Critical Watershed Factsheet, 2014)

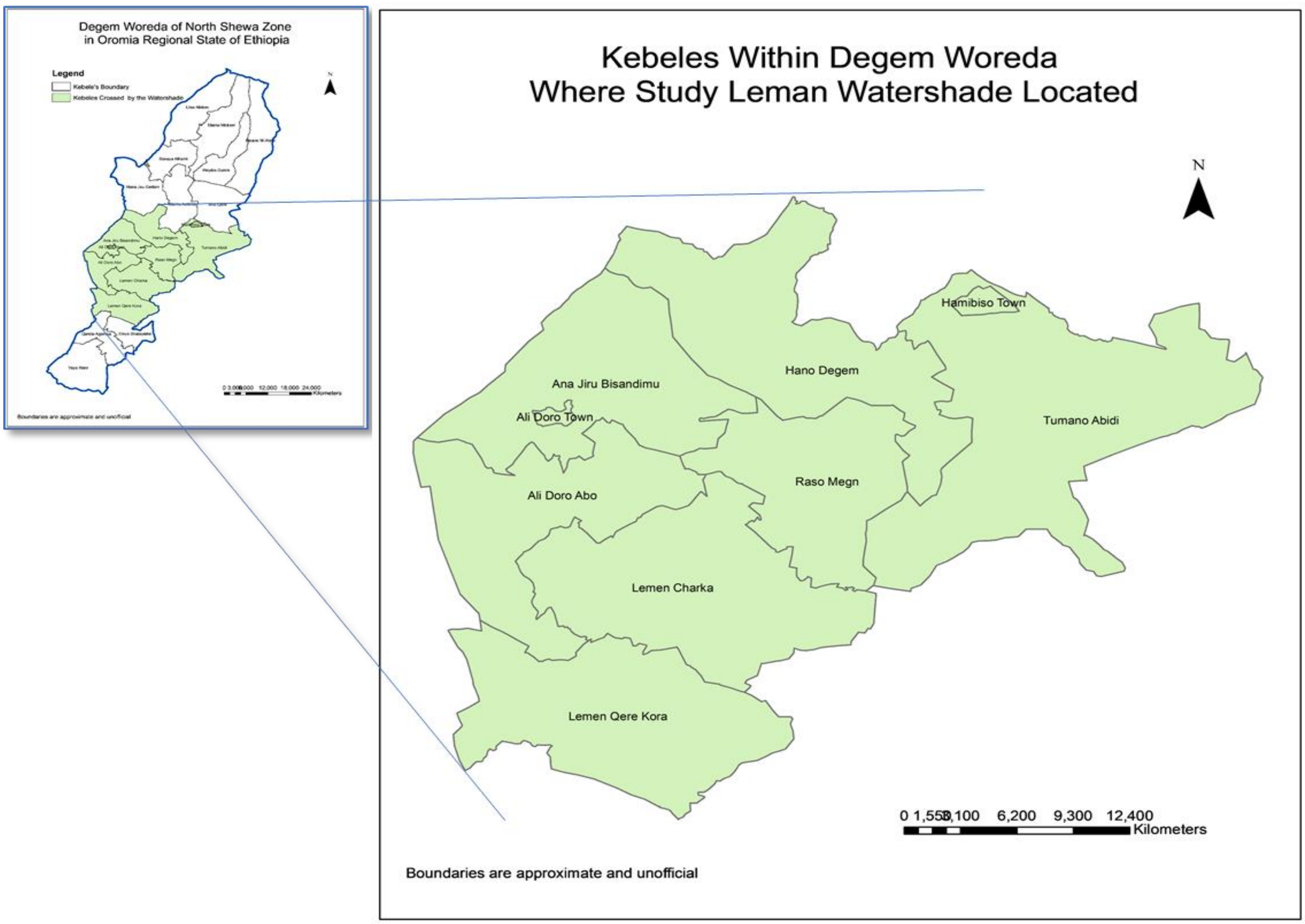

Figure 5: Map of the study area; Leman watershed.

3.1.2 Demography

According to the Central Statistical Authority (CSA) population projection in 2019, the total population of the woreda currently is estimated as 132, 026 (CSA, 2013) . In the Leman watershed a total of 20,719 inhabitants accommodated in 3,654 households, with household size of about 6 persons on the average. Women headed households constitute 14% of the total households (FDRE-SLMP, 2014).

3.1.3 Physical Features

The elevation of the Leman watershed ranges from 2540 to 3240 masl (FDRE-SLMP, 2014). The area is characterized by hilly and rolling characteristics in the middle and upper part of the watershed, while it is with gentle slope and flat in lower part of the watershed.

The major soil types include loam (39%), clay (58%), and sandy (3%). The total land size of this major watershed is about 9344 hectares. Cultivated land covers about 51%, shrubs and forests 1%, homestead 15%, pastureland 7%, and degraded hillsides comprise about 23%, others 3% of the total land size. Cropping activity is encroaching into vegetation sites, hillsides, and steep slope areas. Gully land stretches over 3.1 km covering 9.5 ha (FDRE-SLMP, 2014).

The rainfall is bimodal, with the long-term average annual rainfall of about 1150 mm occurring between June to September locally known as *Kiremt* and the short rainy season (*Belg*) running from January to April . The average maximum and minimum air temperatures of Degem Woreda are 22.09 and 10.24°C (Getachew *et al*., 2012).

3.1.4 Economy

Crop production is the primary agricultural activity in the watershed and is supplemented by livestock production. Crop production is mainly cereal oriented where barley is known as the most important cereal among others. Considering a household, the average land holding which includes crop cultivation, grazing and other purpose is 1.85ha is typically 75 percent dedicated to cereal production which indeed accounts for 61 percent of the total production (FDRE-SLMP, 2014).

Animals kept include cattle, sheep, goat poultry, horse, donkey, and mule. Oxen are used to plough cropland, cows for milk, shoats for sale, and equines for transport. Although irrigation practices exist in the watershed, the potential declined overtime as water sources are affected by extensive deforestation practices of the hillsides.

Improved agricultural inputs utilization is prominent in the area. Application of chemical fertilizer covers 71% of the cropland, natural fertilizer 3% and improved seeds 48% of the total cultivated land. Improved seeds of wheat and Teff are the ones under promotion. The use made of improved seeds covers 68% of total cereal crop field (FDRE-SLMP, 2014).

Land, like other parts of the country, is the property of the State. But farmers have the right to use land themselves or rent to others. The land was distributed during the *Derge* regime and there has not been further redistribution of land since then, except informal land transfer through kinship. The land holding size varies from 1 to 3 hectares (FDRE-SLMP, 2014).

Crop production is the most important sources of households' income which make up 75 percent of the total income and the remaining income is mainly drawn from livestock (FDRE-SLMP, 2014). As per the problem identification exercise done in the watershed by the SLM, lack of access to potable water, soil erosion and poor access road were identified as the top three.

Under the SLM project, there are multiple and integrated natural resource conservation and livelihood enhancement activities were designed and implemented on communal households' farmland FDRE-SLMP (2014).

Figure 6: SWC practices in Leman watershed, Degem woreda, Photo by; GIZ

There are two major sub-components under the farmland which are soil and water conservation (physical and biological conservation measures) farmland agriculture (improved seed provision and soil fertility management)

3.1.5 The SLM Programme

In explaining about Degem woreda and discussion about linkage of the natural resource conservation practices and food security, it is worth mentioning about the SLMP. Between 1995 and 2009, the Ethiopian government incorporated SLM practices into agricultural extension packages/programs for individual farm-households. Recently, SLM practices have been promoted and implemented through community mass mobilization at a watershed level, as part of Ethiopia's Growth and Transformation Plans (GTP I and II) (Meskerem *et al*., 2018).

Sustainable Land Management (SLM) is a countrywide program framework developed by the government of Ethiopia. The framework sets the key priorities for SLM investments in the country, describes the strategy to scale up SLM and define the approach and the mechanisms for coordination, consultation, participation and monitoring and Evaluation. The overall objective is to improve the livelihood of land users and communities through the implementation of SLM activities in the framework of community-based watershed development plans (FDRE-SLMP, 2012).

The development objectives of the project are to reduce land degradation in agricultural landscapes and improve the agricultural productivity of smallholder farmers. Primary development partners in the National SLM Platform include the World Bank, GIZ, SIDA and World Food Program.

The SLM program combines the benefits of land tenure security and sustainable land and water management practices in the watersheds and generally consists five given components (i) Watershed Management (ii) Rural Land Certification and Administration, (iii) Policy Framework Improvement, (iv) Knowledge Management, and (v) Project Management plans (FDRE-SLMP, 2012).

As Degem woreda is one of the areas in North Shewa zone of Oromia Region where land degradation has been identified as a key food insecurity driver and cause of poverty. Multifaceted forms of land degradation include, deforestation, soil erosion and extended gully formation are the major among others which have happened in the watershed.

Subsequently, Degeme woreda has been chosen as one of the woredas where environmental degradation emerged as a key agenda and selected as one of the woredas to be covered by the Sustainable Land management (SLM) programme which is implemented under the leadership of Government of Ethiopia involving other development partners including GIZ, World Bank and other partners FDRE SLMP (2014).

3.2 Research Design

For Durrheim (2004), research design is a strategic framework for action that serves as a bridge between research questions and the execution, or implementation of the research strategy. As this research aims to attain the contribution of natural resource conservation for household’s food security a cross-sectional type of research design which involve the collection of data at a point in time to understand how the natural resource conservation measures relate to food security as the data during the time of the study is capable of exploring the research question.

3.3 Research Approach

The study applied both qualitative and quantitative data collection and analysis in parallel form as the research intends the two methods to complement each other for a complete analysis. From the point of view of quantitative data collection and analysis, primary data is collected from sample households through application of survey that uses questionnaire as a tool for data collection. Regarding the qualitative approach, focus group discussion with the group of mixed households groups who benefitted from the watershed management progemme is undertaken.

3.4 Sampling Method

3.4.1 Sample Size Determination

As household survey is one of information collection technique to collect primary data as part of quantitative approaches of the study, identifying sample households and collecting data is one of the most important activities of the study. To determine the sample size the study carefully considered key parameters that are crucial in determining representative and cost-effective sample size. Sample size is determined by several factors such as homogeneity/heterogeneity of population, tolerable sampling error (level of precision) and confidence (risk) level Messay (2011).

Leman major watershed is inhabited by 3645 households among which 2803 are land holding households. The total sample size is computed using the equation developed by Cochran (1963:75). As we determine sample size from a finite population, the equation that is used for finite population will be applied to calculate the sample size.

The Cochran's equation for sample size determination is:

$$n_0 = \frac{Z^2 pq}{e^2}$$

Which is valid where n_0 is the sample size, Z^2 is the abscissa of the normal curve that cuts off an area α at the tails (1 – α) equals the desired confidence level, e.g., 95% i. e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is 1-p. The value for Z =1.96 is found in statistical tables which contain the area under the normal curve.

For a finite population we further apply the equation below:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

In our case N= 2803, we do not know the variability in the proportion that will adopt the practice; therefore, assume p=.5 (maximum variability). Furthermore, suppose we desire a 95% confidence level and ±5% precision (University of Florida, nd).

Accordingly, the calculation of the sample size generated a total of 338 households needed to be sampled and interviewed. Considering the homogeneity of the population and the cost limitation the researcher decided to bring it down to 300 households.

3.4.2 Selection of Sample Households

Once we know the total sample size, the number is proportionally disaggregated across different community watershed which make up the larger Leman major watershed. In the Leman watershed there are 11 different community (micro) watersheds which constitute different number households as shown in Table 4.

Table 4: Study watersheds, Sample watersheds and Sample size determination

Kebele	**Micro-watershed**	**Area (ha)**	**Total House holds**	**Sampled Watersheds**	**% of total HHs**	**HHs of Sample MWs**	**Sampled HHs**
Leman Chereki	cheraki andode	848	348		10		
Leman Kere Kora	Leman Silase	674	406		11		
Leman Chereki + L K Kora	Chali	891	301		8		
Leman Chereki	Sendafa-Jirmi	770	315		9	315	60
Raso Megna	Tembero	958	396		11		
Leman Chereki	Leman Tika	976	270		7	270	60
Alidoro Abo	Dagamso/	751	284		8	284	60
Raso Megna	Harkiso	753	304		8	304	60
Ana Jiru Bisandimo	Adere Tokicho	752	321		9	321	60
Timano Abdi	Lebu	843	298		8		
Tumano Abdi	Dibdibe	1142	411		11		
	Total	**9358**	**3654**		**100%**	**1,494**	**300**

Source: developed by the researcher which derived based on data from woreda Agriculture office

The households sample survey for this research employed two stage cluster sampling. For the selection of the first stage cluster list of watersheds are taken as a sample frame and from which five watersheds are purposely selected as cluster of households out of eleven watersheds (Table 4). The representativeness of geographic characteristics like watersheds with similar physical features which includes AEZ, topography, belongingness to similar clusters are taken into account to avoid duplication. Discussion with woreda experts was instrumental in selection of these sample watersheds. Determination of household sample size within micro-watersheds is based on the proportion of households in respective watersheds. As number of households in each sample watersheds are closer, the researcher decided to take equal sample size (60) in the 5 sample watersheds. The second stage sampling was the selection of sample households and list of households in each watershed served as sampling frame. Systematic random sampling technique was used to determine the sample households to be interviewed.

3.5 Data Collection Methods

3.5.1 Household Survey

As described above, primary data was collected through both quantitative and qualitative techniques. The most important data acquisition for the study is primary data collection through household survey. As such, questionnaire was designed to facilitate the data collection process. As the survey is conducted with in Oromia region, the questions were translated into *Afan Oromo* (Oromo Language) for simplicity and precision purposes.

Prior to the data collection, the researcher made a critical consultation with the woreda office of Agriculture (WoA) , on the possible options where we get enumerators. Decision was then made to use the community facilitators who were serving as community link agents of SLM project during the project period. They are considered to be appropriate in terms of education background and familiarity of their respective watersheds. Hence, five enumerators were selected one for each cluster watersheds. Moreover, the WoA assigned an expert on natural resource management to supervise and support the data collection process. Once the enumerators were selected, training organized within the MoA office[2] and questionnaire was pretested before actual field work began.

3.5.2 Focus Group Discussion (FGD)

A checklist was developed to serve as a guide to undertake discussion with selected members of the community. Five focus group discussion were done one in every micro watershed. Six to eight people participated in each discussion that also involved women. Women, youth, adult and

[2] The main contents of the training session included; objective of the study, going through the questionnaire and through discussion on how data will be collected on each enquiry of the questionnaire, enumeration tip and discussion on the list of do and don’ts during enumeration and on the necessary ethical considerations.

elderly took part during the discussion so that hosueholds of different age group and economic status represented in the FGD. The discussions were made using the local language and participants were made free to forward their genuine ideas in the course of the discussion. A woreda expert who was versatile in community facilitation and discussion was instrumental to lead the discussion and summarize ideas generated during the discussion.

3.5.3 Field Observation

Field observation and discussion by the researcher was made both at woreda level and site visit employed as techniques of information collection. The selection of sites was made based on the recommendation of the woreda experts, by which the took into account the presence of all sorts of SWC activities. This created a very good opportunity for the researcher to get an insight of the area of the study, acquire deeper understanding of the people and the activities in the study area. During the field observation, the researcher held through discussion with the woreda office of agriculture on the historical background and performances of the SLM project at which the research focuses to investigate the contribution of the effort on food security. While travelling to the site where the communities live and natural resource conservation activities are implemented, it has created opportunity to personally visit the community and activities at the ground. This was extremely beneficial in having a deeper and comprehensive view and input for the study.

3.5.4 Secondary Data

The researcher obtained secondary data from two very important sources; the government and non-government organizations. Woreda office of Agriculture was the major counterpart selected for discussion and secondary data collection, while GIZ was the major source for providing secondary information on project plan, achievement, fact-sheets, reports and other document which were vital in designing the research and served as an input in many pieces of the study.

3.6 Description of Primary data

Empirical literatures indicate that there exist positive or negative relations between the dependent parameter (SWC) and the explanatory variables. On a study made in watershed in the Ethiopia highlands; farm labor, parcel size, ownership of tools, training in SWC, presence of SWC program, social capital (e.g., cooperation with adjacent farm owners), labor sharing scheme, and perception of erosion problem have a significant positive influence on actual and final adoption phases of SWC. In addition, the final adoption phase of SWC is positively associated with tenure security, cultivated land sizes, parcel slope, and perception on SWC profitability (Akalu *et al.*, 2016).

According to Birehan (2009) farmers' level of perception on soil erosion, farmers experience in farming and extension service given by development agents increases the likelihood of adoption of soil and water conservation practices measures by the farmers. On the other hand, involvement in off-arm activities has a negative and significant influence on the adoption of soil and water conservation activities.

As discussed in the sessions above, data for this study is obtained from field through household survey using questionnaires as a tool to collect the necessary data. As the main intention of the study is to understand the impact of SWC technology selection and application, information on the type and extent of SWC technology implementation was the core for collecting data. As such, in this regard different types of SWC practice (soil bund, stone bund, biological plantation and/or combination of any of them) data was collected. In addition , information on involvement of households in other soil fertility improving practices was also part of the data collection. In general , as variables that are believed to explain the adoption and impact of SWC practices, data collection included:

- Household characteristics: Household age, household sex, household size, household education, household training, experience in agriculture, households livelihoods.
- Economic characteristics: land holding, livestock holding, other assets possession, agriculture labour employed, type of livestock improving activities involved, agricultural input utilization.
- Plot characteristics: size of plot, slope, type of soil, perceived soil fertility, perceived severity of soil loss, land ownership and land certification.
- Access to services: Access to irrigation, access to extension services, credit services, access to market and assistance.

- Income and food security indicators: households income from crop sale, households income from livestock and other livelihoods strategies, questions for computing food consumption score (FCS).

The list of main variable included in the data collection and analysis of this study and their description is presented in the Table A1 in the Annexes.

3.7 Data Analysis

As deemed necessary both descriptive and econometrics methods are applied in analyzing and interpreting the data collected. The main techniques included discussion of key descriptive statistics (frequency, mean, standard deviation , maximum and minimum) of the selected variable which are used as dependent and explanatory variables in the models used in the study.

The models used in the study includes:

3.7.1 Multinomial logit model

One of the specific objectives of this study is to examine the impact of natural resource conservation practices on improving production thereby enhancing household's food security. While adoption of new technologies could result in positive outcomes, estimation of such outcomes in observational studies is non-trivial because of the difficulty of observing the counterfactual. Sometimes, technologies that are not randomly assigned to adopters have results that are crowded with bias (Ngombe *et al*., 2017) For instance, adoption of soil and water conservation practices determined by households unobservable characteristics like land quality, level of erosion, awareness, access to relevant programs or project and other aspects of the households and other factors outside the household.

Hence, this study employs an endogenous regime switching (ERS) regression approach to investigate the relationship between household food security and the adoption of natural resource conservation measures while accounting for the heterogeneity effects of households. Multinomial endogenous switching regression (MESR) model assumes households adopt and adapt technologies in this case application of soil and water conservation practices to maximize their utility which raises their income and crop production, thereby improve food security.

In the MESR approach, the decision to adopt the technology its effect on the outcome variable (food security) is estimated in two separate stages. In the first stage, the multinomial logit selection model is used to model farmers' choice of conservation practices while taking into account the inter-relationships among them. In the second stage, the impacts of individual and combined conservation practices on food security evaluated using OLS with selectivity correction terms from the first stage.

The requirement that the ith farmer chooses any combination j over any alternative package m is that $U_{ij} > U_{im}$ $if\ m \neq j$ Let U_{ij}^{*} be the latent variable to index the expected profit derived from adoption of package j which is determined by both observed and unobserved characteristics:

$$U_{ij}^{*} = ¥+ a_j Z_i + \varepsilon_{ij} \text{ .... } (1)$$

Where

U_{ij}^{*} : Expected utility obtained from technology j

Z_i : Observed characteristics such as (Gender, Sex of the household head, Age of the household head, Education level of the house hold head, Household size (number), Training received by HH, Slope of the plot, perceived soil fertility of the plot, perceived soil loss of the plot, livestock holding, land tenure, access to extension, access to credit, access to main market, access to irrigation.

ε_{ij}: Captures all the variables that are relevant to the farm household's decision maker are unknown to the researcher such as skills or motivation.

$$\begin{cases} 1 \;\; iff \;\; U_{i1}^{*} > max_{\,m \neq 1}\, U_{im} \text{ or } ή_{i1} < 0 \\ \vdots \qquad\qquad \vdots \qquad\qquad \vdots \\ j \;\; iff \;\; U_{ij}^{*} > max_{\,m \neq j}\, U_{im} \text{ or } ή_{ij} < 0 \end{cases}$$

Assuming that ε_i is independently and identically Gumbel distributed, so the probability that, the farmer "i_{th}" with characteristics "X_i" will choose package "j" can be specified by a multinomial logit model (Macfadden, 1973).

$$p_{ij} = P(\acute{\eta}_{ij} < 0/Z_i) = \frac{\exp(Z_i\alpha_j)}{\sum_{m=1}^{n}\exp(Z_i\alpha_m)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The parameter estimates of the latent variable model can be estimated by maximum likelihood estimation.

3.7.2 Endogenous Switching Regression Model

In the **second** stage the multinomial endogenous switching regression model evaluates the relationship between the outcome variable (food security measured in FCS) and explanatory variables (Xi) for each of the alternative packages. The technology adoption considered for this study includes; soil bund (S), stone bund (T) and soil bund with biological plantation (P). The base category ($S_0T_0P_0$) is the base category when farmers did not adopt any technology is denoted as j=1. whereas they are considered as adopter if they adopt at list one conservation practice technology (A) (j = 2, …, 8). The outcome equation for each possible jth regime is given as:

$$regime\ 1\ Y_{i1} = X_i\beta_1 + U_{i1}\ if\ A = 1$$

$$regimej\ Y_{ij} = X_i\beta_j + U_{ij}\ if\ A = j \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where

Y_{ij} *are the outcome variable* (food security or income) *of the* i_{th} *farmer in regime* "j", and Xi represents vector of inputs (seed, labour, fertilizer (organic and inorganic) and farm household's characteristics, soil's characteristics, and the past climatic factors included in **Z.** $\boldsymbol{U_{ij}}$ represents the unobserved stochastic component, which verifies $E\ (U_{ij}/\ X,\ Z)$ =0 *and* var $(U_{ij}/\ X,\ Z) = \sigma j$. For each sample observation only one among the *M* dependent variables (food security and income) is observed. When estimating an OLS model, the food security/income equations 4 (1) to 4 (j) are estimated separately. However, if the error terms of the selection model (1) η_{ij} are correlated with the error terms $\boldsymbol{U_{ij}}$ of the food security/income functions in equation 4 (1) to 4 (j) , the expected values of $\boldsymbol{U_{ij}}$ conditional on the sample selection are nonzero, and the OLS estimates will be inconsistent and will be biased. To correct for the potential inconsistency, we employ the model by (Bourguignon, Fournier and Gurgand, 2007)

A consistent estimation of β_j requires inclusion of the selection correction terms of the alternative choices in Eq. (4) which is referred as *"multinomial switching regression model"*. The Dubin and Daniel McFadden, (1984) model assumes the following linearity assumption to account this bias. The model assumes that the expected value of U_j *and* $\varepsilon_j$are linearly related, such that

$$E\left(U_{ij}/\varepsilon_{i1} \dots \dots \dots \dots \dots \varepsilon_{ij}\right) = \sigma_j \sum_{m\neq j}^{j} \rho_j \ (\varepsilon_{im}\text{-}E(\varepsilon_{im})$$

Where

$$\sum_{m\neq j}^{j} \rho = 0$$

(by construction, the correlation between u's and ε's sums to zero). Using this assumption, the equation of the multinomial ESR in Eq. (4) is specified as:

$$Y_{i1} = X_i \alpha j + \sigma \widehat{\lambda_{11}} + \omega_{i1} \text{ if } \text{Ai} = 1$$

.

$$Y_{ij} = X_i B_j + \sigma \widehat{\lambda_{1j}} + \omega_{ij} \text{ if } \text{Ai} = \text{j} \ldots$$

……………………..

(5)Where λ is the selection bias correction term which is estimated from computed probabilities from Equation (3).

$$\lambda = \sum_{j}^{m} \rho_{j_j} \left(\frac{\hat{P}_{im} \, ln(\hat{P}_{im}}{1-\hat{P}_{im}} + \ln(\hat{P}_{ij}) \right)$$

P_{ij} represents the probability that i_{th} farm household chooses technology "*j"; ρ_j* represents the correlation between $\varepsilon_{ij}$and U_{ij}; and $\omega_{ij}$is a residual term which is orthogonal to all ε_{ij}& $E(\omega_{ij})=0$. Practically, the model in Eq. (5) has heteroskedasticity problem that arise from the computation of

λ. In addition, standard errors are bootstrapped to account for the heteroskedasticity arising from the two-stage estimation procedure.

For Equation (5) to be identified, selection instruments are required. Finding true instruments in empirical work is sometimes impossible; however, we use the following selection instruments for identification and are therefore excluded from Equation (5).

3.7.3 Building up a Counterfactual Analysis

The main advantage of an ERS regression model is its capability to estimate the effect of the variable under consideration for actual and counterfactual (hypothetical) conditions. In particular, one can follow (Falco and Veronesi, 2013), and derive the expected net output of farm households who adopted, that in our study means j=2,..7) ‘non-adopting’ “j=1”

Productivity of Adopters with adoption of “j” combination (actual)

$E(Y_{ji}/A=j,X_{ji}, \lambda_{ji})=B_jX_{ji}+ \sigma_j e\lambda\, ji$ …………………………….(6a)

Productivity of Adopters without adoption (counterfactual) .

$E(Y_{1i}/A=j,X_{ji}, \lambda_{ji})=B_1X_{ji}+ \sigma_1 e\lambda\, ji$ ……………………………… (6b)

Non-adopters productivity without technology adoption (actual)

$E(Y_{1i}/A=1,X_{1i},\lambda_{1i})=B_1X_{1i}+\sigma_{1e}\lambda_{1i}$ …………………………… (7a)

Non-adopters productivity if they adopt “j” combination of technology (counterfactual)

$E(Y_{ji}/A_i=1, X_{1i},\lambda_{1i})=B_{ji}X_{1i}+ \sigma_{je}\lambda_{1i}$ …………………………………… (7b)

This allows us to calculate the treatment effects of treated (ATT), for example, as the difference between equations (6a) and (6b).

$ATT= E(Y_{ji}/A=j,X_{ji}, \lambda_{ji})- E(Y_{1i}/A=j,X_{ji}, \lambda_{ji})=X_{ji}(B_{ji}-B_{1i})+\lambda_{ji}(\sigma_{je} - \sigma_{1e})$ …………………. (8)

The first term on right-hand side of Eq. (8) represent the expected change of outcome in adopters of SWC practices (*j =2*…8); if adopters had the same characteristics as non-adopters. The second term (λ_j) is the selection term that captures all potential difference between adopters and non-adopters which arise due to unobserved variable.

Similarly, the average treatment effect on untreated (TU) is calculated as the deference between (7a) and (7b):

$ATU= E(Y_{ji}/A=1,X_{1i},\lambda_{1i})- (Y_{1i}/A=1,X_{1i},\lambda_{1i})= X_{1i}(B_j-B_1)+\lambda_{1i}(\sigma_{je} - \sigma_{1e})$ ………………. (9)

The right-hand side of the model shows expected change of non-adopter output if they decide to adopt SWC practices given that adopters had the same characteristics as non-adopters.
On the other hand base heterogeneity of adopter is calculated as the difference between 7(b) and 6(a)

$E(Y_{1i}/A_i=j, X_{ji},\lambda_{ji}) - E(Y_{1i}/A=1,X_{1i}, \lambda_{1i})=B_{1i} (X_{ji} -X_{1i})+ \sigma_{je} (\lambda_{ji} - \lambda_{1i})$ ……….(10)

The right-hand side of equation 10 shows the food security difference of technology adopter and non-adopters without technology adoption. Base heterogeneity of non-adopters is calculated as the difference between 7(a) and 6(b)

$E (Y_{ji}/A_i=1, X_{1i},\lambda_{1i}) - E(Y_{ji}/A=j,X_{ji}, \lambda_{ji})=B_{ji} (X_{ji} -X_{1i})+ \sigma_{je} (\lambda_{ji} - \lambda_{1i})$ ……….(11)

The right-hand side of equation 11 shows the food security difference of adopters and non-adopters
when both groups adopt similar technology.

Moreover, the conditional expected outcome is used to calculate transitional heterogeneity (TT). Transitional heterogeneity is the difference between treatment effect on treated (TT) and treatment effect on untreated (TU). It provides information, whether the effect of adopting agricultural technology is larger or smaller for households that actually had adopted the technologies or for non-adopters in the counterfactual case.
Table 5 shows how the actual and counterfactual analysis of the impact of each conservation practices in the area.

Table 5: Equations of Counterfactual analysis in alternative technology adoption

Non-Adopters ($S_0T_0P_0$) J=1		
Output Equation	**ATU**	**Description**
$E(Y_{i1}/A=1, X_{i1}, \lambda_{i1}) = \beta_1 X_{i1} + \sigma_{i1}\lambda_{i1}$ … (a)		
$E(Y_{i2}/A=1, X_{i2}, \lambda_{i2}) = \beta_2 X_{i2} + \sigma_{i2}\lambda_{i2}$ … (b)	b-a	Non-Adopters when they adopt soil bund only
$E(Y_{i3}/A=1, X_{i3}, \lambda_{i3}) = \beta_3 X_{i3} + \sigma_{i3}\lambda_{i3}$ … (c)	c-a	Non-Adopters when they adopt stone bund only
$E(Y_{i4}/A=1, X_{i4}, \lambda_{i4}) = \beta_4 X_{i4} + \sigma_{i4}\lambda_{i4}$ … (d)	d-a	Non-Adopters when they adopt soil bund with plantation
$E(Y_{i5}/A=1, X_{i5}, \lambda_{i5}) = \beta_5 X_{i5} + \sigma_{i5}\lambda_{i5}$ … (e)	e-a	Non-Adopters when they adopt soil bund and stone bund
$E(Y_{i6}/A=1, X_{i6}, \lambda_{i6}) = \beta_6 X_{i6} + \sigma_{i6}\lambda_{i6}$ … (f)	f-a	Non-Adopters when they adopt soil bund and stone bund with plantation.
$E(Y_{i7}/A=1, X_{i7}, \lambda_{i7}) = \beta_7 X_{i7} + \sigma_{i7}\lambda_{i7}$ … (g)	g-a	Non-Adopters when they adopt all practices

Adopters of Alternative practices only J=2, 3, 4,5,6,7		
Output Equation	**ATT**	**Description**
$E(Y_{i1}/A=2, X_{i1}, \lambda_{i1}) = \beta_1 X_{i1} + \sigma_{i1}\lambda_{i1}$ … (a)	b-a	Adopters of soil bund when they do not adopt
$E(Y_{i2}/A=2, X_{i2}, \lambda_{i2}) = \beta_2 X_{i2} + \sigma_{i2}\lambda_{i2}$ … (b)		Actual Food security when adopting soil bund
$E(Y_{i1}/A=3, X_{i1}, \lambda_{i1}) = \beta_1 X_{i1} + \sigma_{i1}\lambda_{i1}$ … (c)	d-c	Adopters of stone bund when they do not adopt
$E(Y_{i3}/A=3, X_{i3}, \lambda_{i3}) = \beta_3 X_{i3} + \sigma_{i3}\lambda_{i3}$ … (d)		Actual Food security when adopting stone bund
$E(Y_{i1}/A=4, X_{i1}, \lambda_{i1}) = \beta_1 X_{i1} + \sigma_{i1}\lambda_{i1}$ … (e)	f-e	Adopters of soil bund with plantation when they do not adopt
$E(Y_{i4}/A=4, X_{i4}, \lambda_{i4}) = \beta_4 X_{i4} + \sigma_{i4}\lambda_{i4}$ … (f)		Actual Food security when adopting soil bund with plantation bund
$E(Y_{i1}/A=5, X_{i1}, \lambda_{i1}) = \beta_1 X_{i1} + \sigma_{i1}\lambda_{i1}$ … (g)	h-g	Adopters of soil bund and stone bund when they do not adopt
$E(Y_{i5}/A=5, X_{i5}, \lambda_{i5}) = \beta_5 X_{i5} + \sigma_{i5}\lambda_{i5}$ … (h)		Actual Food security when adopting soil bund and stone bund
$E(Y_{i1}/A=6, X_{i1}, \lambda_{i1}) = \beta_1 X_{i1} + \sigma_{i1}\lambda_{i1}$ … (i)	j-i	Adopters of soil bund and stone bund with plantation when they do not adopt
$E(Y_{i6}/A=6, X_{i6}, \lambda_{i6}) = \beta_6 X_{i6} + \sigma_{i6}\lambda_{i6}$ … (j)		Actual Food security when adopting soil bund and stone bund with plantation
$E(Y_{i1}/A=7, X_{i1}, \lambda_{i1}) = \beta_1 X_{i1} + \sigma_{i1}\lambda_{i1}$ … (k)	l-k	Adopters of all practices when they do not adopt
$E(Y_{i7}/A=7, X_{i7}, \lambda_{i7}) = \beta_7 X_{i7} + \sigma_{i7}\lambda_{i7}$ … (l)		Actual Food security when adopting all practices

3.7.4 Measuring of Food Security

Defining and interpreting food security, and measuring it in reliable, valid and cost-effective ways have proven to be stubborn problems facing researchers and programs intended to monitor food security risks…. Collecting data for a complete analysis of food security can be a virtually impossible task in a situation where household composition is variable and the "household" itself is subject to varying interpretations (Maxwell, 1998).

As the concept and technical analysis on food security advances, there has been a growing need of measuring food security to use results for humanitarian and programme purposes. Thus far, many agencies invented different techniques of measuring food security that fits to their purpose. WFP, FAO and USAID (FANTA) are the principal ones who developed guides and applied them in various contexts. Although there are plenty of food security/insecurity measured used so far, this study used Food Consumption Score (FCS) as a measure of food security and its brief explanation is discussed below.

3.7.4.1 Food Consumption Scores (FCS)

The Food Consumption Score (FCS) is an index that was developed by the World Food Programme (WFP) in 1996. The FCS aggregates household-level data on the diversity and frequency of food groups consumed over the previous seven days, which is then weighted according to the relative nutritional value of the consumed food groups (INNDEX, 2018).

The food consumption groups include; starches, pulses, vegetables, fruit, meat, dairy, fats, sugar. If these groups are surveyed in a disaggregated fashion, the consumption frequencies of the different foods in the groups are summed, with the maximum value for the groups capped at 7 (Table 6).

Table 6_Food items, food groups and their weights for FCS estimation

	Food Items	Food Groups	Weight
1	Maize, maize porridge, rice, sorghum, millet pasta, bread and other cereals Cassava, potatoes and sweet potatoes, other tubers, plantains	Main Staples	2
2	Beans. Peas, groundnuts and cashew nuts	Pulses	3
3	Vegetables, leaves	Vegetable	1
4	Fruits	Fruit	1
5	Beef, goat, poultry, pork, eggs and fish	Meat and Fish	4
6	Milk yogurt and other diary	Milk	4
7	Sugar and sugar products, honey	Sugar	0.5
8	Oils, fats and butter Oil	Oil	0.5
9	spices, tea, coffee, salt, fish power, small amounts of milk for tea.	Condiments	0

Source : WFP, 1996

The formula, based on these groups, with the standard weights, is:

FCS = (starches*2)+ (pulses*3)+ vegetables + fruit + (meat*4)+ (dairy*4)+ (fats*.5)+ (sugar*.5). (WFP, 2015).

Once the food consumption score is calculated, the thresholds for the FCGs should be determined based on the frequency of the scores and the knowledge of the consumption behavior in that country/region (WFP,2008).

The typical thresholds are:

Table 7: Thresholds of FCS

FCS	Profiles
0-21	Poor
21.5-35	Borderline
>35	Acceptable

Source: WFP,1996

However, as discussed in this paper, these thresholds need to be tested and possibly modified based on the context and dietary patterns of the population in question.

3.7.5 Stochastic Frontier Analysis (SFA)

There are four principal methods involved: econometric estimation of average response models; index numbers; data envelopment analysis (DEA); and stochastic frontier analysis (SFA) (Coelli *et al*., 1998). These days, many studies shift from using of average response models towards application of functions of maximum output. The most common and widely used models are the non-parametric data envelopment analysis (DEA); and the parametric model known as stochastic frontier analysis (SFA).

There are a lot of technical details about the two models. However, this paper discusses the principal and basics of the two important models. In the data envelopment analysis (DEA) efficient isoquant must be estimated from the sample data taking the relatively best performing firms as fully efficient (Coelli *et al*., 1998). The data envelopment analysis is a deterministic frontier, meaning that all deviation from the frontier is attributed to inefficiency only. It is difficult to accept this assumption, given the inherent variability of agricultural production in developing countries due to a lot of exogenous factors like weather shocks, pests, diseases, etc (Coelli and Battese, 1995). Non-stochastic/ deterministic production frontier can be estimated using linear programming or econometric techniques such as Corrected Ordinary Least Square (COLS).

On the other hand, the parametric frontier uses econometrics method to estimate the parameters of both stochastic frontier production function and inefficiency effect model. The biggest advantage of stochastic frontier approach is the introduction of stochastic random noises that are beyond the control of the farmers in addition to the inefficiency effects. The disadvantage of this approach is that it imposes explicit restriction on functional forms and distributional assumption for one-sided error term (Battese and Coelli, 1995). This study uses the stochastic frontier analysis (SFA) for measuring production technical efficiency.

The stochastic frontier method requires a prior specification of the most widely used functional forms like Cobb-Douglas and Translog.

The parameter estimation of production function begins with an assumption every decision-making unit are capable of producing the maximum output.

Although Solomon (2014) used a one-stage one stage approach in which both technical efficiency and factors of inefficiency are analyzed simultaneously, this study will attempt to unveil about the two different stages separately.

The stochastic frontier production function that assumed Cobb-Douglas form is given as:

$$\ln Y_i = \beta_0 + \sum_n \beta_n \ln X_n + v_i + u_i$$

Where: βi's are parameters denoted the coefficient of inputs to be estimated by maximum likelihood estimation method (MLE). For simplicity and ease for analysis and interpretation the output (Y_i's) is barley production in kg which is the most important crop in the study area interms of quantity of production and households food and other economic use.

X_i's are inputs used for the production of barley. These are:

- Land (LAND) in hectares: This refers to the area of plot of land allotted for crop production.
- Human Labor (LABOR) in man days (MD): This input captures family, shared and hired labor used for different agronomic practices of crop production.
- Seed (SEED) in kg: This refers to the amount of seed used in the production of output. Hence, total amount of seed used in Kg was used for the analysis.
- Urea (UREA): Urea and DAP, most commonly used fertilizers in Ethiopia, are an important input for production. Hence, total Urea/DAP applied on plot of land per Kg was used in this study.

v_i accounts for the stochastic effects beyond the producer's control, measurement errors as well as other statistical noises are the random variable assumed to be independently, identically, and normally distributed (IID) N (0, σ2v); and u_i - is a non-negative random variable that captures the production inefficiency assumed to be independently and identically distributed (IID) N (μ, σ2u).

The level of technical efficiency is estimated as:

$$TE = \frac{Y^i}{Y_i^*}$$

$$TE = \frac{f(X, \beta)\exp(\varepsilon)}{f(X, \beta)\exp(v)}$$

$$TE = \exp(-u)$$

Where Y^i is the actual output while Y_i^* is the frontier output or the maximum potential output. To test whether technical inefficiency effect is absent and hence the conventional production function is more appropriate or not than stochastic frontier approach, the study uses the generalized likelihood-ratio test.

The determinants of technical, allocative and economic inefficiency can be estimated as:

$$U_i = \delta_o + \delta_i\ Z_i + w_i$$

Where δi's are parameters denoted the coefficient of technical inefficiency effects. Here negative and positive signs of the parameters reveal that they can increase and decrease farmer's technical efficiency, respectively. wi=unobserved random error term; i = number of farmers.

$U_i$is non-negative random variable, assumed to be independently and identically distributed (i.i.d) with truncated-normal distribution N (μ, σ^2_u) (Stevenson, 1980) where μ>0 i.e. u≥ 0 reflects the level of technical efficiency of farmers relative to the frontier. U_i= 0 for a farmer whose production lies on the frontier and U_i> 0 for a farmer whose production lies below the frontier.

The details of these models are elaborated in the respective chapters where each objective of the study is discussed. Meanwhile, it is worth mentioning the study employed MS excel for data entry and STATA 14 for data cleaning and analysis.

Chapter 4: Result and Discussion-Factors Influencing Adoption of SWC Practices

4.1 Background

By adopting different agriculture production intensification technologies, households are able to boost their production and enhance food security. SWC conservation practices contribute to the improvement of soil thickness and soil nutrient and water holding capacity of soil thereby soil become conducive for better production.

There are multiple on-farm and hillside conservation activities implemented in Leman watershed under the SLMP. Focusing on on-farm practices, households of the study area adopted and practiced different single or combination of soil and water conservation techniques that typically includes soil bund, stone bund, soil bund with plantation, and all combination of technologies. Selection and adoption of these technologies are contingent on different household, plot and access to service-related factors.

In light with this, this section of the study attempts to find out and discuss what are the major determinants that affects the selection of these different types of conservation technologies that are implemented on the farms of households. Although, households implement different conservation practices on different fields covered with different crops that include barley, wheat, teff, peas and beans, for the sake of simplifying analysis the most common and widely grown crop; barley is selected for this study.

4.2 Description of Alternative Adoptions

Depending on factors like; households level of skill and knowledge and other demographic characteristics (age, sex, education, training) of households to adopt SWC practices, plot characteristics (slope, soil fertility, and severity of soil loss), and other elements including access to extension and other services, households choose to adopt different SWC techniques to implement on their farm. The most common conservation practices are soil bund, soil faced stone bund, bunds with biological plantation. Households either implement one of these practices or a mix of different combination. Although households apply these practices on their different fields that commonly grow barley, wheat, teff, and pulses, for the sake of simplicity of analysis and reporting of this study only practices on barley fields is considered.

Table 8: Different SWC Practices and Frequencies of observations

	Natural Resource conservation practices				
Binary triplet Packages	**Soil Bund (S)**	**Stone Bund (T)**	**Soil Bund with plantation (P)**	**Freq.**	**Percent**
Non-Adopters ($S_0T_0P_0$)	✓			144	48.65
Soil bund only ($S_1T_0P_0$)		✓		59	19.93
Stone bund only ($S_0T_1P_0$)			✓	16	5.41
Soil bund with plantation ($S_0T_0P_1$)	✓		✓	22	7.43
Soil bund and Stone bund $S_1T_1P_0$)	✓	✓		29	9.80
Soil bund and Soil bund with plantation ($S_1T_0P_1$)	✓		✓	4	1.35
Soil faced stone bund and biological plantation ($S_0T_1P_1$)		✓	✓	1	0.34
All types of practices ($S_1T_1P_1$)	✓	✓	✓	21	7.09
Total				**296.0**	**100.0**

Source : Survey data, March 2019

As presented in Table 8, surveyed households are disaggregated into six technology selection group depending on the specific or combination of SWC activities they practiced on their farm. Accordingly, the first group are those who did not adopt any of the SWC activities and are denotes as $S_0T_0P_0$ and they account 48.6% of households. Those who implement only soil bund

($S_1T_0P_0$) are 19.9%. Proportion of households who adopted stone bund only ($S_0T_1P_0$) are 5.4%. While adopters of soil bund with biological plantation are ($S_0T_0P_1$) are 7.4%. Whereas, those who implemented soil and stone bund accounts 9.8%. As households who practiced soil faced stone bund with plantation and soil bund and stone bund with plantation account very small frequency, and they are excluded from the analysis from the selection group. At last, there are household who implement a mix of all practices (S1T1P1) and they account as 7% of sample households.

Additional information explored from FGD and key informants, availability of local resources such as stone is a major determinant for households in deciding whether to choose either soil bund or stone bund or a combination. Depending on the availability of stone in the area households may restrict themselves in construction of more soil bunds, although the need is there.

4.3 Descriptive Analysis of Variables used in the Model

Table 9 and 10 presents descriptive analysis of continuous , dummy and nominal variables that were used in the analysis of understanding of the household's decision behavior in the selection of alternative SWC practices adoption and their contribution for food security. As seen below 87 percent of the surveyed respondents are headed by males. Although there are households of 80 years of and above included in the survey mean age of households is 49.3 years old. On average, a household had six members living and sharing food and other consumables in the house. Majority of households (53%) sampled are not able to read and write. Whilst 28% can read and write and 19% attended education in formal schools and completed different grades. The average land holding of households was about 2.3hectares which indeed includes land for cultivation, grazing and other purposes, from which, the land cultivated for the most important crop in Leman watershed, barley, on average was 0.8 hectares.

Table 9: List of continuous variables and their descriptive statistics

Variable	Obsns	Mean	SD	Min	Max
Age of household head (years)	296	49.3	12.7	25	80

Household size (number)	296	6.3	2.7	1	17
Household head education (ordinal)	286	1.7	0.8	1	4
Land Size_Barley (heactars)	281	0.8	0.4	0.1	3
Distance to Plot from home (minutes)	280	19.4	12	1	60
Tropical Livestock Unit (TLU)[3]	282	3.9	1.7	0.2	11.9
Number agricultural hand tools	248	4.9	2.3	1	10
Distance to main market from home (hrs)	266	2.7	0.9	0.5	5

Source: Survey data, March 2019

Table 10: List of dummy and categorical variables and their descriptive statistics

Variable	**Category**	**Freq.**	**Percentage**
Households Sex	Male	258	87
	Female	38	13
Marital Status	Currently Married	252	85
	Widowed	33	11
	Divorced	11	4
Households Head Education	Unable to read and write	151	53
	Adult Education	81	28
	Formal Education	53	19
Households head training	Yes	221	75
	No	75	25
Slope of Plot	Flat	99	35
	Gentle	114	40
	Steep	70	25
Perceived Fertility of Plot	Very poor	3	1
	Poor	67	24
	Average	186	66
	Good	23	8
	Very Good	4	1
Perceived severity of Soil loss	Very poor	11	4
	Poor	89	31
	Average	139	49
	Good	33	12

[3] The **TLU conversion factors** used are as follows: cattle = 0.70, sheep and goats = 0.10, pigs = 0.20 and chicken = 0.01

	Very Good	11	4
Land Certificate Given	Yes	231	78
	No	66	22
Access to extension service	Yes	176	60
	No	119	40

Source: Survey data, March 2019

Training of households are considered as an important mechanism to encourage households to take part in implementing soil and water conservation practices. As such, the survey revealed about 75% of households received training in agriculture and natural resources conservation. The mean distance that takes households to travel from their home to their plots (particularly barley plot) is about 19.4 minutes. Gentle slope is a dominant landscape in the Leman watershed constituting 40% and is followed by flat farmland with about 35% share of the total. With regard to perception on soil fertility and severity of soil loss, majority rated as moderate with 66 percent for soil fertility and 49 percent for severity of soil loss. Perhaps, significant households reported poor soil fertility (24%) and sever perceived soil erosion (31%). This represents that vast majority of household's perception on their soil fertility or severity of soil loss is either moderate or poor.

Livestock are important assets in supplementing and complementing survey households livelihoods. Ox, cow, sheep, and donkey are the most commonly livestock types reported. As expressed in Tropical Livestock Unit (TLU) terms the mean TLU of the survey households is 3.9. Agricultural tools are believed as determinant in soil and water conservation practices. Thus, the study revealed the average number of tools is about 5, although there are few households who reported to have nothing. As extension service is key in technology introduction and diffusion as well as technical support, the survey revealed that about 60% of the sample households reported to have received agriculture extension. Nevertheless, 90% of them obtained extension support occasionally. As per the result of the survey, households are living within 30 minutes to 5 hours walking distance from the main market and the mean distance between the market and household residents is about 2 hours and 40 minutes.

4.4 Description of Explanatory Variables Under each Regime

As described in Table 11, considering non-adoption ($S_0T_0P_0$) as base category to compare average households age has no difference in all selection except for that of adopting every combination with a mean age of 53.58 is significant at α=0.1. Vast majority of sample households are male headed households. However, the proportion of female headed households in those who implemented stone bund are higher amongst other groups (25%). As depicted in Table 11, mean values of households size of adopters of different practices ranges from 5 to 8.5 and these are tested to be significantly different across some of the adopters group.

Households education is designated by 1 if illiterate, 2 able to read and write and 3 as someone who attended certain grades of formal education and as seen in the Table 11 mean education level showed as majority are unable to read and write. Whereas, there exists a significantly higher level of education in groups who adopted different SWC conservation practices including biological plantation like $S_0T_0P_1$ (soil bund with planation) and $S_1T_1P_1$ (all sorts of SWC conservation practices). Training received by households certainly affect households decision to participate in available alternative SWC practices and as seen in Table 11 majority (over 90 percent) of SWC adopters received at least one training except for $S_1T_1P_0$ adopters which indicated that only 31% received training. This finding is in agreement with (Temesgen and Bamlaku, 2017) study which unveil that households with more access to credit are more likely to participate in off-farm activities, are more educated. Average land size which is cultivated for barley was 0.8 hectares as those who regarded as group with lowest possession while the group with the highest average hold 1.13 hectares and the mean holding of adopters of $S_0T_0P_1$ and $S_0T_0P_1$ are significantly different from the non-adopters. This study finding was also proved to be true with the study made by (Etsehiwot, 2011) as it was described as:-

> *Landholding and soil fertility are other factors which affect the adoption decision. These variables have significant difference among adopters and non-adopters. The proportion of full technology adopters' fertile land was found to be higher (54 percent) than that of non-adopters' and mixed technology adopters*

The mean of the slope for of plots are between 1.95 and 2.23 which indicate majority owns a land with a gentle slope and few lands are plain.

Perceived soil fertility of the barley land in the study are regarded as a major factor influencing households decision in the adoption of SWC conservation practices. As such, mean reported perceived soil fertility is either moderate or poorer and mean fertility is significantly different among adopters. Likewise, perceived severity of soil loss of different SWC practice implementers are either with moderate severity of soil loss or worse. For instance, those who adopt stone bund $S_0T_1P_0$ are with average 2.75 which implies soil loss verity is between high and moderate while those who practiced soil bun with plantation ($S_0T_0P_1$) are with mean 3.36 which shows severity is moderate for the vast majority households while fewer reported soil loss severity is mild. Livestock holding express in TLU terms is with significantly different mean (4.92) for those who adopt different combinations of soil and water conservation practices ($S_1T_1P_1$). Mean results on land certification revealed, lion share of sample households who adopt either of the technology received land certificate. A significantly different mean is for $S_1T_0P_0$ (86%) and $S_1T_1P_0$ (89 %). A significant portion of households in different alternative groups did not receive extension services, as per the mean values calculated from the variable. However, those who adopted different combination of technologies ($S_1T_1P_1$) reported a significantly different mean (95%).

Distance from the market is used as a proxy for measuring of remoteness to access to different services. Vast majority are between two to three hours distance from the main market to their home. As depicted in Table 11, mean location is significantly different for $S_1T_1P_0$ and $S_1T_1P_1$.

Table 11: Variable and their descriptive statistics under each regime.

Explanatory Variable	$S_1T_0P_0$		$S_0T_1P_0$		$S_0T_0P_1$		$S_1T_1P_0$		$S_1T_1P_1$	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age of household head (years)	48.94	13.24	50.57	13.46	50.54	12.24	50.17	11.03	53.85*	11.6
Sex of household head	0.88	0.32	0.75	0.44	0.9	0.29	0.93	0.25	0.9	0.3
Marital Status (1=married, 2=widowed, 3=divorced)	1.22	0.52	1.37	0.61	0.13	0.61	1.1	0.3	1.09	0.3
Household size (number)	6.93	2.92	5.06*	2.83	6.13	2.07	6	1.98	6.95	2.41
HH head education (ordinal)	1.57	0.74	1.16**	0.57	2.13**	0.83	1.5	0.74	1.95**	0.86
HH head training (1=yes,2=no)	0.74	0.43	1***	0	0.9**	0.29	0.31***	0.47	0.9**	0.3
Experience in Agriculture (years)	30.45*	11.86	24.06	13.3	28.95	8.95	26.48	7.23	30.61	11.83
Land Size_Barley (heactars)	0.8	0.35	0.75	0.27	1.1***	0.67	0.92*	0.53	1.13***	0.5
Distance to Plot from home (minutes)	19.32	11.37	21.81	14.42	16.68	10.28	20.75	9.87	17.82	12.74
Slope of barley plot (ordinal)	1.93	0.73	2	0.53	2.2***	0.76	1.44***	0.73	2.23**	0.83
Perceived fertility of Barley Plot(ordinal)	2.64***	0.58	2.75	0.44	3.45***	0.67	2.96*	0.42	3.47***	0.67
Perceive severity of soil loss of plot (ordinal)	2.54***	0.67	2.75	0.44	3.36***	1.13	2.75	0.57	3.47***	1.07
Land Certificate given (1=yes, 2=no)	0.86**	0.34	0.87	0.34	0.86	0.35	0.89*	0.3	0.76	0.43
Tropical Livestock Unit (TLU)	4.04	1.58	3.5	1.84	4.14	1.47	4.28	1.5	4.92***	2.73
Number of agricultural hand tools	4.84	2.07	3.75	2.05	6.09*	2.2	4.7	1.68	7.09***	2.02
Extension service received (1=yes, 2=no)	0.59	0.45	0.37*	0.5	0.59	0.5	0.44	0.5	0.95***	0.21
Distance to main market from home (minutes)	2.6	1.04	2.91	0.52	2.93*	0.51	1.96***	1.23	3.06***	0.45

* Denotes significance level at 10 percent
** Denotes significance level at 5 percent
*** Denotes significance level at 1 percent

Source : Survey data, March 2019

4.5 Econometric Result

At first, the study develops the model that best explains the households selection to different SWC alternative practices. As such, a multinomial logit used to establish the model. The model reasonably fits the data well since the LR test rejects the null hypothesis that all coefficients are jointly equal to zero [$\chi^2(91) = 228.56$; $p = 0.000$]. The Variance Inflation Factor (VIF) is also computed to test multicollinearity. The VIF result confirms that there is no multicollinearity across explanatory variables as indicated in Table A2 in the appendix. Results indicate that the estimated coefficients substantially differ across alternative combinations of SWC practices.

It is important to remined that, the reference or base category of the model is non-adopter ($S_0T_0P_0$), which is used to compare results of other agricultural technology practices. When looking at factors determining household's adoption of different alternatives, age of household has statistically significant positive effect on households selection of SWC practice using all SWC practices. which could imply that farmers with more years of farming experience are more likely to adopt (Table 12). This is in agreement with the study made by (Etsehiowt, 2011). In the same way, age when taken as experience in agriculture, farmers with higher years of agriculture experience are more likely to select to practice all SWC ($S_1T_1P_1$) activities. This is in line with findings of the study (Kidanemariam *et al*, 2017) .

As per the result of the study, the marital status of household has negative positive of negative impact on adoption of either of the alternative technologies. This implies as the households are in a non-marriage status, are less likely to adopt SWC activities. On the other hand, the study did not indicate households size has any level of significance in influencing households any kind of technology adoption. In other words, households with either smaller or bigger household size has no implication on technology adoption.

Despite the fact that, education empowers households to adopt and enhance participation, the result of the study unveiled education has no statistically significant association with any of the technology selection. However, in a selection of stone bund ($S_0T_1P_0$) where it showed significant association, households with higher education are less likely to choose soil and water conservation made from stone bund. Rather it is the farming experience of households which plays positive role in positive decision of adoption of SWC alternative technologies.

Explanatory Variable	S0T0P0		S1T0P0		S0T1P0		S0T0P1		S1T1P0		S1T1P1	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Age of household head (years)	0.014	0.019	-0.01	0.3	0.014	0.036	-0.10	0.033	0.008	0.024	0.079*	0.042
Marital Status (1=married, 2=widowed, 3=divorced)	-0.019	0.418	0.64	0.68	-0.98	0.97	0.645	0.687	-0.44	0.74	-17.11***	1.37
Household size (number)	0.081	0.059	-0.09	0.11	0.028	-0.08	-0.095	0.11	-0.96	0.89	0.005	0.139
HH head education (ordinal)	0.142	0.207	-0.47	0.39	-1.19*	0.81	0.473	0.391	-0.32	0.36	-0.107	0.515
Experience in Agriculture (years)	-0.004	0.201	0.01	0.02	-0.027	0.05	0.009	0.029	-0.033	0.028	0.086**	0.039
Land Size_Barley (heactars)	-1.433	0.439	1.46**	0.67	-0.18	0.54	1.462***	0.678	1.206***	0.539	0.305	0.616
Slope of barley plot (ordinal)	-0.207***	0.224	0.62	0.51	0.45	0.35	0.626	0.516	-0.623	0.515	0.754	0.641
Perceived fertility of Barley Plot(ordinal)	-0.309	0.240	1.38***	0.46	0.068	0.46	1.38***	0.465	0.267	0.431	3.414***	0.910
Perceive soil loss of plot (ordinal)	0.007	0.178	0.54**	0.28	-0.385	0.36	0.549***	0.281	0.164	0.333	1.610***	0.549
Land Certificate given (1=yes, 2=no)	-0.851**	0.427	0.63	0.543	1.227	1.196	0.631	0.909	0.250	0.837	-1.192	0.897
Extension service received (1=yes, 2=no)	-0.910***	0.325	2.22***	0.80	-0.595	0.86	2.229***	0.805	0.339	0.576	0.248	0.714
Distance to main market from home (minutes)	0.331*	0.197	0.19	0.53	0.259	0.49	0.191	0.531	-0.751**	0.246	-2.698***	1.015
Tropical Livestock Unit (TLU)	-0.086	0.094	-.011	0.15	-0.55*	0.29	-0.117	0.152	-0.008	0.147	0.706***	0.245
Constant	1.57	1.24	2.608	1.903	1.076	3.611	-14.36	3.406	-0.032	1.866	-15.356	7.153

Table 12: Maximum likelihood estimates of the parameters of technology selection equation.

* Denotes significance level at 10 percent
** Denotes significance level at 5 percent
*** Denotes significance level at 1 percent

Source: Survey data, March 2019

Agriculture production could increase either by expanding the area usage or adopting modern technologies. The former is not applicable to small farmers, but the second option could be applicable. However, household's technology preference depends on their farm size (Table 12). As Adekambi *et al* (2006) argues small farmers prefer to use labor intensive and less risky technologies whereas large farmers prefer to use capital intensive and they can afford to assume risks. In line with this description, farmers with large size of land are more likely to adopt different SWC practices. As seen in the result of this survey there is a statistically significant positive association between households with larger plot size with that of selecting technologies soil bund with biological plantation ($S_0T_0P_1$), farmers practicing both soil bund and stone bund as appropriate ($S_1T_1P_0$) and farmers selecting soil bund SWC practices ($S_1T_0P_0$). This finding is consistent with (Etsehiwot, 2018) but in contradiction with (Jhon *et al.*, 2017) work.

As poor soil fertility is a source of low production, households are highly interested in taking measures that improve soil fertility and improve production. The study found that those households with low perceived fertility of their land are more likely to adopt SWC practices. Hence, households with poor perceived soil fertility are more likely to engage in different SWC measure and study revealed a statistically significant positive relation between those who adopted soil bund with biological plantation ($S_0T_0P_1$), farmers practicing on soil bund and ($S_1T_0P_0$) and farmers selecting all combinations of SWC practices ($S_1T_1P_1$) as presented in Table 8. This finding is inconsistent with (Etsehiwot, 2018).

As indicated in FAO, (2003), "there is a widespread problem related to intensive cultivation, overgrazing and deforestation and soil erosion and soil fertility decline, water scarcity, livestock feed and fuelwood crisis. These factors often interact with one another resulting in a reinforcing cycle of the "poverty, food insecurity and natural resources degradation trap". Subsequently, households who perceive the soil on their plot is severely degraded are more likely to practice appropriate soil and water conservation measures to mitigate its impact on production and food security. The result of the study revealed that households who adopted stone bund ($S_0T_1P_0$), farmers practicing on soil bund and ($S_1T_0P_0$) and farmers selecting all combinations of SWC practices ($S_1T_1P_1$) as presented in Table 8 have a strong positive association with their perception of the sever loss of their plot.

Ashenafi (2006) cited in Etsehiwot, (2018) and Sebsibe, *et al* (2014) as access of extension and DAs' services is formal sources of information about agricultural technology. Extension agents and DA's give detailed information about the source, use and importance of the modern inputs to the farmers. Moreover, agricultural extension service providers could influence the adoption decision by building human capital via training and advisory service and engaging in input distribution and farm credit. In line with this, household of the study area who received extension service are more likely to adopt and practice different and pertinent SWC practices, notably the study showed strong and positive significant association of extension service and adopters of soil bund with biological plantation ($S_0T_0P_1$), and farmers selecting soil bund SWC practices ($S_1T_0P_0$). This finding is consistent with the findings of studies made by different scholars such as (Jhon, *et al*., 2017) (Temesgen and Bamlaku, 2017), (Kidanemariam, 2017) and (Etsehiowt, 2011).

Households location with respect to the main markets are considered a proxy for access to different services. The farthest the distance the less will be access to major services. The results of this study reiterate, households living in a more distant location from the major market are less likely to adopt SWC practices. There is a negative statistically significant relation between households who adopted stone bund ($S_0T_1P_{0)}$ and households who practiced all combination of SWC structures ($S_1T_1P_1$). This is proved by (Jhon, *et al*., 2017) (Kidanemariam, 2017) and (Etsehiowt, 2011) as households located in more remote areas to be less likely to adopt technologies than otherwise. This could be because such households have limited access to extension services due to impassable roads which would make them almost disconnected to extension service sources.

Last but not least, households livestock holding has been discovered to have relation with households SWC technology adoption. The result of the study displayed mixed outcomes are households with higher TLU value are less likely to adopt SWC structure made of stone bund ($S_1T_0P_{0)}$. On the contrary, those households with better livestock holding are best placed in implementing all combinations of SWC practices ($S_1T_1P_1$). The result of the study made by Etsehiwo (2011) revealed, households with higher livestock possession are less likely to adopt teff production boosting innovative practices like fertilizer, row planting and improved seed.

Temesgen and Bamlaku (2017) found out no significant relation between households ,livestock possession and their decision to take credit or not.

4.6 Summary

In Summary, according t-test results of adopters and non-adopters in different technology groups shows a statistically significant different in households' education, training, land size, slope of their land, on their perceived fertility and soil loss. Similarly, significant difference is seen with respect to households average livestock ownership, access to extension services and distance of households from the main market. In particular, there exists a significant mean different in many households aspects of households who adopts all types soil and water conservation practices (S1T1P1))from those who did not adopt.

The multinomial logit selection model result revealed that the agricultural technology adoption decision is influenced by observable plot characteristic, household and institutional characteristics. More specifically, the agriculture technology adoption decision is positively related access to with an increased in soil infertility and perception in severity of soil loss, access to extension services, land size and livestock ownership. Whereas adoption of agricultural technology has negative relation with home distance (from the nearest village market, asphalt and nearest input dealer) and marital status (being non-married is less likely to adopt SWC practices.

Chapter 5: Result and Discussion-Impacts of Adoptions of SWC Practices

5.1 Background

Once household's selection of appropriate technology and determinants of selection are identified, the study attempted to examine what are the impacts of adoption of respective technologies on households crop production as well as food security. It is obvious, different SWC structures (physical or biological or a combination) have different impacts on production and food security. In the study area, the soil and water conservation practiced includes; soil bund, stone bund, soil bund with plantation and a combination of these.

This chapter of the study examines the impact of these practices on households food security. The multinomial endogenous switching regression model is employed to assess the impact of respective soil and water conservation practices. This impact benefit is expressed by the counterfactual analysis which calculate the benefit of a particular technology by comparing with what is the counterfactual impact if they hadn't adopted the technology mentioned.

5.2 Overall Food Security

Food security of households of the survey area can be dealt from different perspectives. This study collects data that helps to compute the famous WFP food security measuring index, the food consumption score. According to WFP the result of the score are classified into three categories as discussed in the above sections. As shown in (Table 13), 66 percent of the survey population are within the acceptable food security condition . It is only 5 percent of the population who are found out to be 'poor' in terms of their food security status. The food security status for the remaining 29 percent of is with FCS results between 21.5 and 35 and are rated as 'borderline'. This finding is in line with the facts of the Degem woreda, is considered as one of the food secure woredas where there have not been no emergency food assistances in the past years, and it is not the woreda included with the countrywide PSNP programme. However, the study at the same time found out there are also areas and households where food security is a concern and caused by multiple factors.

Table 13: Result summaries of FCS, Degem woreda, Leman Watershed

FCS	No of HHs	Percent of HHs
0-21 (Poor)	15	5
21.5-35 (Borderline)	87	29
>35 (Acceptable)	196	66

Source: Survey data, March 2019

5.3 Impacts of SWC Practices on Food Security

This study mainly aims at understanding on the impacts of soil and water conservation activities on households food security. As efforts on implementing different soil and water conservation activities has been immense through the support of SLMP, it makes sense to examine what are their impacts in enhancing on households crop and livestock productivity and food security. Within the spectrum of different SWC practices, the study made an effort to examine which SWC practice contributed most to households food security. The results in the Table 14 presents, the non-adopters are those with the lowest food security status with mean FCS of 33 compared to other groups of households adopting different types food security technologies. Among the adopters, those who adopt and practices all types of SWC practices are with much better food security status represented by mean FCS of 45. As per the results of the mean FCS of adopters of different technologies, other groups showed closer results; those who only practices soil bund (38.8), stone bund only (41.3), soil bund with plantation (43.1),and soil bund and stone bund (41.5)

Table 14: Results of FCS by each regime, Degem woreda, Leman Watershed

SWC2	mean	SD	Median	min	max
Non-Adopters ($S_0T_0P_0$)	33.8	7.7	36	10.5	45
Soil bund only ($S_1T_0P_{0)}$	38.8	11.9	38.5	13	69
Stone bund only ($S_0T_1P_0$)	41.3	12.5	42	19	74
Soil bund with plantation ($S_0T_0P_1$)	43.1	6.7	42	32	65
Soil bund and Stone bund $S_1T_1P_0$)	41.5	8.9	42	24	61
Soil faced stone bund and biological plantation ($S_0T_1P_1$)	41.2	8.3	43	26	52
All types of practices ($S_1T_1P_1$)	45.1	6.1	44	33	58.5

Source: Survey data, March 2019

The above result can be reiterated and clearly visualized by the chart (Figure 7) presented below as it shows adopters of all practices (number 7) are within high and consistent food security status. On the other hand, the non-adopters are represented by low food security median and box-plot position is lower from the boxes representing other categories.

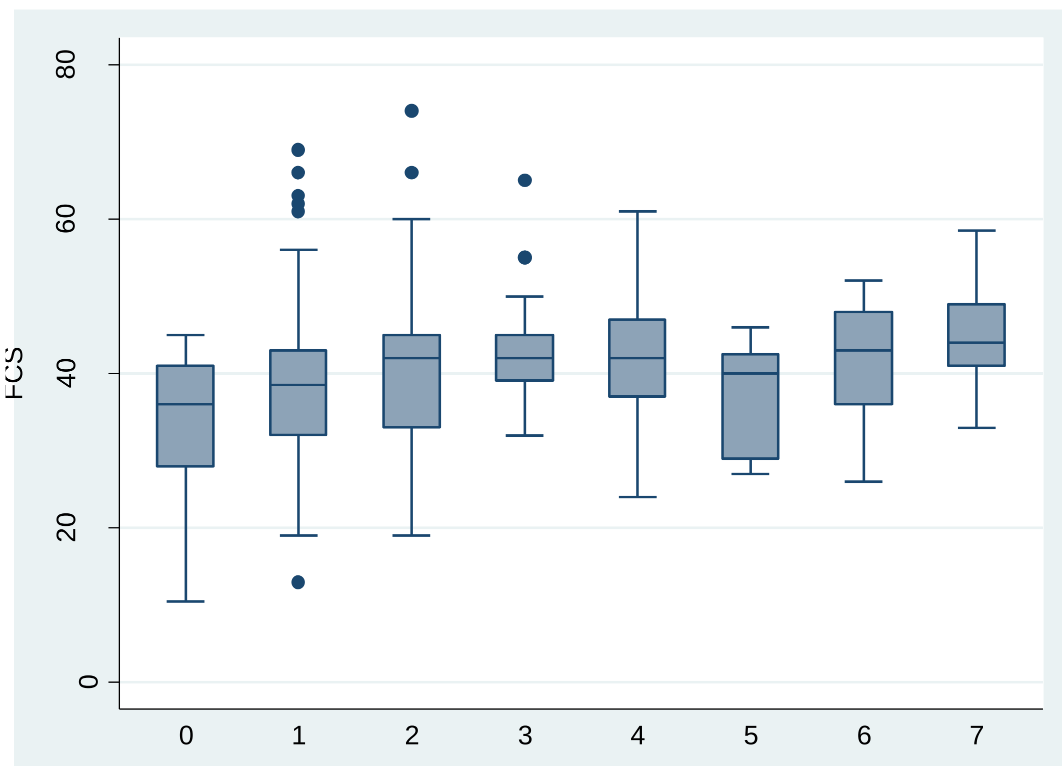

Figure 7: Box-graph of FCS by regime, Leman watershed, Degem woreda

Source: Survey data, March 2019

5.4. Econometric Analysis

5.4.1 OLS Estimates

The other possible way of examining impact of technology adoption on food security if constructing of linear regression equation and see the results of the OLS estimates of the equation.

Table 15: OLS estimates of variables affecting HHs food security, Leman watershed, Degem woreda

FCS	Coef. Std.	SE	t	P>t
Soil bund only ($S_1T_0P_0$)	2.65	2.37	1.12	0.27
Stone bund only ($S_0T_1P_0$)	-4.86	7.24	-0.67	0.50
Soil bund with plantation ($S_0T_0P_1$)	4.70	3.64	1.29	0.20
Soil bund and Stone bund $S_1T_1P_0$)	1.16	4.09	0.28	0.78
All types of practices ($S_1T_1P_1$)	3.38	3.48	0.97	0.33
Sex of Households	4.14	3.18	1.30	0.20
Household Size	0.38	0.36	1.07	0.29
Household Head Education	-0.44	1.33	-0.33	0.74
Income from Crop Production (ln)	0.53	1.92	0.28	0.78
Total Households Income (ln)	0.00	0.00	-0.92	0.36
Households Agriculture Experience	-0.04	0.10	-0.38	0.70
Barley land size (ha)	0.04	2.69	0.01	0.99
Land Certification	-1.59	2.47	-0.64	0.52
Tropical Livestock Unit (TLU)	1.03	0.64	1.62	0.11
Number of Hand tools	0.84	0.52	1.60	0.11
Barley Seed Utilization	0.01	0.01	0.69	0.49
UREA	-0.03	0.02	-1.55	0.13
Amount of Barley Production	0.14	0.20	0.68	0.50
Access to Extension Services	3.06	2.55	1.20	0.23
Distance from Home to Market	-1.94	1.44	-1.35	0.18
Barley Labour_Cultivation	2.12	2.02	1.05	0.30
Barley Labour_Weeding	-0.39	0.95	-0.41	0.69
Barley Labour_Harvesting	0.19	0.29	0.67	0.50
Constant	19.38	16.84	1.15	0.25

Source: Survey data, March 2019

As per the results in the Table 15 stone faced soil bund with plantation at first and others also impact positively the food security status of households. Adoption of all combination of SWC practices , as indicated in the table results higher food security status as the model coefficient shows 3.38, although not statistically significant.

However, the above approaches can be misleading, and should not be implemented to evaluate the impact of SWC technology adoption on the households food security. The methods assume that adopting SWC technology is exogenously determined, while it is a potentially endogenous variable. The difference in food security could be caused by unobservable characteristics of the farm households such as their skills. For instance, the apparently most successful farm households could also be the most skilled ones, and so, those that would have done better than the others even without adopting SWC technologies. The current study addresses this issue by estimating a multinomial endogenous switching regression model as described in above chapter: in a first stage, the researcher estimate the aforementioned multinomial logit model of choice between multiple combinations of strategies, and in a second stage, researcher estimates production function account for the endogenous strategy decision.

5.4.2 Endogenous Switching Regression Model

The true average effect of adoption on food security is estimated based on the result of conditional average treatment effect. It is estimated by comparing their outcome variables with their respective counterfactual; (i.e. the outcome variables of farm households who adopted at least one SWC technology are compared with the outcome variables if the farm households had not adopted it).

As indicated in Table 16, there is a significant variation on the food security status of households between the adopters of any of the SWC practices than those who did not adapt. The adopters of all conservation practices ($S_1T_1P_1$) are more benefitted with an actual food security of 63.97 than the others who adopted other types SWC practices except with those who practice soil bund and stone bund depending on the availability of the local SWC resources. The food security status of households who adopted all conservation practices ($S_1T_1P_1$) would have dropped to the level 39.88 had they not been implementing and benefiting from the conservation practices which implies the average treatment effect (ATT) of households who adopted all conservation practices ($S_1T_1P_1$) is 24.09.

Table 16 : Treatment effects by different SWC regimes, Leman watershed, Degem woreda

SWC Practices (Regimes)	Actual Food Security (FCS)	Counterfactual Food Security (FCS)	Impact (treatment effect) (FCS)
Non-Adopters ($S_0T_0P_0$)	46.42*** (15.02)	54.79*** (11.13)	-8.36 (24.37)
Soil bund only ($S_1T_0P_{0)}$	89.16** (47.96)	40.83*** (3.94)	48.32 (47.7)
Stone bund only ($S_0T_1P_0$)	60.62 (89.47)	38.82*** (1.28)	21.8 (89.3)
Soil bund with plantation ($S_0T_0P_1$)	47.94* (27.64)	39.46*** (1.20)	8.47 (27.9)
Soil bund and Stone bund ($S_1T_1P_{0\,)}$	158.55** (68.74)	35.62*** (2.58)	122.2** (68.61)
Adoption of all conservation practices ($S_1T_1P_1$)	63.97*** (13.95)	39.88*** (1.24)	24.09* (13.99)

* Denotes significance level at 10 percent
** Denotes significance level at 5 percent
*** Denotes significance level at 1 percent

Source : Survey data, March 2019

The findings of the study unveiled ; non-adopters of soil and water conservation practices missed the advantage of having an improved food security status when compared to situations if they had implemented at least one of the SWC practices. As per the data the actual food security of the non-Adopters ($S_0T_0P_0$) is 46.42 while the counterfactual value or the value they could have attained if they had participated in SWC activities is 54.79. Thus, the average treatment effect for being untreated (ATU) is -8.36 as presented in Table 17.

The study revealed, adopting both soil bund and stone bund depending on the technical requirement of the filed as well as the availability of resources for the construction of physical structures is provide more benefit. As per the result of the study the actual food security of households who practiced soil bund and stone bund when needed is 158.55 while the counterfactual is very low (35.62). The actual food security status of households of those who adapted Soil bund only ($S_1T_0P_0$) is 89.16 while the counterfactual is 40.83.

On the other results, food security of households is found to be much better for households who adopted Soil bund with plantation ($S_0T_0P_1$). The actual value of food security of adopters is 47.94, whereas the it would have dropped to 39.46 if they had not implemented the soil bund structures along with plantations. That means, the average treatment effect (ATT) of the adopters of Soil bund with plantation ($S_0T_0P_1$) technology is 8.48.

5.5 Summary

In general, when looking at the choice between adopting any SWC technology against non-adopting the study proved there is a clear benefit of having better food security status for those who adopted any one of the single or combination of technologies. Non-adopter loses a benefit of 8.36 FCS for their failure to participate in any of the SWC practices. Result showed all technologies provide better food security benefit when adopting the technology than the counterfactual (non- adoption). There is disparity on food security benefit among adopters of different SWC practices. More actual food security benefit with FCS of 158.55 obtained for households implemented soil and stone bund on a field when technically required and availability of resource allows them to do so. The study also found out; physical structure complemented with biological is important in enhancing households food security.

Chapter 6: Result and Discussion- Technical Efficiency of crop production as factor influencing food security: Stochastic Frontier Analysis

6.1 Background

Increase in crop production significantly contributes to boost food security as supply of food via own production is integral to the availability dimension of food security conceptual model (Degefa, 2005). Production and productivity can be basically boosted using two ways. The first method is through increased use of inputs and/or improvement in technology given some level of input. The other option of improving productivity is to enhance the efficiency of producers or firms, given fixed level of inputs and technology (Solomon , 2014).

Food insecurity is multifaceted and influenced by multiple factors. It is at the same time imperative to understand limited production and its impact on food insecurity is also attributed to production inefficiency and identify which are factors contributing to production inefficiency. Empirical researches find out policies that geared towards enhancing technical efficiency (TE) key for improving production and food security. As per the study by Kaleab and Birhanu (2011) done on analysis of TE on wheat producing commercial farms in Ethiopia, confirmed as the average TE of farmers was limited to 82 percent, implying that there is a room to enhance productivity by 18 percent.

According to the neo-classical definition of technical efficiency, a production process is technically efficient if and only if it yields the maximum possible output from a give level of technology and input set.

Even though there is some similarity between terms production efficiency and technical efficiency, however, they are not same. The simplest way to differentiate production and technical efficiency is to think of productive efficiency in terms of cost minimization by adjusting the mix of inputs, whereas TE is output maximization from a given mix of inputs (Palmer and Torgerson, 1999).This study is aimed at examining what is the best possible mix of input to attain maximum output.

6.2 Descriptive Statistics

According to results data from sample survey that is presented on Table 17, on average households in Leman watershed produced 11ql of barley in 2010/11 production season. However, there was a big variation of production among household that ranges between 1 ql to a maximum of 30 ql. The result of the survey also revealed, average land cultivated for barley was 0.75 ha and the productivity per hectar during the year was 14.8 ql. As compost is one of the most important inputs of production, the average amount of compost application as per the study is nearly 78kg.

Variables	Observations	Mean	SD	Min	Max
Barley production (kg)	282	1110	672	100	3000
Land cultivated for barley (ha)	282	0.74	0.35	0.13	2.50
Compost	202	78	47	30	500
Labour (days)	284	12.5	5.4	0	30

Table 17: Summary of continuous variables used in the estimation of production functions

Source: Survey data, March 2019

Last but not least, labour was also considered as one of the necessary inputs of production about which the data was collected on days spent on cultivation (land preparation), weeding and harvesting. The study computed the aggregate labour used on these three major activities and on average households invest 12.5 days of labour throughout the process of barley production.

Table 18: Summary of dummy variables used in the estimation of production functions

Variables	Frequencies		Percentage	
	Yes	No	Yes	No
Use of compost (Yes=1, No=0)	226	70	77	23
Extension service received	175	120	60	40

Source: Survey data, March 2019

This study used both continuous and dummy variables to explain the variation in output due to technical inefficiency. The most important continuous variables which are assumed to explain the production technical inefficiency are listed in Table 19.

Table 19: Summary of continuous variables used in the inefficiency models

Variables	Observations	Mean	SD	Min	Max
Age of household head (years)	296	49.3	12.7	25.0	80.0
Household size (number)	296	6.2	2.6	1	17
Total HH Income	296	6984	5930	0	34000
Distance to Plot from home (minutes)	280	19.4	12.0	1.0	60.0
Tropical Livestock Unit (TLU)	282	3.9	1.7	0.2	11.9
Number agricultural hand tools	248	4.9	2.3	1.0	10.0

Source: Survey data, March 2019

Accordingly, the mean age of households included in the sample is 49 years. However, households ranged from the youngest (25 years) to the oldest 80 years old. On average household size of the study area is about 6. The survey also revealed that the total income households reported is on average 6984 birr, nonetheless, there are households who reported zero income and the highest and one to the most extreme annual income was 34,000 birr. The other continuous variable used in the model is distance of plot from home and on average households travel 20 minutes. The average number of livestock, measured in terms of TLU, among sample was found to be 3.9. The study also considered the availability of hand tools are one of a key variables to determine production inefficiency and as per the result of survey the average number of agricultural hand tools per household was about 5.

Looking at the dummy variables used in the model. The list of variables indicated in Table 20 are considered as the principal ones. Thus, as per the study the male is dominating households head accounting 87% of the surveyed households.

Table 20: Summary of dummy variables used in the inefficiency models

Variables	Frequencies		Percentage	
	Yes	No	Yes	No
Sex of household head (Yes=1=M, No=2=F)	258	38	87	13
Slope of barley plot	105	191	35	65
Perceived fertility of Barley Plot	211	85	71	29
Perceive soil loss of plot	185	111	62	38
Land certificate given	227	68	77	23
Soil and Water Conservation participation	152	144	51	49
Extension service received	168	127	57	43

Source: Survey data: March 2019

Among the total samples, the proportion of households with flat land are 35% while the remaining cultivate a land which is either gentle or steep slope. 71% of the sample households perceive that their land is either moderately fertile or fertile and the remaining are those who perceive their land is infertile. Likewise, 38 percent of households replied about “high severity’ when asked about on the perception of soil loss on their plot. The other important variable to explain about the production efficiency is the households participation on soil and water conservation practices and 51% replied "yes" indicating that they participated on the SWC practice one way or the other. The study also discovered, 57% of households received extension services but majority described the frequency of the visit as "rarely"

6.3 Econometric Results

The overriding objective of this section will be to examine if households are productive and thereby productivity contributed to the improvement of households food security as the two are positively correlated. Thus, the study tries to estimate production function using both OLS and MLE. Basically, before rushing to discuss the econometric model results, it is very important to test hypotheses of the study.

Table 21: Estimates of the average and frontier production function

Variables	**Barley production**	
	OLS	**MLE**
Area cultivated for barley	14.47*** (0.73)	12.51*** (1.25)
Labour used for barley production	0.25*** (0.52)	0.2*** (0.06)

Compost application (Yes/No)	-1.04** (0.54)	-1.03* (0.71)
Extension services	-1.75*** (0.47)	-2.55** (1.28)
Adjusted R^2	0.61	
F-Statistics	111.83	
σ_u^2		0.18 (0.38)
σ_v^2		4.16*** (0.20)
$\lambda = \frac{\sigma_u}{\sigma_v}$		0.43 (0.43)
$\gamma = \frac{\lambda^2}{1+\lambda^2}$		0.15
LL		-586.36

* Denotes significance level at 10 percent
** Denotes significance level at 5 percent
*** Denotes significance level at 1 percent

Source: Survey data, March 2019

First, I tested whether the average production function best fit the data or not. Alternatively, this is to test whether the SFP function is more appropriate than the convectional production function or not. This can be done using the null hypothesis, H0: γ = 0, where the parameter $\gamma = \gamma = \frac{\lambda^2}{1+\lambda^2}$. If this null hypothesis is not rejected, the SPF is equivalent to the convectional production function which is estimated by OLS.

The γ parameter estimates of all production functions are significant at 5% significance level (Table 21). In constructing the production function, the input variables; barley seed, DAP and UREAD were dropped because of having many missing information. Hence, the null hypothesis was rejected indicating SFP function is more appropriate than convectional production function or there is significant technical inefficiency variation among plots. The γ value of 0.156 for barley production function can be then interpreted as, 15% of the variation in output among plots is explained by technical inefficiency. Solomon (2014) reiterated this finding on his study on the production efficiency of teff as the γ value of 0.636 for the major crops production function can be then interpreted as, 63% of the variation in output among plots is explained by technical inefficiency.

Total of four input variables were used in the estimation of the production functions. Table 20 presents both OLS and ML estimates of production functions. The OLS estimate for barley production shows as 61 percent of the variation in barley output among plots was explained by the input variables.

6.4 Technical Efficiency

Once the establishing and test of the SFP function is done the next task is to compute the technical production efficiency and know what are the key determinants of technical efficiency (TE). The challenge with this analysis is having many observations with missing values of different production input variables.

Overall, the mean technical efficiency is 0.55, minimum 0.10 and maximum 0.99. As presented in the Table 22 below, majority farmers accounting 30% percent of the respondents are within technical efficiency of 0.9 and above. The second bigger category are those within TE of 0.1 to 0.2 which represents significant share of households are way below the efficient production pattern. This is in agreement with the study that deals with the issue of improving economic efficiency in Sawnwood production in Ondo and Osun states, southwest Nigeria; mean technical, allocative and economic efficiencies of Sawnwood producers in Ondo and Osun states are 68%, 81% and 54% and 79%, 83% and 67%, respectively (Kehinde and Awoyemi, 2009). Likewise, (Solomon, 2014) described relatively lower value (63.56%) of TE score for major crops can be interpreted as, given the level of input and the current technology, there is a room to boost major crops production by 36.44 percent.

Table 22: Technical Efficiency Category and Frequency

Technical efficiency category	Freq.	Percent	Cum.
0.1-0.2	26	23.85	23.85

0.21-0.3	13	11.93	35.78
0.31-0.4	9	8.26	44.04
0.41-0.5	6	5.5	49.54
0.51-0.6	7	6.42	55.96
0.61-0.7	6	5.5	61.47
0.71-0.8	3	2.75	64.22
0.81-0.9	6	5.5	69.72
>0.91	33	30.28	100
Mean		0.55	
SD		0.33	
Minimum		0.1	
Maximum		0.99	

Source: Survey data, March 2019

6.5 Estimation of determinants of inefficiency model

As explained in the model specification in the earlier section one stage approach, which includes all inefficiency explanatory variables and conventional input variables simultaneously, was employed in this study. However, to make it readable the model results are presented with two tables, independently. Hence, the Table 23 presents the determinants of technical inefficiency among plots.

Table 23: Determinants of technical efficiency

Variables	Barley production	
	Coefficient	**SE**
Household Age	-0.03	0.06
Household sex	0.07	1.03
Distance from home to plot	-0.02	0.03
Household size	0.14	0.12
Agriculture experience of households	0.08	0.07
Slope of barley plot	4.16**	1.83

Perceived fertility of barley plot	1.26	1.82
Perceived soil loss of barley plot	2.06	1.72
Land Certification	-0.67	0.98
Livestock Possession (TLU)	-0.36*	0.26
Number of agricultural tools	3.02*	1.69
Participation on SWC practices	-2.81*	1.66
Access to extension services	-1.29	1.39

* Denotes significance level at 10 percent
** Denotes significance level at 5 percent
*** Denotes significance level at 1 percent

Source: Survey data, March 2019

Among the variable, the slope of barley plot to be cultivated is the source significantly affect efficiency of barley production. The higher the slope of the land scape implies the less the households are productive. As a higher slope land implies the vulnerability of the land to different biophysical factors including erosion and soil and vegetation degradation that lead to low productivity, the study unveiled the fact that it is the major factor hindering the productivity of households and thereby affecting the food security.

Livestock ownership enhances the cultivation capacity of the households as they own more oxen to repeatedly prepare the land for crop production. In addition, households with higher livestock ownership attends to accumulate more cash that helps to buy more agricultural input to boost production and productivity. The study, therefore, revealed that farmers with higher livestock possession where the TLU coefficient is (-0.36) are more likely to be less-inefficient and thus become more productive. Livestock could support crop production in many ways; it can be source of cash, draft power and manure that will be used to maintain soil fertility (Wassie, 2012).

Likewise, participation in soil and water conservation activities was found to have negative and significant effect on technical inefficiency of major crops and wheat production. As it entails the core subject of this study, studies proved that SWC practices have positive contribution for enhancing production as they retain the soil and soil nutrients and moisture within the soil which is key for improved production. This has also been proved on this study as households participating in different types of soil and water conservation practices tend to be more efficient in area's major crop, barley production. There are evidences that show soil and water conservation measures bring a meaningful impact on income and improved household level of food consumption. As noted by (FAO,2003) where examples mentioned using controlled and stationary scenarios explained as "under the "Stationary" scenario (no soil conservation and no change in technology and no migration), agricultural production will be reduced to 30 percent by 2030, and per capita per annum will decrease from $372 in 2000 to $162 in 2030, while food availability per capita will plunge from 1971 kcal per day to 685 kcal per day in 2030. In the "Control" scenario (soil conservation is practiced) productivity will improve by 9 percent in 2030, per capita income will decrease to $260 in 2030 while food per capita will improve from 685 kcal to 1085 kcal per day. Thus, a development path without soil conservation would be disastrous and clearly not an option.

6.6 Summary

This study unveiled that production inefficiency/ efficiency is instrumental in undermining or enhancing the food security as multiple findings reinforce this conclusion. In the econometric result revealed 15 percent of the variation in output among plots is explained by technical inefficiency. Looking at the technical efficiency of barley, production the mean performance is 0.55, with minimum 0.10 and maximum 0.99. The result also added, majority farmers accounting 30% percent of the respondents are within technical efficiency of 0.9 and above. The inefficiency is caused by different factors; Slope of farmland, livestock possession, agricultural tools ownership and SWC participation are factors that significantly determine efficiency.

Chapter 7: Summary, Conclusion and Recommendations

According t-test results of adopters and non-adopters in different technology groups shows a statistically significant different in households' education, training, land size, slope of their land, on their perceived fertility and soil loss. Similarly, significant difference is seen with respect to households average livestock ownership, access to extension services and distance of households from the main market. In particular, there exists a significant mean different in many households aspects of households who adopts all types soil and water conservation practices (S1T1P1))from those who did not adopt.

The multinomial logit selection model result revealed that the agricultural technology adoption decision is influenced by observable plot characteristic, household and institutional characteristics. More specifically, the agriculture technology adoption decision is positively related access to with an increased in soil infertility and perception in severity of soil loss, access to extension services, land size and livestock ownership. Whereas adoption of agricultural technology has negative relation with home distance (from the nearest village market, asphalt and nearest input dealer) and marital status (being non-married is less likely to adopt SWC practices.

When looking at the choice between adopting any SWC technology against non-adopting the study proved there is a clear benefit of having better food security status for those who adopted any one of the single or combination of technologies. Non-adopter loses a benefit of 8.36 FCS for their failure to participate in any of the SWC practices. Result showed all technologies provide better food security benefit when adopting the technology than the counterfactual (non-adoption). There is disparity on food security benefit among adopters of different SWC practices. More actual food security benefit with FCS of 158.55 obtained for households implemented soil and stone bund on a field when technically required and availability of resource allows them to do so. The study also found out; physical structure complemented with biological is important in enhancing households food security.

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Analysis and results of inefficiency also revealed, the level of production and food security status can further be improved through the efficient use of agricultural inputs of production (labour, land, compost and other inputs). It is believed that the findings of the study provide paramount importance in an effort to design and review implementation guidance based on the following recommendation:

- The natural resource conservation in general and the SWC practices in particular are proved to have positive impact in improving household's production and food security. Food security is more enhanced by adoption of more than (combination) of practices instead of single technology adoption like soil bund or stone bund only rather better outcome is possible if more efforts in promoting SWC structure complemented by plantations of livestock feed and other vegetation types.

- Investing more on education and training significantly contributes on changing household's decision behavior and are positive in technology adoption. Therefore, promoting and increasing access to formal and informal education as well as enhancing efforts in improving the access and frequency of extension service to farmers.

- Distance from the asphalt and market increase the agriculture technology adoption decision. Thus, the government should increase the access of infrastructure.

- Inefficiency of production is stemmed out of households higher slope of farm land at the same time efficiency is improved through SWC participation. Hence, it would be more vital if areas with sloppy farmland are aggressively engage in SWC activities.

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Appendix

Table A1: Dependent and independent variables used in the study and their description

Variables	Definition
Dependent	
FCS	Food Consumption Score
$S_0T_0P_0$	Dummy = 1 if farm households did not adopt any CF practice, 0 otherwise
$S_1T_0P_0$	Dummy = 1 if farm households adopted only Stone bund, 0 otherwise
$S_0T_1P_0$	Dummy = 1 if farm households adopted only Soil bund, 0 otherwise
$S_0T_0P_1$	Dummy = 1 if farm households adopted only Soil bund with biological plantation, 0 otherwise
$S_1T_1P_0$	Dummy = 1 if farm households adopted only Soil and stone bund, 0 otherwise
$S_1T_0P_1$	Dummy = 1 if farm households adopted only Soil bund and Soil bund with plantation, 0 otherwise

$S_0T_1P_1$	Dummy = 1 if farm households adopted only Stone bund and Soil bund with plantation, 0 otherwise
$S_1T_1P_1$	Dummy = 1 if farm households adopted all CF practices jointly, 0 Otherwise
Explanatory	
HH_Age	Age of Household
Age_Actv	Number of households of active age group
HH_Sex	Dummy = 1 if farm households is male, 0 otherwise
HH_Size	Total number of people with in household
HH_Educ	Ordinal: 1 if Unable to read and write, 2 if able to read and write, 3 attended formal education, 4 if joined college
HH_trang	0 if received only one training or none, 1 if received more than one traing
lnAginc	Logarithm of Income from Agriculture
lnincom	Logarithm of HH Total income
Ag_Exp	Number of years of experience in agriculture
Land_Cu	Total size of land cultivated
Plt_Dist	Distance of plot from hone
Plt_Slp	Categorical: 1 if flat, 2 if gentle and 3 if steep
SoilFert	Ordinal: 1 if very poor, 2 if poor, 3 if average, 4 if good and 5 if very good
SoilLoss	Ordinal: perceived severity of Soil loss; 1 if very poor, 2 if poor, 3 if average, 4 if good and 5 if very good
Landten	Dummy = 1 if certificate is given, 0 otherwise
TLU	Livestock holding in measured in Tropical Livestock Unit
Agtools	Number of Agricultural tools
Seed_Ba	Amount of Barley seed used
DAP_Ba	Amount of DAP fertilizer used
UREA_Ba	Amont of Urea fertilizer used
Mannure	Dummy = 1 if manure applied, 0 otherwise
Herb_Du	Dummy = 1 if Herbicide used, 0 otherwise
Ba_Area	Area Cultivated for barley production
Ba_Prdn	Amount of barley production
Irrigat	Dummy = 1 if household has access to irrigation, 0 otherwise
Extension	Dummy = 1 if household has access to extension, 0 otherwise
Credit	Dummy = 1 if household has access to credit, 0 otherwise
Market	Distance of households from the main market
Cropres	Dummy = 1 if crop residue is used as fertilizer, 0 otherwise
Cultlabr	Barley cultivation labour (days)
Weedlab	Barley weeding labour (days)
Harvstlb	Baley Harvesting labour

Table A2 : Test of multicollinearity of variables used

Variable	VIF	1/VIF
Ba_Seed	3.59	0.28
UREAP_1	3.53	0.28
Ba_Prod	2.38	0.42
LandS_Ba	2.28	0.44
Labcu_Ba	2.11	0.47
lncrpinc	2.05	0.49
Tool_Num	1.87	0.53
lnincom	1.83	0.55
Mark_dist	1.73	0.58

TLU	1.72	0.58
Ext_YN	1.71	0.59
LabHa_Ba	1.69	0.59
SWC001	1.66	0.60
LabWd_Ba	1.6	0.63
Ag_Exp	1.52	0.66
SWC111	1.52	0.66
Cert_1	1.47	0.68
HH_Educ	1.38	0.72
SWC110	1.35	0.74
SWC100	1.31	0.77
HH_Size	1.26	0.79
HH_Sex	1.26	0.79
SWC010	1.11	0.90
Mean VIF	1.82	

Figure 8: output oriented production efficiency curve

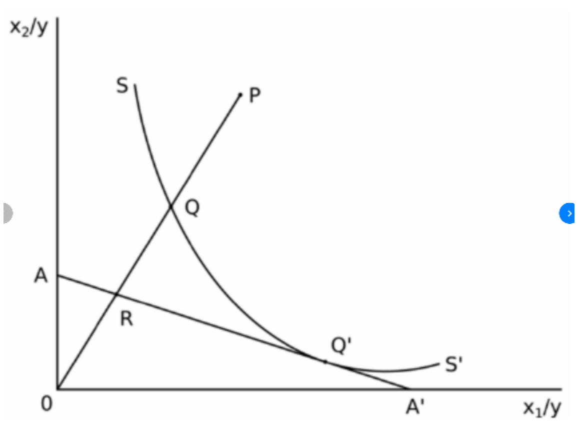

Figure 9: Input-oriented production efficiency curve