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IMPACT OF SOIL AND WATER CONSERVATION STRUCTURES ON þÿ H O U S E H O L D S   F O O D   S E C U R I T THE CASE OF WEST AND EAST BELESA WOREDAS, CENTRAL GONDAR ZONE, AMHARA REGION, ETHIOPIA.

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M.Sc. Thesis

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THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. Mehariw Worku entitled "**Impact of Soil and Water Conservation Structures on Households' Food security: the case of West and East Belesa *Woredas*, Central Gondar Zone, Amhara Region, Ethiopia**". We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Agricultural Economics.

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Name of Internal Examiner Zemen Ayalew (PhD) Signature_______ Date 17/12/2020

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DECLARATION

This is to certify that this thesis entitled "**Impact of Soil and Water Conservation Structures on Households' Food Security: the case of West and East Belesa *Woredas*, Central Gondar Zone, Amhara Region, Ethiopia**", submitted in partial fulfillment of the requirements for the award of Master of Science in Agricultural Economics to the Graduate Program College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. Mehariw Worku (ID No. BDU1100574) who is an authentic work carried out by himself under our guidance. The matter embodied in this thesis work has not been submitted earlier for the award of any degree or diploma to the best of our knowledge and belief.

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Co-advisor	Signature	Date

DEDICATION

This thesis is dedicated to my family. Your love, prayers, and support have been the driving force that pushed me through this course of study.

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ABSTRACT

Although the government of Ethiopia and non-governmental organizations have invested substantial resources in promoting soil and water conservation practices (SWC) to improve environmental conditions; ensure sustainable and increased agricultural production, and thus improve food security, there is no enough study dealing with the impact of SWC structures on food security. This study's major aim was to analyze the impact of SWC structures on households' food security in the semi-arid areas of Belesa. Specifically, the study assessed on-farm adoption of SWC structures and its impact on households' food security measured in households' dietary diversity score (HDDS), food consumption score (FCS), food insecurity experience scale (FIES), and food security scale(FSS). Data was generated from 546 households using a multi-stage sampling technique from four sample kebeles in East and West Belesa Woredas. The study used both primary and secondary data. Descriptive statistics, inferential statistics, and econometric models were used to analyze the data collected. A binary probit model and an endogenous switching regression (ESR) model were employed to analyze the determinants of on-farm adoption of SWC structures and its' impact on food security respectively. The survey result shows that 52.01% of the sample households adopted SWC structures on their farm. Age of the household head, household size, frequency of SWC training, average plot area, the proportion of owned plots, and proportion of lower position plots from watersheds had a significant positive effect on the adoption of SWC structures. However, the amount of non-farm income, average plot to home distance, and proportion of flat-sloped plots affected the adoption of SWC structures negatively. The ESR model result shows, the HDDS and the FCS of adopters increased by 7.316 and 18.707 points due to adopting SWC structures. Besides, the FSS and FIES of adopters decreased by 4.462 and 0.221 points due to adopting SWC structures. For non-adopters, the HDDS and the FCS could be increased by 0.631 and 4.016 points if they had adopted SWC structures. Furthermore, the FSS and FIES could be decreased by 0.322 and 0.527 points if they had adopted SWC structures. SWC structures are contributing to the improvement of the food security of the households. Policymakers, extension agents, Woreda, and kebele level agricultural offices should consider the findings of the study and come with better approaches and solutions to improve the adoption of SWC structures.

Keywords: Soil and water conservation; Impact; Probit model; ESR; Food security; Ethiopia

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ABBREVIATIONS AND ACRONYMS

ADB	African development bank
AE	Adult equivalent
ATT	Average treatment effect on the treated
ATU	Average treatment effect on untreated
Chi2	Chi-square
EBWOA	East Belesa *Woreda* office of agriculture
ESR	Endogenous switching regression
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization of the United Nations
FCS	Food consumption score
FDRE	Federal democratic republic of Ethiopia
FGDs	Focus group discussions
FIES	Food insecurity experience scale
FSS	Food security scale
GDP	Gross domestic product
HDDS	The household dietary diversity score
HE	Heterogeneity effect
IFSP	Integrated Food Security Program
Kcal	kilocalorie
Kg	Kilogram
LDCs	Less-developed countries

LR Likelihood ratio

MoFED Ministry of finance and economic development

PSM Propensity score matching

SD Standard deviation

SLM Sustainable land management

SWC Soil and water conservation

TLU Tropical livestock unit

UNCCD The United Nations Convention to Combat Desertification

US United States

WBWOA West Belesa *Woreda* office of agriculture

WFP World food program

WOCAT World Overview of Conservation Approaches and Technologies

Chapter 1. INTRODUCTION

1.1. Background

Ethiopia's economy is highly dependent on Agriculture and the fate of this sector directly affects economic development, food security, and poverty alleviation (Mohammed Gedefaw *et al*., 2018). Soil erosion and soil nutrient depletion are threatening the agriculture sector and rural livelihoods (Birhan Asmame and Assefa Abegaz, 2017; Asnake Mekuriaw *et al*., 2018). Since the majority (nearly 90%) of the population lives in the highlands where land is continually cultivated, soil erosion and land degradation continue to be a serious threat to the agriculture sector (Daniel Asfaw and Mulugeta Neka, 2017; Asnake Mekuriaw *et al*., 2018; Fontes, 2020). In Ethiopia, soil erosion rates on cultivated lands and formerly cultivated degraded lands was about 20 and 33 tones per hectare per year respectively (Hurni *et al.*, 2015). These losses had been associated with biophysical and socio-economic factors and heated by rapid population growth and resulted not only in a decline in land productivity but also worsen ecological degradation and social problems (Belete Limani, 2018).

The threat of land degradation is more credible in Amhara Region (Assemu Tesfa and Shigdaf Mekuriaw, 2014). It is estimated that the annual rate of soil loss in the region due to water erosion is about 119 million tons, which accounts for about 70% of the country's total soil loss (IFSP, 2004).

Sustainable use of natural resources can improve the welfare of households and help them become food secure while escaping the vulnerability trap (Million Sileshi *et al*., 2019). The Ethiopian government has considerable investments in conserving the environment, with the purpose of not just reducing soil loss but also improving crop yields and livelihood of the rural farmers (Million Sileshi *et al*., 2019). During the 1980s, the country started soil and water conservation (SWC) campaigns, encouraging the implementation of SWC practices in drought-prone and extremely land degraded parts of Ethiopia (Asnake Mekuriaw *et al*., 2018). Many catchments have been covered with bio-physical terracings such as bunds, area closure, and tree plantation since the 1970s and 1980s (Yitayal Abebe and Adam Bekele, 2014; Agere Belachew *et al*., 2020).

Although there were strong efforts towards SWC structures, the achievements are below expectations since farmers were forced to implement conservation structures (Nigussie Haregeweyn *et al*., 2015; Asnake Mekuriaw *et al*., 2018; Agere Belachew *et al*., 2020). The low rate of adoption of SWC measures is peculiar to Ethiopia (Tenge, 2011; Daniel Asfaw and Mulugeta Neka, 2017; Kebede Wolka *et al*., 2018). The low rate of adoption of SWC practices is not only due to technical problems; rather it is also due to socio-economic and biophysical problems (Kessler, 2006; Tadele Amedemariam *et al*., 2011).

Amhara region started to implement land rehabilitation measures through massive SWC programs in the 1970s. Since then, the region has been realized the treatment of vast degraded areas through a mass movement of the community in line with different projects lead by Governmental and Nongovernmental organizations. The conservation structures include terracing, cut off drain, and bunds followed by biological measures like plantation of grasses and forage plants to stabilize physical measures (Dessalew Meseret, 2016).

SWC practices can reduce runoff and hence increases soil fertility and moisture content, improves soil health and function, and restores and maintains the eco-system (Tenge *et al*., 2011; Zemenu Degie and Minale Amare, 2014; Solomon Hishe *et al*., 2017; Keesstra *et al*. 2018). In the long run, SWC will improve the ecology and environment as well as the local climate, which is associated with sustainable agriculture. SWC technologies can reduce erosion, increase soil moisture, and lead to increases in land productivity (Di Falco *et al*., 2011; Nigussie Haregeweyn *et al*., 2015). Thus, adopting SWC could substantially impact not just crop production, but also the household income of smallholder farmers (Million Sileshi *et al*., 2019). High production and household income increase farmers' purchasing power and consumption from own production (Ayalneh Bogale and Abebaw Shimelis, 2009; Mozumdar, 2012). Households with higher income are more likely to be food secure and less vulnerable to external shocks (Devicienti, 2002; Finnie and Sweetman, 2003; Jenkins *et al*., 2003).

Like other areas of the Amhara region, West and East Belesa *Woredas* are also highly vulnerable areas to the problem of land degradation and soil erosion. Despite different efforts to improve livelihood opportunities, as well as increase farm productivity through improved environmental conditions, the impacts of SWC practices on households' food security status is not yet systematically analyzed. This study is done to analyze the impact of SWC structures on households' food security and to identify the determinants of households' on-farm SWC adoption decision.

1.2. Statement of the problem

Land degradation causes soil and nutrient loss and is one of the key problems threatening agriculture in Ethiopia (Kirubel Mekonen and Gebreyesus Berhane, 2011). Due to soil erosion, the country loses 30,000 hectares of soil or one billion tons of topsoil, 30 kilograms (kg) of nitrogen, and 15-20 kg of phosphorous per hectare annually (Berry, 2003). Further losses of about $23 million of the forest as a result of deforestation and $10 million of livestock capacity are also reported annually (Mahmud Yesuf *et al*., 2007).

In Ethiopia, land degradation adversely affects the productive capacity of the land. The country losses at least 3% of its agricultural Gross Domestic Product (GDP) annually due to land degr adation and unsustainable land management (Samuel Gebreselassie *et al*., 2016). Land and water degradation reduces agricultural productivity and contribute highly to food insecurity and poverty (Shibru Tedla, 2010). The amount of grain lost by land degradation could feed more than 4 million people (Teklay Demel, 2001).

Serious natural resource base deterioration over time is resulting in food insecurity and related vulnerability (Pender and Berhanu Gebremedhin, 2007; Berhanu Gebremedhin *et al*., 2010). Land and water degradation could affect all dimensions of food security (food availability, accessibility, stability, and utilization) in complex ways. Land and water degradation has reduced agricultural production and productivity, while also affecting dietary diversity due to changes in the suitability of land for crop production (Pimentel and Burgess, 2013). This may directly affect household income and food availability. Lower yields could increase the prices of major crops due to reduced market supply at the local and national level (Slaymaker, 2002). This leads to subsistence farmers to sacrifice further to meet their adequate nutritional requirements and also, would be unable to escape food insecurity shortly (Stockings, 2003).

In response to the threats of land degradation, the government of Ethiopia, and non-governmental organizations have invested substantial resources in promoting SWC practices as part of efforts to improve environmental conditions and ensure sustainable and increased agricultural production (Asnake Mekuriaw and Hurni, 2015). In particular, the central government started massive SWC campaigns in the 1980s, targeting the low potential (drought-prone and highly degraded) parts of the highlands. Although the adoption of alternative improved technologies, such as the use of fertilizers and improved seeds, to enhance productivity per unit of the cultivated area was encouraged, farmers' implementation of SWC measures in the high potential area was discouraged (Asnake Mekuriaw *et al*., 2018). As such, SWC has been considered as an important part of the agricultural extension package in the country since 1991. However, it should be noted that the introduction of these measures and technologies has largely used the top-down approach with little participation of the target farmers. Consequently, these efforts have generally failed mainly due to a lack of support and awareness among farmers (Kebede Wolka, 2014; Mekuriaw and Hurni, 2015; Nigussie Haregeweyn *et al*., 2015; Asnake Mekuriaw *et al*., 2018).

Different SWC practices like bench terracing, soil bund, stone bund, farm forestry, and so on were implemented in different areas using an integrated SWC approach. The main goal of this approach was to improve the living standards and welfare of the most vulnerable rural households and communities through SWC practices. These consist of not only rainwater harvesting but also promoting sustainable and income diversifying agricultural practices (Gebrehaweria Gebregziabher *et al*., 2016).

The central question is thus, do these SWC structures bring an impact on productivity, gross annual income, and food security? If yes, how much is the impact of these structures? Various studies in Ethiopia and elsewhere by (Menale Kassie *et al*., 2007; Pender and Berhanu Gebre medhin, 2007; Haileselassie Medhin and Kohlin, 2009; Nyangena and Köhlin, 2009; Judith *et al.*, 2011; Enyew Adgo *et* al., 2013; Yenealem Kassa *et al*., 2013; Abdulai and Huffman, 201 4; Yitayal Abebe and Adam Bekele, 2014; Gatbel Chot *et al*., 2019, and Tesfaye Tanto and Fanuel Laekemariam, 2019) have examined the impact of SWC on technical efficiency, productivity, livelihood, and household income. However, some of these studies come with contradicting conclusions about the impact of SWC practices on different outcome variables. Judith *et al.* (2011), and Yitayal Abebe and Adam Bekele (2014) reported no significant impact due to SWC structures. Menale Kassie *et al*. (2007); Pender and Berhanu Gebremedhin (2007); Haileselassie Medhin and Kohlin (2009); Enyew Adgo *et al*. (2013); Yenealem Kassa *et al*.

(2013), and Gatbel Chot *et al*. (2019) reported a positive impact of SWC. However, Nyangena and Köhlin (2009) reported the negative impact of SWC structures.

Studies by Janvier *et al*. (2014), Masila *et al*. (2015), and Sita *et al*. (2018) tried to see the contribution of SWC structures on households' food security. However, they did not apply appropriate econometric models to analyze the impact. They simply used simple comparison through T-test and multiple linear regression.

A study by Million Sileshi *et al*. (2019) is the only rigorous study on the impact of SWC practices on households' food insecurity and vulnerability. This study employed only a single measurement, which is the consumption expenditure approach to measure food security. However, by using a single indicator it is difficult to account for the different dimensions of food security. Therefore, it is better to use a combination of indicators to capture the complexity of measuring food security. To address this issue, we employed four measurements of food security.

Moreover, in the study area the impact of the SWC structures on the household's food security status is not studied yet. This condition initiated the researcher to deal with this issue.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study is to assess the impact of SWC structures on the household's food security in West and East Belesa *Woredas.*

1.3.2. Specific objectives

The specific objectives of this study are to:

- Identify the determinants of households' on-farm SWC structures adoption decision.
- Analyze the impact of SWC structures on households' dietary diversity, food consumption score, food security scale, and food insecurity experience.

1.4. Research Questions

- What are the factors affecting households' decision to adopt SWC structures on their farm?

- Does the adoption of SWC structures has an impact on households' diet diversity, food consumption score, food security scale, and food insecurity experience?

1.5. Significance of the study

This study will contribute to the empirical literature on the impact of SWC structures on household food security in Ethiopia. It will also assist decision-makers to identify challenges encountered towards SWC practices and to take possible corrective measures.

In addition to this, understanding the impact of SWC measures is a crucial issue for designing and implementing appropriate agricultural development policies and strategies, as well as technology interventions.

Assessing the impact of past efforts and proper understanding of the improvement in the food security of smallholder farmers' is essential to draw lessons and as baseline information for future studies. It can also assist the setting of agricultural research and development priorities.

1.6. Scope and limitations of the study

This study focused on the impact of SWC on food security in West and East Belesa *Woredas* by taking only four *kebeles* within the two *Woredas*. However, it could be more interesting if this scope was widened to include more *kebeles* within the *Woredas* and if it was possible more *Woredas* with similar agro-ecosystem settings. Moreover, this study was executed using cross-sectional data. If it had used panel data, we would have captured more time-variant effects of the SWC practices on household food security.

1.7. Organization of the Paper

The thesis is organized into five chapters. The first chapter is an introduction laying out the background, statement of the problem, and objectives of the study. The rest of the thesis is organized as follows: Different theoretical and empirical works of literature are reviewed under chapter two and chapter three focuses on methodological aspects and model specification. The fourth chapter of the study presents data analysis and presentation of the main findings of the study. The last chapter discusses the summary, conclusion and recommendations part of the study based on the major findings.

Chapter 2. LITERATURE REVIEW

2.1. Definitions and Concepts

Land degradation can be defined as a natural process or a human activity that causes the land to be unable to provide intended services for an extended time (FAO, 2004). It is a temporary or permanent decline in the productive capacity of land resulted from deforestation, a change in water quality and quantity, and soil degradation (Lanckriet *et al*., 2015). It also refers to any decline or loss in the biological or economic productive capacity of the land caused by human activities, exacerbated by natural processes, and often magnified by the impacts of climate change and biodiversity loss (UNCCD, 2013).

Soil and Water Conservation is the improvement or improved management of the two resources "soil" and "water" to maintain in a medium to the long-term perspective of the production capacity of the resources, often measured in terms of yield (WOCAT, 2004).

Food Security is a condition that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for active and healthy life (FAO, 2009).

Impact: impact is the effect expected to result after practicing a certain practice/measure and can be positive or negative depending on the performance (Solomon Asfaw and Bekele Shiferaw, 2010)**.**

2.1.1. Soil and water conservation practices in Ethiopia

Since soil degradation is a major threat to agricultural yield, it is also threatening the economic growth of developing countries like Ethiopia (it is because the economy of LDCs is highly dependent on agriculture). About 65–85% of incomes in rural Ethiopia, and particularly the highlands, come from crop agriculture (MoFED, 2006). Furthermore, the incomes and consumption levels of these primarily subsistence farmers are extremely low. For example, in 1999/2000 the average rural adult income was only about US$ 95.00 per year and consumption was $136.28 per year, with about 42% of adults unable to obtain 2200 calories per day on average (Menale Kassie *et al*., 2008).

Typical SWC technologies used in Ethiopia include soil bunds, stone bunds, terraces, stone-faced soil bunds, grass strips, waterways, trees planted at the edge of farm fields, contours, and irrigation (chiefly water harvesting) (Kato *et al*., 2011).

Before the 1974 revolution, soil degradation did not get the policy attention it deserved (Wagayehu Bekele and Drake, 2003, and Habtamu Ertiro, 2006). The famines of 1973 and 1985provided an impetus for conservation work through a large increase in food aid (imported grain and oil). The use of food aid as payment for labor replaced voluntary labor for conservation campaigns. By most performance measures, the SWC effort of the country ended up in remarkable failure. A large sum of money has been spent in the name of encouraging environmental protection, encouraging and coercing farmers to adopt conservation measures. Nevertheless, the implementation was very poor few structures persisted causing erosion rather than preventing it (Habtamu Ertiro, 2006).

Between 1995 and 2009, soil conservation activities have been undertaken as part of the agricultural extension package of the present government through mass mobilization with a top-down approach and without incentives for the time farmers spent on SWC activities. The approach was to construct conservation measures at the individual level but not at the watershed level. Emphasis was given to the number of measures rather than the quality of measures. SWC is mainly limited to physical measures. Dis-adoption and non-adoption of SWC measures were common phenomena in this period. This indicates that the extension system did not bring about behavioral changes among farmers probably because the focus was on changing the farmland rather than farmers' behavior (Akalu Teshome *et al*., 2016).

Since 2010, the government of Ethiopia has been involved again in a massive SWC campaign. The current approach is also mass mobilization, but then at the watershed level. And there is an attempt to make such an SWC program more participatory. In each watershed area, agricultural offices along with local administrators organize a 15-day farmers workshop to create awareness about the problems of soil erosion and its causes. During the workshop, farmers prioritize their major natural resource problems, causes, and possible solutions. Then, they reach a consensus about the natural resource problems that require collective action. Farmers participate in SWC activities in nearby sub-watershed areas (Akalu Teshome *et al*., 2016).

2.1.2. Food security situation in Ethiopia

Ethiopia is facing a massive drought and food insecurity crisis over the years. According to ADB (2014) , Ethiopia is one of the most food-insecure and famine-affected countries. Drought, recurring food shortages, and famine are great challenges facing the Ethiopian people.

A large portion of the country's population has been affected by chronic and transitory food insecurity. According to CARE Ethiopia (2014) findings, chronic and acute food insecurity are prevalent, especially among rural populations and smallholder farmers. The findings indicated that about 10% of Ethiopia's citizens are chronically food insecure, and this figure rises to more than 15% during frequent drought years. The El Nino -driven drought has greatly expanded food insecurity and malnutrition, and devastated the livelihoods of the poorest and vulnerable people across the country. Food Security and Hunger/ Undernourishment Multiple Indicator Scorecard indicated that Ethiopia ranked first in having the highest number of people in the state of undernourishment/ hunger which is 32.1 million people. This makes it, the fourth African country scoring (37.1%) of the population being undernourished/ in hunger (FAO, 2016).

2.2. Empirical Literature Review

2.2.1. Empirical studies related to the adoption of SWC practices

Many studies have been conducted on the determinants of households' SWC practices adoption decision. These studies are presented below.

Addisu Damtew *et al*. (2015) employed descriptive statistics and bivariate correlation to identify determinants of SWC techniques in Goromti Watershed, Western Ethiopia. They found that the slope of the plots, contact with extension workers, tenure status, age of the household head, size of household, and training significantly influenced farmers to adopt SWC methods.

A study conducted by Akalu Teshome *et al*. (2016) used an ordered probit model to identify household-level determinants of SWC adoption. They found Farm labor, parcel size, ownership of tools, training related to SWC, presence of SWC program, social capital (e.g., cooperation with adjacent farm owners), labor sharing scheme, tenure security, cultivated land sizes, parcel slope, and perception on SWC profitability and perception of erosion problem have a significant positive influence on actual and final adoption phases of SWC. They recommend that policymakers should have to consider those factors affecting the adoption of SWC when designing and implementing SWC policies and programs.

Daniel Asfaw and Mulugeta Neka (2017) conducted a study to examine the factors influencing the adoption of SWC practices in Wereillu Woreda, South Wollo Zone, Amhara Region, Ethiopia using primary data. They applied a binary logistic regression model to analyze the collected data. They found that household head sex, education accessibility of training, and extension services were positively significant associated with the farmers' decisions to adopt SWC practices. However, the age of the household, off-farm activity, and distance between homestead and farmland influenced the farmers' decisions to adopt SWC practices negatively. Based on their findings they recommended that agricultural stakeholders such as Woreda Rural and Agricultural Development Office and other concerned bodies should collaborate to promote agricultural productivity and quality of the environment by taking into consideration these particular influential factors.

Tizazu Toma (2017) applied the Logit model to analyze the determinants of adoption of SWC Practices at the household level in Aletawendo *Woreda*, Sidama Zone, SNNPR, Ethiopia. The study found that the educational level of the household head, training participation, total income, perception of farmers for SWC Structures, preference of farmers, extension contact, and land ownership certificate had a positive and significant effect on the adoption of SWC practices. However, the study did not give attention to plot-level characteristics that can affect the adoption of SWC practices.

Asnake Mekuriaw *et al*. (2018) studied factors influencing the adoption of physical SWC practices in the Ethiopian highlands. They employed a binary logistic regression model. They reported that engaging in off-farm activities and the use of free grazing systems had a negative and significant effect on the adoption of physical SWC practices. However, the age of the household head, sex of the household head, education status, labor availability, landholding, and livestock holding affects the adoption of SWC structures insignificantly. However, they forget to emphasize plot-level characteristics.

Belete Limani (2018) conducted a study on identifying factors affecting the adoption of SWC practices in the case of Damota watershed, Wolaita zone, Southern, Ethiopia. The study applied a binary logit model to analyze the factors affecting SWC adoption. This study found that education, perception of erosion as a problem, household size, land size, slope, and sex affects the adoption of SWC practices positively while participation in non-farm activities and proximity of farm from the residence affects the adoption of SWC practices negatively. The study suggests a strategy that focuses on enhancing the willingness and ability of farmers sho uld be adopted, strengthen learning opportunities through facilitating the establishment of farmers' training center, and strengthen extension.

Adjepong *et al*. (2019) assessed the determinants of the adoption of sustainable SWC practices in Techiman Municipality of Ghana. They employed the Poisson model for assessing factors that vary with the number of different SWC practices used by farmers. The study found that household size, farm size, access to credit services, and formal training had a positive and significant association with the number of SWC practices adopted by farmers. However, distance to the nearest output market, distance to input center, access to extension services, and risk of pest and diseases had a negative and significant association with the number of SWC practices adopted by farmers. They suggest that agricultural policies formulated should be targeted at supporting farmers to have access to extension services to facilitate the dissemination of agricultural technology information.

A study by Million Sileshi *et al*. (2019) on the impact of SWC measures on households' food insecurity and vulnerability employed a binary probit model to examine the determinants of adoption of SWC technologies. The author reported that sex of the household head, age of the household head, educational status of the household head, dependency ratio, use of fertilizer, size of cultivated land, access to information from government extension agent and farmers' cooperative, and use of credit are the main factors affecting the adoption of SWC measures. They reported that the sex of the household head, educational status of the household head, use of fertilizer, size of cultivated land, and access to information from government extension agents and farmers' cooperatives affect the adoption of SWC positively and significantly.

Olawuyi and Mushunje (2019) conducted a study on the determinants of adoption and use-intensity of SWC practices among smallholder farmers in Nigeria. They applied binary probit and binomial regression models to analyze the determinants of adoption and use intensity of SWC practices. They reported that age of the farmers, gender, years of formal education, and farm size under cultivation were significant determinants of SWC practices adoption and based on the binomial regression model they revealed that age of the farmer, gender, and the size of farmland under cultivation found to affect the log counts of SWC practices adopted by smallholder farmers significantly.

Another study conducted by Agere Belachew *et al*. (2020) used a multivariate probit model to address the factors affecting the adoption of SWC practices in the North West Ethiopian highlands using primary data from households. They also identified that Sex, age, education level, household size, livestock holding, land size, access to credit, access to extension service, and training as significant factors affecting the adoption of SWC practices. This study recommended that the government and stakeholders should focus on strengthening the provision of formal and non-formal training and facilitate an effective extension service.

Aveline *et al.* (2020) studied the determinants of soil Conservation technologies among small-scale farmers in Tanzania using secondary data from a national panel survey. They employed a binary probit model to estimate the determinants of the adoption of soil conservation technologies. Based on the model, they reported that access to extension services and training as well as plot value had a positive correlation at a significant level with the adoption of the introduced SWC practices. However, they found that soil steepness influenced the adoption of soil conservation practices negatively. They concluded that the adoption of different soil conservation structures affected by physical, socioeconomic, and institutional factors. Based on their finding they recommended that the concerned bodies should consider the influential factors that can affect the adoption of soil conservation to enhance farmers' adoption of soil conservation practices and promote agricultural productivity and environmental quality.

A study by Muluken G Wordofa *et al*. (2020) employed a multinomial logistic regression model to analyze the factors influencing the adoption of improved structural SWC measures in Eastern Ethiopia. They found that the educational status of the household head, farming experience, plot area, distance of the plot from dwelling unit, number of economically active household members, and extension contact affecting the adoption of SWC measures significantly. They recommended that the encouragement of an extension system; creating better learning opportunities by facilitating the education and training programs for farmers, and focusing on appropriate management of economically active household members.

The summary of all the above works of literature indicates that farmers' decision to adopt SWC structures is influenced by personal, and household characteristics, institutional, farm characteristics, and other related factors. However many of the studies give less attention to plot-level factors that can affect the adoption of SWC structures.

2.2.2. Empirical studies on the impact of SWC practices on food security

Although there are many studies on the impacts of SWC measures on income and productivity in Ethiopia and elsewhere, only a few studies are available on the impact of SWC structures on food security. These studies are presented below as follows.

A study by Janvier *et al*. (2014) on the impacts of water and soil conservation strategies on households' food security in North West of Benin employed a t-test to compare the food supply and food consumption of beneficiaries and non-beneficiaries. They found no effect on the food reserve after exogenous strategies released by the erosion control projects. However, they reported that the frequency of food consumption was improved statistically among project beneficiaries than non-beneficiaries after the intervention. This study employs only a t-test to compare the impact of erosion control interventions on food supply and the frequency of food consumption. They did not employ econometric models to measure the impact of SWC practices on households' food security.

Masila *et al*. (2015) conducted a study on the influence of SWC technologies on small-scale farmers' food security in Kenya. The study employed a multiple linear regression model to analyze data. They revealed that SWC technologies did not significantly influence households' food security at a 5% level of significance.

Sita *et al*. (2018) conducted a study on whether the practice of water and soil conservation techniques influences the food security situation in the northern region of Burkina Faso. They found that water and soil and water conservation techniques help to reduce food insecurity. The prevalence of food insecurity was reduced by stone bunds in combination with the inter-row ridges technique and possession of formal education. However, they did not use a clear econometric model to measure the impact of SWC structures on food security.

Million Sileshi *et al*. (2019) conducted a study on the impact of SWC practices on household vulnerability to food insecurity in eastern Ethiopia by using a sample of 408 households selected using a multi-stage stratified sampling procedure from three *Woredas*. This study employed both endogenous switching regression and propensity score matching approaches to obtain consistent impact estimates. Using the results of the endogenous switching regression and propensity score matching models, the authors revealed that, the adoption of SWC practices not only generated a significantly positive impact on per capita food consumption expenditure and net crop value, but it also reduced food insecurity and vulnerability to food insecurity. According to their results, the probability of food insecurity and vulnerability to food insecurity decreases by 10.5 and 14.1%, respectively, compared to their counterfactuals. Further, the per capita food consumption expenditure and net crop value increased by Birr 205.97 and 3284.088 per hectare due to SWC adoption, respectively. As far as the researcher found, this is the only rigorous paper examining the association between food insecurity with the adoption of SWC in Africa, in general, and Ethiopia specifically by using econometric models. However, this study employed only per capita food consumption expenditure as a proxy to measure food security.

Generally, there are only a few studies on the impact of SWC structures on households' food security status. Almost no studies employed series econometric models (they employed simple comparisons between adopters and non-adopters food security using t-test and narration). Additionally, they only employed a single measurement for food security.

2.3. Conceptual Framework

Different factors could affect on-farm adoption of SWC structures by households. These factors can be categorized as socio-economic, demographic, plot, and institutional factors. Socio-economic factors include livestock ownership in tropical livestock units (TLU), perception towards the risk of soil erosion and the benefit of SWC, and non-farm and off-farm income. Demographic factors affecting the adoption of SWC structures are the age of the household head, sex of the household head, educational level of the household head, and household size. Farm and plot characteristics are also one of the factors affecting the adoption of SWC structures by households. These factors include variables like the average plot area in hectares, plot to home distance, plot ownership, the slope of the plot, and plot position from the nearest watershed. Institutional factors like frequency of training on SWC and frequency of extension visits and contacts are also among the factors affecting on-farm adoption of SWC structures.

Adopting SWC structures first improves the texture and moisture of the soil. After improving the moisture of the soil, the level of soil fertility will be improved. The fertile soil brings an increase in crop productivity. The increased crop productivity leads to an increase in diet diversity and frequency of food consumption and more crop income for the household. The more income the household possesses, the increase in the consumption level of food and brings food security and reduces food insecurity level.

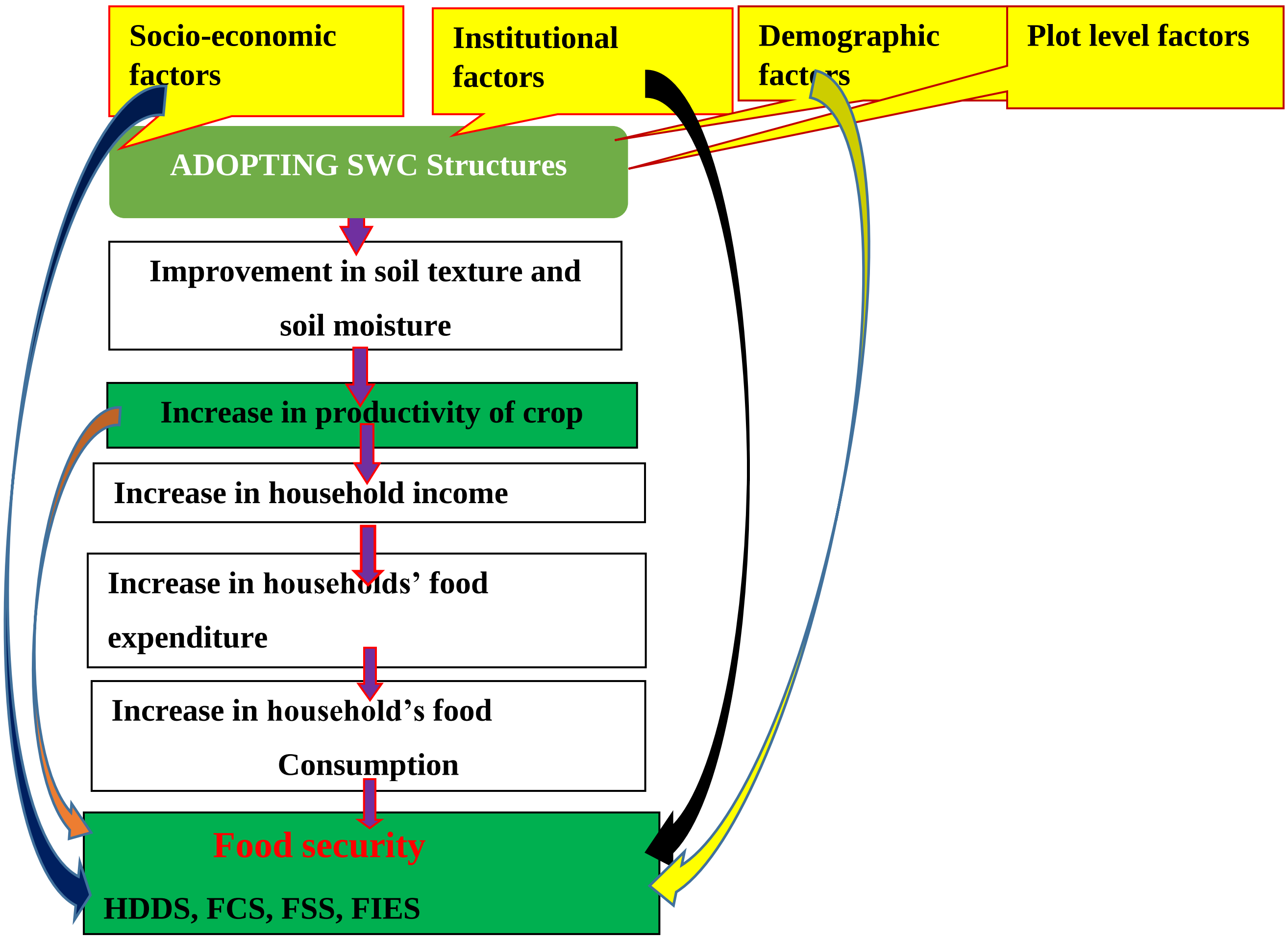

Figure 2. 1. The Conceptual framework

Source: own computation, 2020

Chapter 3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

The study was conducted in West Belesa and East Belesa *Woredas* at Central Gondar Zone of Amhara National Regional State, Ethiopia.

West Belesa *Woreda:* is located about 706 km North of Addis Ababa and about 82 km of Gondar town. It is bordered by Libo Kemkem on the south, Gondar Zuria on the west, East Belesa on the East, and Wogera Woreda on the North. Its agro-ecology is predominantly Kolla (59.8 %), followed by Woina Dega (38.7%) and Dega (1.5%). The topography of the *Woreda* is mainly characterized by a plateau with a share of 50%, mountains 40%, and hilly 10% (West Belesa Woreda office of agriculture (WBWOA, 2019)).

It is largely, covered with small vegetation of bushes and shrubs. The economy of the *Woreda* is mixed farming largely participated in crop production, followed by livestock rearing which has special importance among wealthier farmers. Its altitude ranges from 1100 to 2350 meters above sea level while the annual temperature ranges between 13^0C and 35^0C. The mean annual rainfall ranges from 800-1200 mm. The majority (97%) of the population are Orthodox Christians while 2.9% of the population are Muslims. The Woreda has an estimated total population of 156,080, of whom 78,009 are men and 78,071 are women. The total number of male-headed and female-headed households is 23510 and 5139 respectively (WBWOA, 2019).

East Belesa *Woreda*: is one of the Woreda in the central Gondar zone. It is named after the former province of Belesa, which lay in the same area. It is bordered on the south by South Gondar Zone, on the west by West Belesa, on the Northwest by the Wegere, on the North by Jan Amora, and on the East by Wag Hemra Zones. Towns in East Belesa include Gohala and Hamusit. The *Woreda* is situated at an altitude ranging from 1496 to 2000 m above sea level. About 90% of the *Woreda* is desert *(kola)* with minimal annual rainfall leading to frequent drought and famine. Despite the climatic condition, the people depend on agriculture and cultivate cereals, like teff, beans, sorghum, and wheat. The *Woreda* has an estimated total population of 136,198, of whom 67,936 are men and 68,262 are women. The total number of male-headed and female-headed households is 22,742 and 5,554 respectively. Around 13.4% of the total population are urban inhabitants. The majority of the inhabitants practiced Ethiopian

Orthodox Christianity, with 98% reporting that as their religion, while 2% of the population said they were Muslim (EBWOA, 2019).

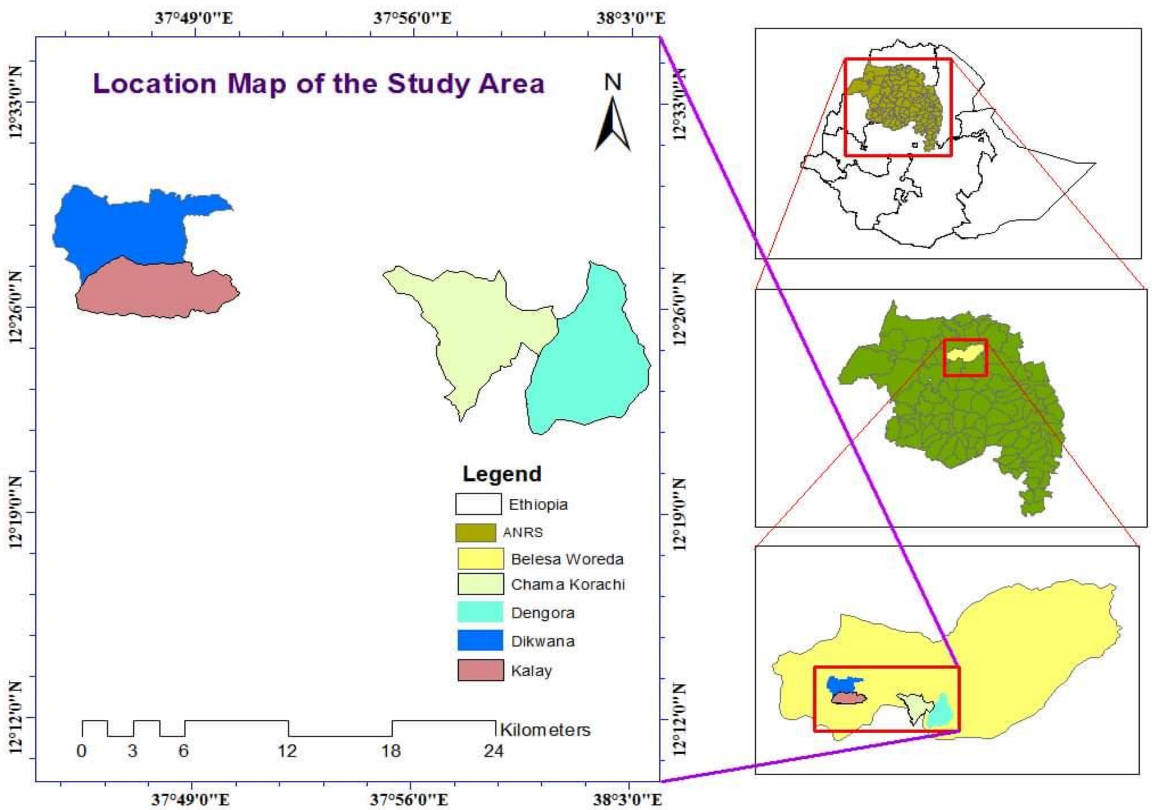

Figure 3. 1. Location Map of the Study Area

Source: Own computation

3.2. Type and Source of Data

This study used both qualitative and quantitative data. To assess the impacts of SWC structures on households' food security, we collected data on the perception of the respondents towards SWC structures and the risk of soil erosion, socio-economic, demographic, plot-level characteristics, and institutional variables, SWC practices, as well as food security. Sample households were the main sources of primary data. The study also used secondary data from reports of offices of agriculture at *Woreda*[1], and *kebele*[2] level.

3.3. Methods of Data Collection

Focus group discussions (FGDs) and key informant interviews from elders, Women, and selected farmers and key informants who have adequate knowledge and information about the study area were held. One focus group discussion per *kebele* with a member of 10 individuals was conducted. The general information about the agricultural production, land use, land management practices, livelihood activities, the types of SWC structures constructed, the food security condition, the adoption of SWC structures, the extent and role of agricultural training, and other background information about the study area was obtained.

The researcher with seven trained enumerators collected data through face-to-face interviews using a structured questionnaire. The questionnaire was pretested before the actual survey. The questionnaire covers household characteristics, land use, agricultural production, farm characteristics, plot-level questions, SWC practices, and food security-related questions. The data collection method was tablet assisted online format with an offline data entry facility. The survey was conducted from March 8, 2020, to March 19, 2020.

3.4. Sampling Technique

A multi-stage sampling technique was used to select sample *kebeles* and sample households. West and East Belesa *Woredas* are semi-arid areas susceptible to land degradation and have long experience of constructing SWC structures. After selecting the target *Woredas*, the researcher selected two *kebeles* from each *Woreda* randomly. Chama Korach and Dengora from East Belesa *Woreda* and Kalay and Dikuana from West Belesa *Woreda* were the sample *kebeles* for this study. After selecting the sample *kebeles* from the sample *Woredas*, the households in the sample *kebeles* were selected randomly using a proportionate probability sampling technique. To identify households, a list of the household heads was taken from the *Woreda* Office of Agriculture and the records of *kebele* development agents.

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[1] *Woreda* is the third-level administrative divisions of Ethiopia.
[2] *Kebele* is usually a named peasant association and is the lowest administrative unit in the country.

3.5. Sample unit and Sampling Frame

For this study, households were the units of analysis from whom different data were collected. The sampling frame for this study is the list of households in the sample *kebeles* whose livelihood depends on farming. These households include both those who adopted and did not adopt SWC structures.

3.6. Sample Size Determination

After selecting the sample *kebeles*, the researcher determined the size of the sample households using Yemane (1967) sample size determination formula.

$$n=\frac{N}{1+N(\varepsilon)^2}=\frac{56945}{1+56945(0.05)^2}=397 \text{ households}$$

Where n is the number of sample households that the researcher selected, N is the total number of farming households living in the *Woredas*, and ε is the level of precision. The researcher takes a 5% level of significance. According to the 2019 *Woreda* level report, the total number of households' in the two *Woredas* is 56945.

Although the minimum required sample size was 397 households, 546 farm households were included in the survey.

Table 3. 1. Sample households from West and East Belesa *Woredas* with four *kebeles*

No	*Woredas*	Sample *Kebeles*	Number of households			Samples households
			Male headed	Female Headed	Total	
1	East Belesa	Chama Korach	804	345	1149	153
		Dengora	881	167	1048	140
2	West Belesa	Kalay	712	164	876	117
		Dikuana	841	179	1020	136
Total sample households						**546**

3.7. Data Analysis

After downloading the collected data from the kobo toolbox, the researcher cleaned the data by using Excel and SPSS version 23 and STATA version 15 and executed essential operations like converting string variables to numeric variables and other data transformations using STATA software. After executing all the above operations, the researcher analyzed the cleaned and organized data using STATA software. We employed descriptive statistics, inferential statistics, and econometric models to analyze the data. Mean, standard deviation, percentage, and frequencies were used to describe household, institutional, and plot characteristics. The researcher also used inferential statistics (t-test and chi-square test) to check the mean difference between adopters and non-adopters in terms of continuous variables and to check the association between categorical variables and the adoption of SWC structures respectively.

In the econometric analysis, the researcher applied the endogenous switching regression (ESR) model to analyze the impact of SWC on households' food security. The ESR model is selected since it considers both observable and unobservable characteristics and heterogeneity. In addition to the ESR model, the binary probit model was used to analyze the factors affecting on-farm adoption decision of farmers towards SWC structures.

3.7.1. Binary probit regression model

The binary probit regression is usually employed to model the dichotomous or binary outcome variables like the adoption of SWC structures. According to Long and Freese (2014), regression models for dichotomous outcomes estimate the pattern of effect of the explanatory variable(s) on the probability of occurrence of an event. However, because of the non-linearity of this model, the levels of the explanatory variables involved determine the degree of change in the outcome probability that is associated with a given change in one of the explanatory variables. Following the estimation procedures of Long and Freese (2014), and Williams (2018), binary probit regression was used to model the drivers of SWC adoption. The probit model can include the error term distribution as well as realistic probabilities (Nagler, 2002). Meanwhile, the probit model assumes that while 0 and 1 values for non-adopters and adopters respectively are only observed for the response variable Y, there is a latent, unobserved continuous variable Y* that determines the value of the response variable Y (Sebopetji and Addisu Belete, 2009). Therefore, Y* is assumed to be expressed as

$Y^* = \beta X_i + \varepsilon$ …………………………………………………………… (1)

Where: ε~ N (0, 1). Then, Y can be viewed as an indicator for whether this latent variable is positive, such that:

Y = 1 (Y* > 0), that is, 1 if Y* > 0 i.e. (ε <βX_i), and 0, Otherwise.

Where: Y =vector of the response variable (1 for SWC structures adopter, 0, otherwise);

X_i = a vector of explanatory variables;

β = probit coefficients; and

ε = random error term.

3.7.2. Endogenous switching regression model

To analyze the impact of on-farm SWC adoption on food security, the observable and unobservable characteristics of the adopters and non-adopters must be captured. However, most impact assessment techniques using non-experimental data fail to capture both observable and unobservable characteristics that affect adoption and outcome variables (Million Sileshi *et al*., 2019). For instance, instrumental variables capture only unobserved heterogeneity, but the assumption is that the parallel shift of outcome variables can be considered as a treatment effect (Kabunga *et al*., 2012; Bekele Shiferaw *et al*., 2014; Musa Hasen *et al*., 2017). In contrast, using regression models to analyze the impact of a given technology using pooled samples of adopters and non-adopters might be inappropriate since it gives a similar effect on both groups (Menale Kassie *et al*., 2009; Menale Kassie *et al*., 2010; Musa Hasen *et al*., 2017). Propensity score matching (PSM) was not used in this study since it does not control the unobservable characteristics.

A methodological approach that overcomes these limitations of different impact evaluation methods is the ESR model, which is the most used method to analyze the impact of a given technology (Di Falco *et al*., 2011; Menale Kassie *et al*., 2011; Kabunga *et al*., 2012; Solomon Asfaw *et al*., 2012; Abdulai and Huffman, 2014; Bekele Shiferaw *et al*., 2014; Musa Hasen *et al*., 2017; Moti Jaleta *et al*., 2018). The parametric ESR model is an appropriate model to reduce the selection bias and assure consistent results by capturing both the observed and unobserved heterogeneity that influences the outcome variable as well as the adoption decision (Million Sileshi *et al*., 2019).

The impact of SWC structures on households' food security under the ESR framework follows two stages. In the first stage, adoption of SWC is estimated using a binary probit model as selection, while in the second stage both linear regression and binary probit models are employed to assess the association between an outcome variable and adoption of SWC (Bekele Shiferaw *et al*., 2014; Moti Jaleta *et al*., 2018). This study adopted the expected utility maximization theory for farmer adoption of SWC structures. Individual i adopts SWC on their farm plot if the expected utility from adoption (Uswc) is greater than the expected utility from non-adoption (Unswc), i.e. Uswc -Unswc > 0.

I_i*=βX_i + V_i where I_i=$\begin{Bmatrix} 1\ if\ I_i^* > 0 \\ 0\ otherwise \end{Bmatrix}$…………………..(1)

Where I_i* is the latent variable capturing the unobserved preferences associated with the adoption of SWC determined by observed farm and socio-economic characteristics of the household (X_i) and the error term (V_i). I_i is the observed binary indicator variable that equals 1 if a farmer adopts SWC structures and zero otherwise, while β is a vector of parameters to be estimated.

It is vital to use instrumental variable methods to identify the second-stage equation from the first-stage equation of the ESR model (Million Sileshi *et al*., 2019). The instrumental variable should affect the adoption of SWC but not the outcome variable which is food security in this case. For this study, the average plot to home distance, average plot area, and the proportion of flat-sloped plots were instrumental variables used. The validity of the instrument variable was checked by using a falsification test. The test shows that the variable significantly affects the adoption decision but not food security.

The outcome regression equations both for adopters and non-adopters of SWC structures can be written as an endogenous switching regime model:

$Regime\ 1: Y_{1i} = \theta 1 Z_{1i} + \varepsilon_{1i}, \quad if\ I = 1 \quad (2a)$

$Regime\ 2: Y_{2i} = \theta 2 Z_{2i} + \varepsilon_{2i}, \quad if\ I = 0 \quad (2b)$

where Y_i represents outcome variables such as HDDS, FCS, FSS, and FIES for adopters and non-adopters, Z_i is a vector of plot, institutional, demographic and socio-economic characteris tics of a household that affects outcome variables, and θ_i is a vector of parameters to be estimated.

The error terms are distributed to be trivariate normal, with mean zero and a non-singular covariance matrix:

$$cov(\varepsilon_1, \varepsilon_2, v) = \begin{pmatrix} \sigma_1{}^2 & \sigma_{12} & \sigma_{1v} \\ \sigma_{21} & \sigma_2{}^2 & \sigma_{2v} \\ \sigma_{v1} & \sigma_{v2} & \sigma_v{}^2 \end{pmatrix} \qquad (3)$$

where σ_{21}, σ_{22}, and σ_{2v} are the variance of the outcome function of regimes 1 and 2, as well as the selection equation, respectively, σ_{12}, σ_{1v} , and σ_{2v} represent the covariance of ε_{1i}, ε_{2i}, and v_i. The variance of selection question (σ_{2v}) is assumed to be equal to 1 since the coefficients (β) are estimable only up to a scale factor. Maddala (1983), confirmed that the covariance of the error terms (ε_{1i} and ε_{2i}) is not defined since outcome variables ($Y_{1i}$and Y_{2i}) are not captured at the same time.

The expected values of the error term of the second stage are nonzero because of the error term of the first stage (v_i) and second stage (ε_{1i} and ε_{2i})) are associated with each other. The expected value of error terms of the question (2a) and (2b) can be expressed as follows:

$$E(\varepsilon_{1i}) / Y_i = 1) = \sigma_{1v} \frac{\emptyset(\beta X_i)}{\Phi(\beta X_i)} = \sigma_{1v} \lambda_{1i} \quad (4a)$$

$$E(\varepsilon_{2i}) / Y_i = 0) = \sigma_{2v} \frac{\emptyset(\beta X_i)}{1 - \Phi(\beta X_i)} = \sigma_{2v} \lambda_{2i} \quad (4b)$$

Based on the above context, comparing real and counterfactual scenarios of expected values of the outcomes of adopters, the average treatment effect on the treated (ATT) can be obtained. Similarly, the average treatment effect on the untreated (ATU) also can be calculated by comparing the expected values of the outcomes of non-adopters in real and counterfactual sce narios (Khonje *et al.*, 2015). Following Solomon Asfaw *et al*. (2012), Kabunga *et al*. (2012), Abdulai and Huffman (2014), Bekele Shiferaw *et al*. (2014), and Moti Jaleta *et al*. (2018) the expected values of the outcomes of both adopters and non-adopters in reality and the counterfactual can be described as follows:

Adopters with the adoption of SWC (real):

$$E(Y_{1i}/X, I = 1) = \theta_1 X_{1i} + \sigma_{1v} \lambda_{1i} \qquad (5a)$$

Non-adopters without adoption of SWC (real):

$$E(Y_{2i}/X, I = 0) = \theta_2 X_{2I} + \sigma_{2v} \lambda_{2i} \quad (5b)$$

If adopted had non-adopted SWC (counterfactual):

$E(Y_{2i}/X, I = 1) = \theta_2 X_{1i} + \sigma_{2v}\lambda_{1i} \quad (5c)$

If non-adopted had adopted SWC (counterfactual):

$E(Y_{1i}/X, I = 0) = \theta_1 X_{2i} + \sigma_{1v}\lambda_{2i} \quad (5d)$

Hence, the ATT of adopter is computed as the difference between

(5a) and (5c):

$$ATT = E(Y_{1i}/X, I = 1) - E(Y_{2i}/X, I = 1) = (\theta 1 - \theta 2)X_{1i} + (\sigma_{1v} - \sigma_{2v})\lambda_{1i} \quad (6)$$

Likewise, the ATU of non-adopters is computed as the difference

between (5b) and (5d):

$$ATU = E(Y_{1i}/X, I = 0) - E(Y_{1i}/X, I = 0) = (\theta_1 - \theta_2)X_{2i} + (\sigma_{1v} - \sigma_{2v})\lambda_{2i} \quad (7)$$

According to Khonje *et al*. (2015), Bekele Shiferaw *et al*. (2014), and Musa Hasen *et al*. (2017), ESR models have a very strong exclusion restriction.

The endogenous switching regression model accounts for both endogeneity of technology adoption and possible sample selection and allows the different household and farm characteristic variables to play differential roles, both in terms of qualitative and quantitative effects on the respective varietal technologies (Arega Alene and Manyong, 2007). This is why the researcher used the ESR model in this study to measure the impact of SWC on households' food security.

3.7.3. Measuring households food security

Since there is no single indicator that can account for the different dimensions of food and nutrition security, suites of indicators are being proposed to capture this complexity within the range of various contexts, a useful step towards promoting multi-sectoral approaches for improving food security (WFP, 2008; FAO, 2012; Coates, 2013).

There are different methods of measuring households' food security. These alternate measures of food security are discussed below.

A. Food consumption expenditure and calorie intake measures

Households' food security can be measured by a direct survey of income, expenditure, and consumption and comparing it with the minimum subsistence requirement (Braun *et al*., 1992). In Ethiopia, the minimum acceptable weighted average food requirement per adult equivalent (AE) per day is 2100 kcal as a cut-off value between food-secure and food-insecure households

(FDRE, 2001; MOFED, 2002). Those households below the minimum subsistence requirement (2100 kcal) are considered as food insecure, and those who managed to attain the 2100 kcal per AE per day can be considered as food secure households. However, this approach of measuring households' food security is hard to get accurate information, data consuming, and bulky to conduct, and due to this; the researcher did not use this approach.

B. Households' dietary diversity score (HDDS)

Dietary diversity is a qualitative measure of food consumption that shows households' access to a group of foods and is used as a proxy for nutrient adequacy of the diet of individuals. The dietary diversity questionnaire is a rapid, user-friendly, and low-cost assessment tool. The dietary diversity score is mainly focused on whether a household consumes the foods in the food group and it is a simple count of food groups that a household or an individual has consumed in the past 24 hours (Swindale and Bilinsky, 2006).

Households were asked whether they consumed the 12 food groups or not and their "yes" responses were coded as 1 and their "no" responses were coded as 0. The next step is summing the dietary diversity variable values of all the food groups and, the potential score ranges from 0 to 12 for HDDS. The higher score indicated that households consumed more diversified food groups and the lower score indicated that a household consumed less diversified food groups. The HDDS of ≤3, 4-5, and ≥ 6 imply low, medium, and high dietary diversity respectively (Kennedy *et al*., 2010).

C. Food consumption score (FCS)

This measure of food security is the core indicator of consumption recommended by the world food program. The FCS captures both Dietary Diversity and Food frequency. It was measured by interviewing individuals to assess how many days in the past 7 days the household has eaten any of the food in the predefined food groups (WFP, 2008).

According to WFP (2008), the food groups listed in the FCS questionnaire can be grouped into 9 main food groups: cereals, starchy tubers and roots; legumes and nuts; meat, fish, poultry, and eggs; vegetables (including green leaves); fruit; oils and fats; milk and dairy products; and sugar/sweets. Condiments are considered separately.

According to WFP (2008), the following four procedures are important to calculate the FCS. These are:

(i) Group all the food items (the 16 food items) into specific food groups (9 food groups),

(ii) Sum up all the consumption frequencies of food items within the same group, and recode the value of every group above 7 as 7,

(iii) Multiply the value obtained for each food group by its weight (the standard weights for main staples 2, pulse 3, vegetables 1, fruit 1, meat and fish 4, milk 4, sugar 0.5, oil 0.5, condiments 0) and create new weighted food group scores and,

(iv) Sum the weighed food group scores, thus creating the food consumption score (FCS). FCS 0-21, 21.5-35, and >35 indicated poor, borderline, and acceptable household consumption respectively.

D. Food Security Scale (FSS)

Since any single indicator cannot capture the full range of food insecurity and hunger; a household's level of food insecurity or hunger must be determined by obtaining information on a variety of specific conditions, experiences, and behaviors that can be used as indicators of the varying degrees of severity of the condition. Food insecurity cannot be measured directly. Therefore, to measure food insecurity and hunger, 18 food insecurity questions were used to provide the statistically strongest set of indicator items for constructing a 12-month measurement scale. The sum of affirmative ("Almost every month", "Often true", "Sometimes true", and "Yes" coded as 1) and negative responses ("Never true", "only one or two months", "No", and questions that a household does not answer because it has been screened out, coded as 0) provide the FSS (Bickel *et al*., 2000). This measure expresses the household's level of food security or insecurity in terms of a numeric value that ranges between 0 and 10. The scale value of 0 indicates the household did not experience any of the conditions of food insecurity in the past 12 months and the scale value of 10 indicates the most severe level of food insecurity. For those households with children having a scale value of 0-1.6 (0-2 affirmative response), 2.3-4.3 (3-7 affirmative responses) and 4.7-6.4 (8-12 affirmative response) 6.8-10 (13-18 affirmative responses) out of the 18 food insecurity questions, were classified into four food security status categories; these are, food secure, food insecure without hunger, food insecure with hunger, food insecure with severe hunger respectively. For those households without children having a scale value of 0-2 (0-2 affirmative responses), 2.8 - 4.3 (3-5 affirmative responses), 5-6.5 (6-8 affirmative responses), and 7.5-8.2 (9-10 number of affirmative responses) were also classified into food secure, food insecure without hunger, food insecure with hunger, food insecure with severe hunger respectively (Bickel *et al*., 2000).

E. Food insecurity experience scale (FIES)

The Food Insecurity Experience Scale (FIES) is an experience-based scale for the severity of food insecurity and relies on people's direct responses to a series of questions regarding their access to adequate food. Accumulated evidence over the past two decades has convinced the FAO of the potential for using this method of measurement to provide valid and reliable population estimates of food insecurity in the different countries of the world (Ballard *et al*., 2013).

Experience-based food insecurity scales represent a simple, timely, and less costly method for measuring the access dimension of food insecurity based on data collected at the household or individual level. This measurement technique does not focus on actual food consumption, diet quality, and food expenditures like household expenditure surveys and individual food intake surveys might do, but rather focus on food-related behaviors of households associated with the experience of food insecurity due to limited access to food (Ballard *et al*., 2013).

This measurement uses only 8 questions and these questions focused on whether the household was worrying about how to procure food in the past 12 months. The questions focused on whether the household was compromising on quality and variety of food in the past 12 months, whether the household was reducing quantities of food and skipping meals in the past 12 months and whether the household experienced hunger in the past 12 months. These questions involve a continuous scale of food insecurity from mild food insecurity to severe food insecurity (Kennedy *et al*., 2010). The responses for the 8 questions are aggregated to give raw scores ranging from 0 to 8. According to the responses, the food security status can be classified into food secure (with the raw score of 0 to 3), moderate food insecure (with a raw score of 4 to 6) and severe food insecure (with a raw score of 7 to 8) (Wambogo *et al*., 2018).

By considering the breadth of the concept of food security an array of measurement instruments is needed to account for its complex nature and to monitor its multiple dimensions (Ballard *et al*., 2013). Therefore, in this study, the researcher used the combination of HDDS, FCS, FIES, and FSS to measure food security.

3.8. Definition, Measurement, and Hypothesis of Study Variables

A. Dependent variable

The dependent variable of this study was the adoption of SWC structures. It is a dummy variable taking a value of 1 if the households adopted SWC structure on their plot (s) and 0 otherwise. By the very nature, SWC technologies take time to bring a real impact on the households' food security. It takes 3-5 years for a SWC structure to bring an effect on productivity (Kebede Wolka *et al*., 2018). Taking this into account, for this study the researcher considered SWC adopters as those farmers who constructed and sustained at least one of the SWC structures on at least one of his/her farm plots and the age of the SWC structure should be greater or equal to 5 years since constructed.

Outcome variables: In this study, HDDS, FCS, FSS, and FIES are the outcome variables used to measure food security.

Household dietary diversity score (HDDS): It indicates households' economic access to food and it was calculated by summing the number of food groups consumed in the household respondent over the 24-hour recall period. The higher score indicated that households consumed more diversified food groups.

Food Consumption Score (FCS): is a proxy indicator for food security which able to capture both Dietary diversity and food frequency.

Food security scale (FSS): is a variable, which measures the household's level of food security or insecurity in terms of a numeric value that ranges between 0 and 10. The scale values of 0, indicating that the household did not experience in the past year any of the conditions of food insecurity, and the scale value 10 indicates the most severe level of food insecurity.

Food insecurity experience scale (FIES): It is an experience-based scale for the severity of food insecurity and relies on people's direct responses to a series of questions regarding their access to adequate food. It uses only 8 questions and these questions focused on whether the household was worrying about how to procure food in the past 12 months.

Independent variables

Farmers' decision to use a given SWC structure is influenced by the several demographic and socio-economic characteristics of the household, institutional, farm, and plot-level characteristics.

Sex of the household head (SEX): it is a dummy variable coded as 1 for male-headed households and 0 otherwise. The sex of the household-head can affect the adoption of SWC structures. Women have been involved in both productive and reproductive roles within a household. This results in more workloads on women so they may not have enough time to participate in SWC training. However, Male-headed households have better access to information than female-headed households do. Therefore, it was hypothesized that male-headed households have a better chance of adopting SWC structures. This hypothesis is supported by the findings of Million Sileshi *et al*. (2019), and Agere Belachew *et al*. (2020).

Age of the household head (AGE): this variable represents the age of the household head and was measured in years. The age of a farmer can enhance or prevent the adoption of SWC structures. With age, a farmer may get experience about his/her farm and can react in favor of constructing and maintaining SWC measures. On the other hand, older farmers may be reluctant to accept and implement technologies and are more likely to reject conservation practices. In addition, as the age of the household head increases, the acceptance level about the introduced soil and water conservation practices may decrease. Thus, age may have a positive or negative effect on using SWC structures. The positive hypothesis is supported by the findings of Fikru Assefa (2009) while the negative hypothesis is supported by the findings of Daniel Asfaw and Mulugeta Neka (2017), and Tiwari *et al*. (2008).

Educational status of the household head (EDUC): This variable is a dummy variable that represents the educational status of the household head. This variable was coded as 1 if the head of the household is literate and 0 otherwise. This is a proxy for the capacity of the head of a household to access and understand technical aspects related to soil erosion and soil conservation. Literate farmers can have better knowledge and awareness on how to conserve water and soil to prevent run-off. It was hypothesized that those literate farmers are set out to adopt SWC practices because of increased information on soil erosion control techniques as well as the associated benefits and costs. Educated farmers can understand, analyze, and interpret the advantages of new technologies easily than uneducated farmers. Therefore, households with literate household heads were expected to be more likely to adopt soil and water-conserving structures. This hypothesis is supported by Melkie Erkie (2016), Daniel Asfaw and Muluget Neka (2017), Belete Limani (2018), and Agere Belachew *et al*. (2020).

Household size (HHSIZE): This variable is a continuous variable representing the number of people who live in a household in terms of AE. The establishment and maintenance of the SWC structures is labor-intensive. Consequently, the availability of farm labor at the household level affects the adoption of SWC structures. Households with a large amount of farm labor are probably better able to provide the labor required for the construction and maintenance of SWC measures (Tenge *et al*., 2004). Larger households will be able to provide the labor that might be required for maintaining conservation structures. A household with a larger household size can supply larger human capital in terms of labor for the adoption of SWC measures. Therefore, household size was expected to have a positive influence on the adoption of SWC practices. The hypothesis is in line with the findings of Adissu Damtew *et al*. (2015), Belete Limani (2018), and Agere Belachew *et al*. (2020).

Livestock holding (LIVES): This variable is a continuous variable that represents the livestock holding of a household in a tropical livestock unit (TLU). Livestock is considered as an asset that could be used in the production process or be exchanged for cash or other productive assets. Large livestock size may discourage farmers from engaging in SWC practices on plots for crop production due to the attractive income they get from livestock. Aklilu Amsalu and de Graaff (2007) indicated that the effect of livestock on conservation decision is negative. On the other hand, those farmers who have more livestock may have more capital to invest in soil conservation practices (Agere Belachew *et al*., 2020). This affects SWC positively. Hence, the effect of the size of livestock holding on conservation decisions can be either positive or negative.

Non-farm and off-farm income (NONFARM): This variable indicates the amount of income that a household earns from non-farm and off-farm activities annually in thousands of Birr[3]. Devoting more time to non-farm and off-farm activities keeps the labor force needed for conservation away from the farm. Furthermore, the short-term benefit obtained from non-farm

[3] Birr is an Ethiopian currency. 1 Ethiopian Birr≈0.027 US dollar

and off-farm works may obscure the benefits accruing from investments in soil conservation. Therefore, in this study, it is hypothesized that non-farm and off-farm income has a negative relationship with SWC adoption. This hypothesis is supported by the findings of Daniel Asfaw and Mulugeta Neka (2017), and Belete Limani (2018).

Frequency of extension contact (EXTEN): This variable is a continuous variable that refers to the average number of contacts with extension agents per year. Extension service provides the necessary information to acquire new skills and knowledge related to agriculture in general. Here, household heads with more frequent contact with extension agents are believed to accelerate the effective dissemination of appropriate agricultural information like SWC practices which has positive implications for farmers to make an informed decision in their farm that facilitate increased production. Therefore, it is expected that the frequency of extension contact have a positive association with the adoption of SWC structures. Wagayehu Bekele and Drake (2003), Million Sileshi *et al*. (2019), and Agere Belachew *et al*. (2020) shown the positive relationship between extension contact and the adoption of improved soil conservation technologies.

Frequency of SWC training (TRAIN): This variable indicates the average number of days where the household took training related to SWC structures per year. SWC Training can fill the knowledge gap of the farmers about SWC structures. The more the households attend training on benefits and implementation of various SWC; it will be easier to adopt these technologies compared to those households who do not attend training and those who attend less. Therefore, this variable was hypothesized to have a positive effect on the adoption of SWC structures. This hypothesis is supported by Daniel Asfaw and Mulugeta Neka (2017), and Agere Belachew *et al*. (2020).

The slope of the plot (SLOPE): This variable represents the proportion of flat-sloped plots under a household. First, the slope of a plot was coded as 1 if the slope is flat and 0 otherwise. Then the proportion of flat slopped plots under a household are calculated. The slope of plots` affects SWC development. Steep slopes are susceptible to more rapid runoff surface water that might force a farmer to use soil conservation measures. The more percentage of flat-sloped plots that the household has the less chance of adopting SWC structures. However, the more proportion of non-flat sloped plots that the household has a high probability of adopting SWC structures. The slope of the plot is positively affecting the farmer's decision to invest in SWC structures (Agere Belachew *et al.*, 2020). Therefore, the proportion of flat-sloped plots was expected to have a negative relation with the adoption of SWC structures.

Plot ownership (OWN): This variable represents the proportion of owned plots under a household. Plots can be either owned plots or share-in/rented-in plots. First plots under a household were coded as 1 for owned plots and 0 otherwise. Then, the proportion of owned plots under a household were calculated. Owned plots give more security to the household to make a long-term investment like SWC structures on the plot with full potential. However, non-owned plots are less secured, due to this; a household becomes more reluctant to invest in non-owned plots. Previous studies found a positive relationship between plot ownership and the use of soil conservation technologies (Aklilu Amsalu and de Graaff, 2007). Therefore, it is hypothesized that households with more proportion of owned plots have more probability of adopting SWC structures.

The average distance of the plots from homestead (DIS): This variable represents the average minutes of walking from the homestead to the plots. It is calculated by summing the distance between each plot from the homestead in minutes of walking and divide it by the number of plots under a household. Plots far from the homestead have less chance of being maintained by SWC. This is because the closer the plot to the residential area the closer supervision and attention it will get from the household. Less time and energy are needed to manage and maintain closer plots than too far plots and as a result households may be discouraged from conserving their plots (Agere Belachew *et al.*, 2020). The study by Wagayehu Bekele and Drake (2003), and Million Sileshi *et al.* (2019) had reported a negative relationship between the distance of the plots from the homestead and the adoption of SWC structures. Therefore, it was expected that the distance of the plot from the homestead in minutes of walking and the adoption of SWC structures have a negative relationship.

Average plot area (AREA): This variable represents the average area of households' plots in hectare. It was calculated by summing the area of each plot and divide it by the number of plots under a household. SWC structures may take some area that would have been used for cultivation (crop production). Larger area plots are better to allocate some part of the plot to soil conservation structures than smaller area plots. Aklilu Amsalu and de Graaff (2007) found that farmers with larger average plot area were found to be more likely to invest in conservation technologies. SWC structures occupy part of the productive land and farmers with larger plot area can afford retaining structures compared to those with relatively lower plot area (Agere Belachew *et al*., 2020). Therefore, it is hypothesized that the average area of the plots has a positive effect on the adoption of SWC structures.

Position of the plots (POSITION): This variable represents the proportion of downstream plots from the nearest watershed. This variable was first coded as 1 for downstream plots and 0 otherwise. Then the proportion of downstream plots was calculated. The percentage of downstream plots from the nearest watershed for each household was calculated by collapsing the position of each plot from the nearest watershed. Plots found in the downstream position from the watershed are more vulnerable to a runoff. Therefore, it is expected that households with more proportion of plots in the downstream position have a high probability of adopting SWC structures. In this study, this variable is hypothesized to have a positive relationship with the adoption of SWC structures.

Table 3. 2. Definition, measurement, and expected sign of variables

Variables	Description	Measurement units	Expected sign
Adoption of SWC	The adoption of SWC structures	1 for the adopter, 0 otherwise	
	Demographic variables		
SEX	Sex of the household head	1 if male, 0 otherwise	Positive
AGE	Age of the household head	Number of years	Positive/Negative
HHSIZE	Number of individuals in the household	Adult equivalent ratio	Positive
EDUC	Educational status of the household head	1 if the household head is literate, 0 otherwise	Positive

Socio-economic variables			
NONFARM	Income generated from off-farm and non-farm activities	Amount in Birr	Negative
LIVES	Number of Livestock under a household	Tropical livestock unit (TLU)	Negative /positive
Institutional factors			
TRAIN	Frequency of SWC trai ning per year	Number of days	Positive
EXTN	Frequency of extension contact per year	Number of days	Positive
Physical characteristics			
DIS	The average distance of the plots from the homestead	Minutes	Negative
AREA	The average area of the plot	Hectare	positive
SLOPE	The proportion of flat sloped plots	Percent	Negative
OWN	The proportion of owned plots	Percent	Positive
POSITION	The proportion of downstream plots from the watershed	Percent	Positive

Chapter 4. RESULT AND DISCUSSION

This chapter presents the results and discussion of the study. The chapter has five main sub-sections. The first sub-section deals with the different SWC structures adopted by sample households; the second sub-section deals with household, institutional, and plot characteristics, and the third chapter deals with food security measurements. The fourth and the fifth sub-section deal with the factors affecting households' decision to adopt SWC structures and the impact of SWC structures on households' food security respectively.

4.1. SWC Structures Adoption by Sample Households

According to our survey, households construct different SWC measures on their plots. These measures include soil bund, stone bund, stone-faced soil bund, terracing, waterway, diversion ditch, plantation, and trench. However, sample households adopted the four major SWC structures. These structures are soil bund, stone bund, stone-faced soil bund, and terracing. As we defined in Chapter 3, a household is an adopter if and only if there is at least one SWC structure on their plot, the structure is kept in maintenance when it needs, and the SWC structure's age is greater or equal to five years since the structure is constructed.

Table 4. 1. Soil and water conservation structures adopted in the study area

Source: Own analysis from survey data, 2020

No	Type of SWC structure	Adoption of the structures			
		Adopter		Not adopter	
		N	%	N	%
1.	Soil bund	117	21.43	429	78.57
2.	Stone bund	162	29.67	384	70.33
3.	Stone-faced soil bund	265	48.53	281	51.47
4.	Terracing	46	8.42	500	91.58

According to the survey result of this study, out of the total 546 sample households, 284 (52.01%) households were found to be adopters of SWC structures and the rest 262 (47.99%) households were non-adopters of SWC structures.

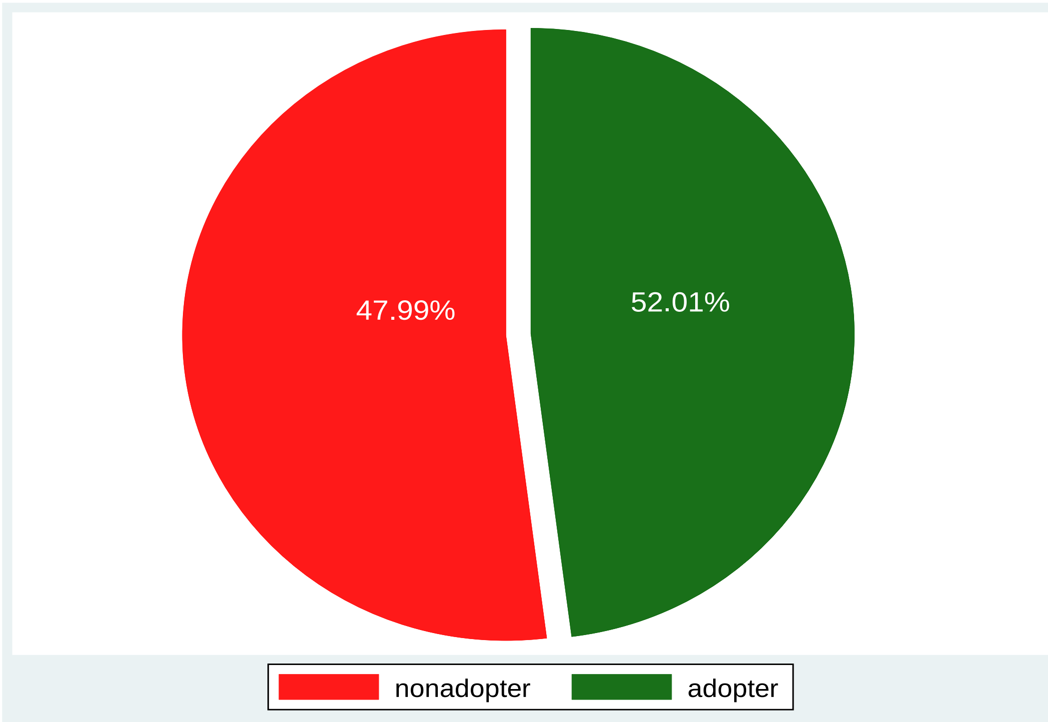


Figure 4. 1. The adoption of soil and water conservation structures

4.2. Household, Institutional, and Plot Characteristics

Descriptive statistics like minimum, maximum, frequency, percentage, mean, and standard deviation are executed to describe these variables. In addition, inferential statistics like chi-square and t-tests are used to check the association between categorical variables and the adoption of SWC structures and to see whether there is a significant mean difference between adopters and non-adopters of SWC structures or not in terms of continuous variables respectively.

4.2.1. Household characteristics of sample households

Sex of the household head: From the total 546 observations, 400(73.26%) households were male-headed households while the rest were female-headed households. From the male-headed households, 206(51.50%) households were found to be adopters of SWC structures and the remaining households were non-adopters of SWC structures. Out of the female-headed households, 78(53.42%) were adopters and the rest were non-adopters of SWC structures.

A Chi-square test was employed to check the association between the sex of the household head and the adoption of SWC structures. The chi-square test of association result shows that there is no statistically significant association between the sex of the household head and the adoption of SWC structures. This result is in contradiction with the result of Belete Limani (2018).

Educational status of the household head: The educational status of household head influences farmers' decision to adopt technologies by enhancing farmers' ability to adopt the technology.

In this study, the educational status of the sample household heads was first classified into no schooling at all, read-write without schooling, adult education, religious education, and formal education. Based on this classification, 313 household heads were at no schooling at all category, 13 household heads can read and write without schooling, 52 household heads engaged in adult education in the past, 36 household heads education background was from religious education and 131 household heads learned formal education. For this study, educational status is grouped into literate (those who only learned through formal education) and illiterate (those who are with no schooling and those whose educational background is through informal education) to make it simple to understand. Based on this category, literate and illiterate household heads were 130(23.81%) and 416 (76.19%) respectively. Among those households headed by a literate household head, 65 (50.00%) households were adopters and 65 (50.00%) were non-adopters of SWC structures. From households headed by an illiterate household head, 219 (52.64%) were adopters and the remaining 197(47.36%) were non-adopters of SWC structures.

The chi-square test of association result shows that there is no statistically significant association between the educational status of the household head and the adoption of SWC structures.

Age of the household head: The minimum and the maximum age of the household head was 19 years and 85 years respectively. The average age of the household head was 42.18 years with a standard deviation of 12.10 years.

The average age of adopters of SWC structures was 44.92 years with a standard deviation of 12.07 years. However, the average age of non-adopters of SWC structures was 39.22 years with a standard deviation of 11.43 years. These results were below the average age of adopters and non-adopters reported by Tizazu Toma (2017).

An Independent t-test was employed to check whether there is a significant mean difference between adopters and non-adopters of SWC structure in terms of age or not. The test result shows that there is a statistically significant mean difference between adopters and non-adopters of SWC structures in terms of age at a 1%($p<0.01$) level of significance. This result was in contradiction to the result found in Belete Limani (2018), and Tizazu Toma (2017).

Household size: The household size of the sample households in terms of AE ranges from 0.75 to 10. The average household size was 4.40 AEs with a standard deviation of 1.68 AEs.

For adopters of SWC structures, the average household size in AE is 4.59 with a standard deviation of 1.76 AEs. The average household size for non-adopters of SWC structures is 4.20 AEs with a standard deviation of 1.55 AEs. This result is below the household size reported by Million Sileshi *et al*. (2019). They reported that the average household size of adopters and non-adopters is 6.24 and 6.18, respectively.

The independent t-test result shows that there is a statistically significant mean difference in terms of household size between adopters and non-adopters of SWC structures at a 1%($p<0.01$) significant level.

Livestock holding: In Ethiopia, livestock has a higher role in agricultural production and farming activity. It can be used for plowing, transporting, crashing the crop and other purposes.

The minimum and the maximum number of livestock in terms of TLU was 0 and 11.57 respectively.

The average number of livestock was 2.60 TLU with a standard deviation of 2.07 TLU. The average number of livestock for adopters and non-adopters of SWC structures were 2.76 TLU and 2.43 TLU with a standard deviation of 2.17 TLU and 1.93 TLU respectively. Million Sileshi *et al*. (2019) also reported that adopters have larger livestock holdings than non-adopters.

The result of an independent t-test indicates that there was a statistically significant mean difference in terms of the number of livestock holding between adopters and non-adopters of SWC structures at a 10% ($p<0.1$) level of significance.

Non-farm and off-farm income: In addition to farming, households may engage in different non-farm and off-farm activities. In this study, from the total sample households, 191(34.98%)

households earn money from different non-farm and off-farm activities while the other 355(65.02%) households were not engaged in non-farm and off-farm activities. The amount of income earned from non-farm and off-farm income ranges from 200 ETB to 54000 ETB per year. The average income earned from non-farm and off-farm activities is 1852.78 ETB with a standard deviation of 4796.20 ETB.

For adopters of SWC structures, the average income earned from either non-farm or off-farm activities is 1386.20 ETB with a standard deviation of 3364.07 ETB. For households who did not adopt SWC structures, the average amount of non-farm and off-farm income is 2358.55 ETB with a standard deviation of 5938.83 ETB.

The independent t-test result indicates that there is a statistically significant mean difference in the amount of non-farm and off-farm income between adopters and non-adopters of SWC structures at a 5%(p<0.05) level of significance.

Table 4. 2. Continuous household characteristics of sample households

Source: Own analysis from survey data, 2020

Variables	**Adopters (284)**		**Non-adopters (262)**		**Total sample (546)**				**T-test**
	Mean	**SD.**	**Mean**	**SD.**	**Min.**	**Max.**	**Mean**	**SD.**	
AGE	44.92	12.07	39.22	11.43	19	85	42.18	12.10	-5.65***
HHSIZE	4.59	1.76	4.20	1.55	0.75	10	4.40	1.68	-2.74***
LIVES	2.76	2.17	2.43	1.93	0	11.57	2.60	2.07	-1.85*
NONFARM	1386.20	3364.07	2358.55	5938.83	200	54000	1852.78	4796.20	2.38**

***, ** and * represents significant at 1% (p<0.01), 5% (p<0.05) and 10% (p<0.1) significant level respectively.

Table 4. 3. Categorical household characteristics of sample households

Source: Own analysis from survey data, 2020

Variables	Categories	Adopter (284)		Non-adopter (262)		Total (546)		Chi-square value
		N	%	N	%	N	%	
SEX	Female	78	53.42	68	46.58	146	26.74	0.1587
	Male	206	51.50	194	48.50	400	73.26	
EDUC	Illiterate	219	52.64	197	47.36	416	76.19	0.2775
	Literate	65	50.00	65	50.00	130	23.81	

4.2.2. Institutional characteristics of sample households

Frequency of extension contact: Having a good contact with extension agents helps farmers to be aware of improved SWC structures in reducing threats associated with soil erosion and land degradation. The extension agents can provide technical information and advice as well as training on improved SWC structures.

The minimum and maximum average number of extension visits per year are 0 and 30 days respectively. The average number of extension contact per year is 8.17 days with a standard deviation of 7.93 days.

The average number of extension contacts per year for adopter households is 8.98 days with a standard deviation of 8.36 days. Whereas, for non-adopters of SWC structures, the average number of extension contacts per year is 7.28 days with a standard deviation of 7.35 days. This result is in line with the finding of Million Sileshi *et al*. (2019). They reported that those who adopted SWC structures had greater access to information through extension agents than non-adopters.

The independent t-test result shows that there is a significant mean difference in the number of extension contacts between adopters and non-adopters at a 5% ($p<0.05$) significant level. **Frequency of SWC training:** The minimum and the maximum number of SWC training per year are 0 and 10 days respectively. The average number of SWC training per year is 0.97 days with a standard deviation of 1.88 days.

For adopters of SWC structures, the average number of SWC training per year is 1.20 days with a standard deviation of 2.08 days. While for non-adopters of SWC structures, the average number of SWC training per year is 0.72 days with a standard deviation of 1.61 days.

As the independent t-test result shows, there is a statistically significant mean difference in the number of SWC training per year between adopters and non-adopters of SWC structures at 1% ($p<0.01$) level of significance.

Table 4. 4. Institutional characteristics of sample households

Source: Own analysis from survey data, 2020

Variables	**Adopters (284)**		**Non-adopters (262)**		**Total sample (546)**				**T-test**
	Mean	**SD.**	**Mean**	**SD.**	**Min.**	**Max.**	**Mean**	**SD.**	
EXTN	8.98	8.36	7.28	7.36	0	30	8.17	7.93	-2.51**
TRAIN	1.20	2.08	0.72	1.61	0	10	.96	1.88	-3.02***

***, and ** represents significant at 1% ($p<0.01$), and 5% ($p<0.05$) significant level respectively.

4.2.3. Plot characteristics

The adoption of SWC structures can also be affected by plot characteristics. Plot characteristics include variables like the slope of the plot, plot ownership, position of plots from the nearest watershed, area of the plots, and distance of the plots from the homestead. In the survey, sample households had 2400 plots in total. However, for simplicity of analysis, all plot-level characteristics were converted into the household-level variable format by collapsing these variables using the household identification number. For categorical variables, the percentage of one of the categories of the variables was considered, and for the continuous plot characteristics, the average of the variable was considered. Each of these variables are described below.

The slope of the plots: In this study, the slope of the plots was categorized into flat, gentle, and steep slope. Out of the 2400 plots, 1293(53.88%) plots were flat sloped, 749(31.21%) plots were gentle slopped, and the rest 358 (14.92%) plots were steep-sloped.

The proportion of flat-sloped plots under each household is considered in this study. The minimum and maximum proportion of flat-slopped plots were 0 and 69.61%. The average proportion of flat-sloped plots for the sample households was 18.30% with a standard deviation of 13.82%. The average proportion of flat slopped plots for the adopter households was 17.13% with a standard deviation of 15.33%. For non-adopter households, the average proportion of flat slopped plots was 19.57% with a standard deviation of 11.87%.

The independent t-test result shows that there is a statistically significant mean difference between adopters of SWC structures and non-adopters of SWC structures in terms of the proportion of flat slopped plots at 5%($p<0.05$) level of significance.

Plot ownership: Among the 2400 plots, the households owned 1632 (68.00%) plots and the rest 768 (32.00%) plots ownership is non-owned (rented in or shared in). Among the total owned plots, 32.33% of the plots had SWC structures adopted on it.

The minimum and maximum proportion of owned plots were 0 and 55.15% respectively. The average proportion of owned plots for the total observations is 18.32% with a standard deviation of 11.12%. For adopters of SWC structures the mean of the proportion of owned plots was 21.06% with a standard deviation of 11.49%, whereas, for non-adopter households, the mean of the proportion of owned plots was 15.34% with a standard deviation of 9.89%.

The t-test comparison showed a significantly higher proportion of owned plots in favor of SWC structures adopters at a 1% level of significance.

Position of plots from watershed: out of the total 2400 plots, 1223(50.96%), 862(35.92%), and 325(13.13%) plots are located in the lower, middle, and upper stream from the nearest watershed respectively. The average proportion of plots found in the lower position of the watershed was 18.33% with a standard deviation of 15.33%.

For adopters of SWC structures, the mean proportion of plots found in the lower position from watershed was 21.33% with a standard deviation of 16.00%. However, for non-adopters of

SWC structures, the mean proportion of plots found in the lower position from watershed was 15.07% with a standard deviation of 13.88%.

The independent t-test result shows that there is a statistically significant mean difference between adopters and non-adopters of SWC structures in terms of the proportion of plots found in the lower position from the nearest watershed at 1% ($p<0.01$).

Average plot area: According to this study, the minimum and maximum average area of the plots are 0.06 hectare and 1.04 hectare respectively. The mean of the average plot area is 0.34 hectare with a standard deviation of 0.14 hectare.

For the adopters of SWC structures, the mean of the average plot area of plots is 0.35 hectare with a standard deviation of 0.13 hectare. For non-adopters of SWC structures, the mean of the average plot area of plots is 0.32 hectare with a standard deviation of 0.14 hectare.

The independent t-test result shows that there is a statistically significant mean difference in the average plot area between adopters and non-adopters of SWC structures at a 5%($p<0.05$) level of significance.

Average plot home distance: The minimum and maximum average distance between plots and homesteads were 0 and 105 minutes of walking respectively. The mean of the average distance between plots and homestead was 18.99 minutes of walking with a standard deviation of 13.30 minutes of walking.

For adopters of SWC structures, the mean of the average minute of walking from plots and homestead is 17.16 walking minutes with a standard deviation of 10.95 minutes of walking. However, for the non-adopters of SWC structures, the mean of the average minutes of walking from homestead to plots of the household is 20.97 minutes with a standard deviation of 15.23 minutes.

The independent t-test result shows that there is a statistically significant mean difference between adopters and non-adopters of SWC structures in terms of the average plot home distance in minutes of walking at 1% ($p<0.01$) significant level.

Table 4. 5. Plot characteristics Source: Own analysis from survey data, 2020

Variables	Adopters (284)		Non-adopters (262)		Total sample (546)				T-test
	Mean	SD.	Mean	SD.	Min.	Max.	Mean	SD.	
DIS	17.16	10.95	20.97	15.23	0	105	18.99	13.30	3.37***
AREA	0.35	0.13	0.32	0.14	0.06	1.04	0.34	0.14	-2.13**
SLOPE	17.13	15.33	19.57	11.87	0	69.61	18.32	13.82	2.07**
OWN	21.06	11.49	15.34	9.89	0	55.15	18.32	11.12	-6.21***
POSITION	21.33	16.00	15.07	13.88	0	65.41	18.33	15.33	-4.87***

***, and ** represents significant at 1% ($p<0.01$), and 5% ($p<0.05$) significant level respectively.

4.3. Food Security Measurements

Household dietary diversity score (HDDS) was one of the techniques used to measure the food security of the households. By using this technique, we categorized households' food security into low, medium, and high. From the total observation, 36(6.59%), 130(23.81%), and 380(69.60%) households were in the low, medium, and high category dietary diversity category respectively.

Among adopters of SWC structures, 15(5.28%), 59(20.77%), and 210(73.95%) households were in the low, medium, and high dietary diversity category respectively. From the non-adopters of SWC structures, 21(8.01%), 71(27.10%), and 170(64.89%) households were in the low, medium, and high dietary diversity category respectively.

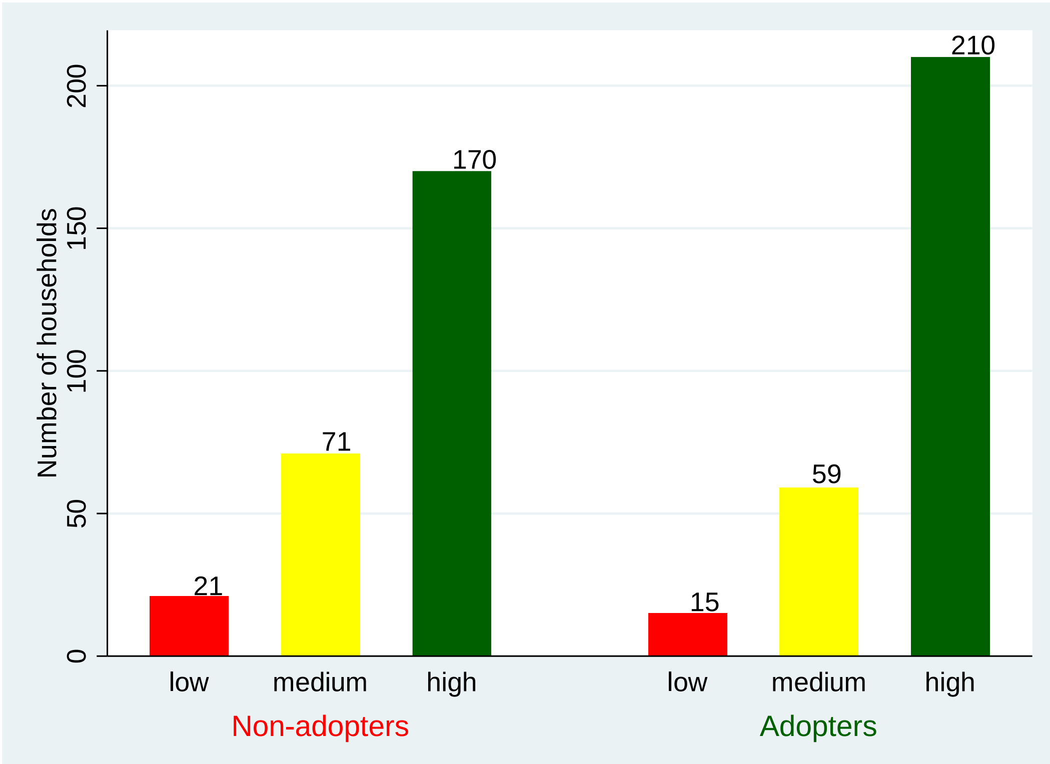


Figure 4. 2. Dietary diversity of households and adoption of soil and water conservation structures

Food consumption score (FCS) was also another measure of food security used in this study. Out of the total sample households, 30(5.49%), 122(22.34%), and 394(72.16%) households were in the poor, borderline, and acceptable category of food consumption respectively.

From adopters of SWC structures, 59(20.77%) and 213(75.00%) households were in the poor, borderline, and acceptable category of food consumption respectively. Among the non-adopters of SWC structures, 18(6.87%), 63(24.05%), and 181(69.08%) households were in the poor, borderline, and acceptable category of food consumption respectively.

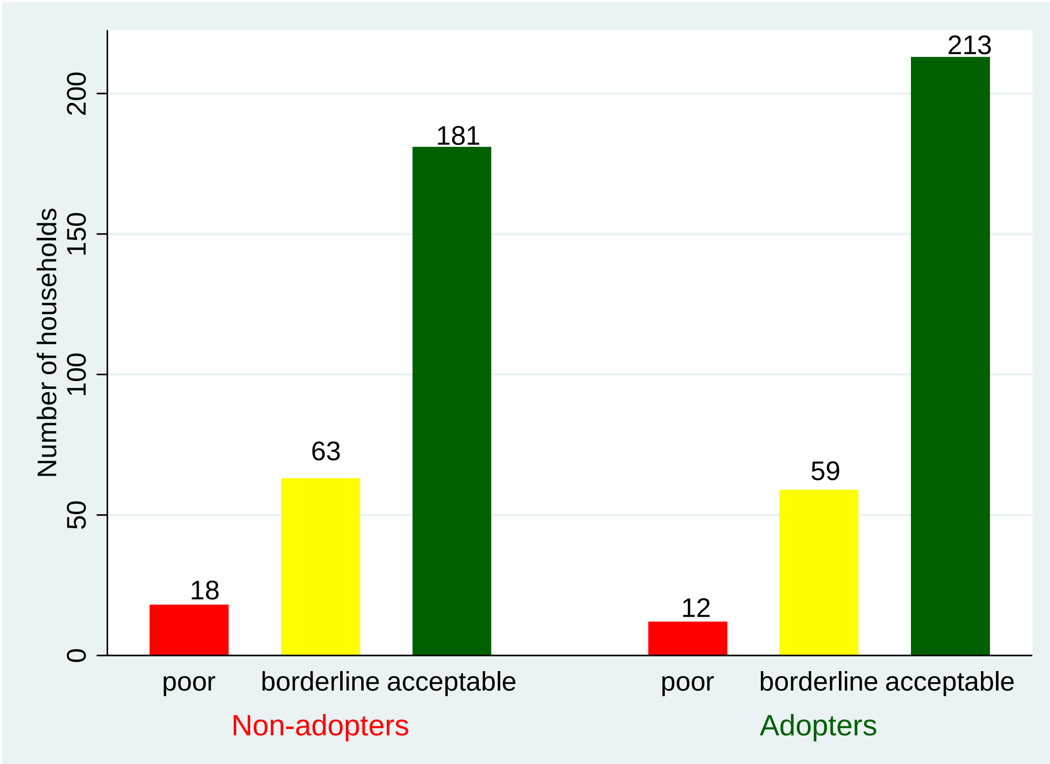
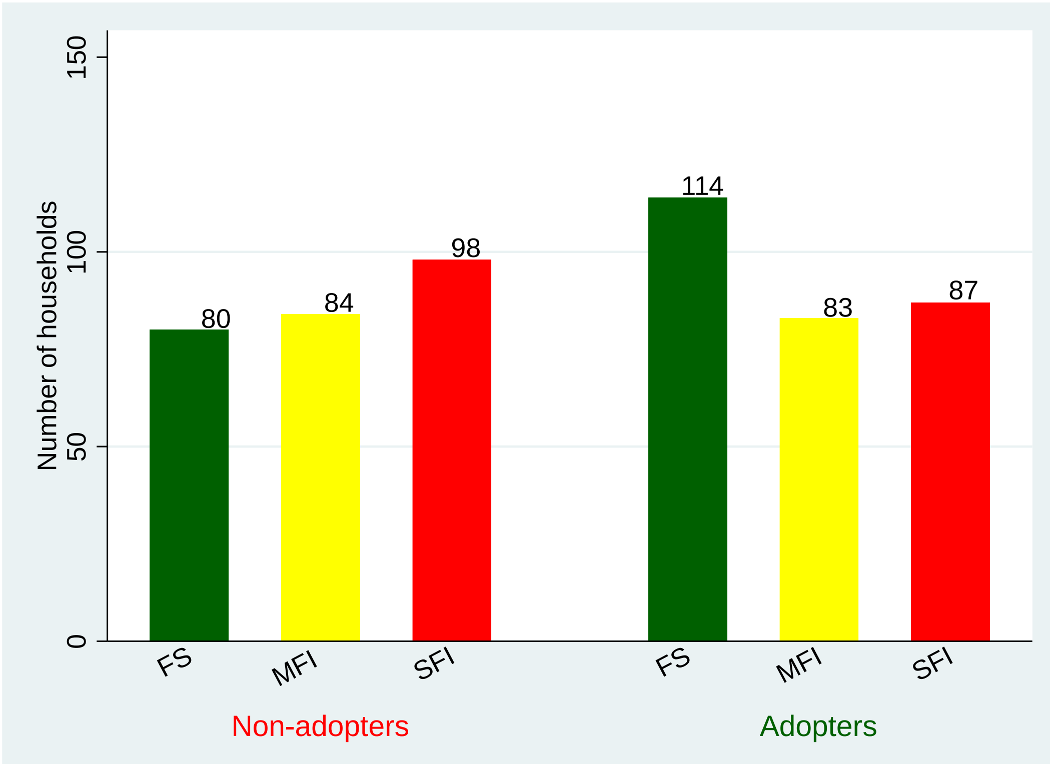


Figure 4. 3. Food consumption and adoption of soil and water conservation structures

The other way of measuring food security used in this study was the food insecurity experience scale (FIES). According to this measurement of food security, 194(35.53%), 167(30.59%), and 185(33.88%) households were in the food secure, moderate food insecure and severe food insecure category respectively.

Among the adopters of SWC structures, 114(40.14%), 83(29.23%), and 8(30.63%) households were in the food secure, moderate food-insecurity experience, and severe food-insecurity experience category respectively. Of the 262 non-adopter households, 80(30.53%), 84(32.06 %), and 98(37.41%) households were in the food secure, moderate food insecurity experience, and severe food insecurity experience category respectively.



NB. FS=Food secure MFI=Moderate food insecure SFI=Severe food insecure

Figure 4. 4. Food insecurity experience of households and adoption of soil and water conservation structures

The last technique to measure food security used in this study was the food security scale (FSS). Based on this measurement, 221(40.48%), 286(52.38%), 34 (6.23%), and 5(0.92%) households were in food secure, food insecure without hunger, food insecure with hunger, and food insecure with severe hunger category of food security respectively.

Out of the adopters of SWC structures, 159(55.99%), 111(39.08%), 1(0.35%), and 13 (4.58%) households were food secure, food insecure without hunger, food insecure with hunger, and food insecure with severe hunger respectively. From non-adopters of SWC structures, 62(23.66%), 175(66.79%), 21(8.02%), and 4(1.53%) households were food secure, food insecure without hunger, food insecure with hunger, and food insecure with severe hunger respectively.

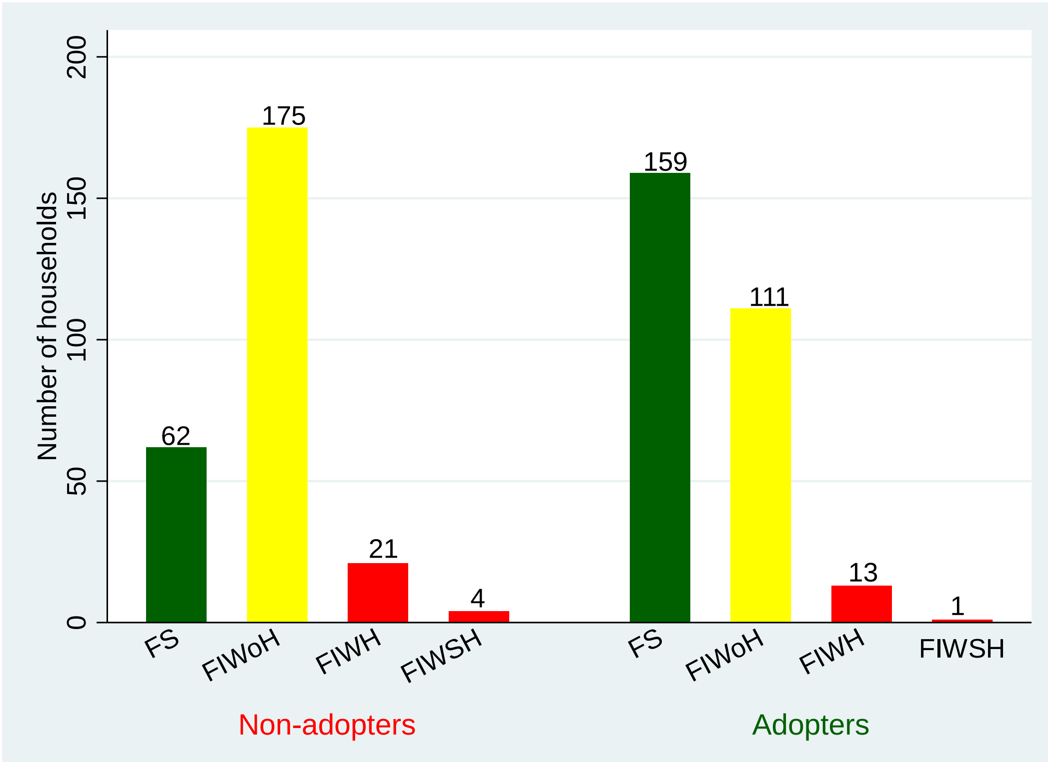


Figure 4. 5. Food security scale and adoption of soil and water conservation structures

FS=food secured

FIWoH=food insecure without hunger

FIWH=food insecure with hunger

FIWSH = food insecure with severe hunger

Table 4. 6. Food security measurements Source: Own analysis from survey data, 2020

Variables	Categories	Adopter (284)		Non-adopter (262)		Total (546)		Chi-square value
		N	%	N	%	N	%	
HDDS	Low	15	5.28	21	8.01	36	6.59	5.4406*
	Medium	59	20.77	71	27.10	130	23.81	
	High	210	73.95	170	64.89	380	69.60	

FCS	Poor	12	4.22	18	6.87	30	5.49	3.0486
	Borderline	59	20.77	63	24.05	122	22.34	
	Acceptable	213	75.00	181	69.08	394	72.16	
FIES	Food secure	114	40.14	80	30.53	194	35.53	5.7417*
	MFI	83	29.23	84	32.06	167	30.59	
	SFI	87	30.63	98	37.41	185	33.88	
FSS	Food secure	159	55.99	62	23.66	221	40.48	59.7893***
	FI Wo. Hunger	111	39.08	175	66.79	286	52.38	
	FI W. hunger	13	4.58	21	8.02	34	6.23	
	FI W. S. hunger	1	0.35	4	1.53	5	0.92	

*** And * significant at 1% (p<0.01) and 10% (p<0.1) respectively.

Where,

MFI medium food insecure FI Wo. hunger Food insecure without hunger

SFI severe food insecure FI W. hunger Food insecure with hunger

FI W. S. hunger Food insecure with severe hunger

These descriptive statistics indicate that households adopting SWC are more food secure and less prone to food insecurity than non-adopters. Million Sileshi *et al*. (2019) also found a similar result. However, at this level, it is difficult to conclude that adopting SWC improves the food security status of households and reduces the food insecurity status. Thus, an impact assessment is needed to determine if this increase in food security and decrease in food insecurity is due to SWC adoption or not, by controlling for the observed and unobserved heterogeneity that affects the adoption decision and food security.

4.4. Factors Affecting Households' Decision to Adopt SWC Structures.

The binary probit estimation results are presented in Table 4.7 below. The model fits the data reasonably well and better than a model with no predictors (LR chi2 (13) = 137.07 with Prob > chi2 = 0.0000). The model result indicates demographic, socio-economic, institutional, and plot characteristics significantly influence the SWC structures adoption decision. Out of the thirteen variables considered in the model, nine variables were found to have a statistically significant effect on the adoption of the SWC decision. These variables are discussed below:

Table 4. 7. Determinants of on-farm adoption of soil and water conservation structures: binary probit model result Source: Own analysis from survey data, 2020

Variables	Coefficients	Marginal effect (dy/dx)	Standard error
SEX	-0.1243	-0.0493	0.2298
AGE	0.0254***	0.0101	0.0087
EDUC	-0.1517	-0.0604	0.2299
HHSIZE	0.0887**	0.0353	0.0612
LIVES	0.0485	0.0193	0.0502
NONFARM	-0.0326**	-0.0130	0.00002
EXTN	0.0124	0.0049	0.0129
TRAIN	0.0864***	0.0344	0.0554
AREA	0.7618*	0.3032	0.7383
DIS	-0.0103**	-0.0041	0.0078
SLOPE	-0.0235***	-0.0094	0.0083
OWN	0.0343***	0.0137	0.0111
POSITION	0.0144***	0.0057	0.0075
Constant	-2.0365		0.6360

*, ** and *** represents significant at 10% (P<0.1), 5% (P<0.05) and 1% (P<0.01) respectively.

Age of the household head: According to the model result, the age of the household head was found to have a positive and significant influence on the adoption of SWC structures. As the age of the household head increases by one year, the probability of adopting SWC structures increased on average by 1.01% at a 1%(p<0.01) level of significance, keeping other variables constant. This may be because older farmers may have longer years of farming experience to understand the benefits of SWC structures. This result is in line with the results of previous studies (Chomba, 2004; Aklilu Amsalu and de Graaff, 2007; Fikru Assefa, 2009). However, the result is in contradiction to the study by Yitayal Anley *et al*. (2007), and Daniel Asfaw and Mulugeta Neka (2017).

Household size: It is known that constructing SWC structures needs more labor and effort. In Ethiopia, family labor is the main source of labor for farming activities, especially for small-scale farmers. Based on the Probit model result, household size in terms of AE was found to have a positive and significant effect on the adoption of SWC structures at a 5% (P<0.05) level of significance. As the size of the family increased by one more individual, the probability of adopting SWC structures increased on average by 3.53%, ceteris paribus. The possible justification could be the labor intensiveness of building SWC structures. Previous studies also claimed that the larger sized family could provide the required labor for constructing and maintaining conservation structures (Million Tadesse and Kassa Belay, 2004; Habtamu Ertiro, 2006; Eleni Tesfaye, 2008; Adjepong *et al*., 2019). However, contrary to this result, other studies (Wagayehu Bekele and Drake, 2003; Aklilu and de Graaff, 2007; Fikru Assefa, 2009) argued that large size families may face competition for labor between food generating off-farm activities and investment in maintenance of SWC structures.

Non-farm and off-farm income: The amount of income earned from non-farm and off-farm activities can affect a household's probability of adopting SWC structures. The binary probit model result indicates that the amount of income earned from non-farm and off-farm activities affects the adoption of SWC structures significantly. This variable was found to have a negative on the adoption of SWC structures at a 5% (P<0.05) level of significance. An increase in the income earned from non-farm and off-farm activities by one thousand ETB decreased the probability of adopting SWC structures on average by 1.30%, ceteris paribus. As the household earns more and more from non-farm and off-farm activities, they will give less attention to farming. Likewise, the more the household earns an income from non-farm and off-farm activities they will not have enough time to invest in their plots and they give less attention to protect their land from soil erosion and land degradation. The labor competition between non-farm and off-farm activities and SWC structures may restrain farmers from getting more time to involve in implementing and maintaining conservation structures on their farmlands. A similar result was reported by previous studies (Tenge *et al*., 2004; Eleni Tesfaye, 2008; Daniel Asfaw and Mulugeta Neka, 2017; Asnake Mekuriaw *et al*., 2018). However, Tiwari *et al*. (2008), and Mulugeta Demelash and Stahr (2010) reported that income from on-farm and off-farm activities can increase the financial potential of farmers, which in turn encourages investment in SWC structures.

Frequency of SWC training: The frequency of training related to SWC structures was found to have a positive and significant effect on the adoption of SWC structures at a 1% ($P<0.01$) significant level. The marginal effect result showed that as the frequency of SWC training increased by one, the probability of adopting SWC structures will increase on average by 3.44%, ceteris paribus. The appropriate justification for this can be, giving more training for farmers on the importance and method of implementation of SWCs can fill the knowledge gap on the benefits of SWC structures that constrained the adoption of SWC structures. This result is in line with the findings of Habtamu Ertiro (2006), Eleni Tesfaye (2008), Tiwari *et al*. (2008), Daniel Asfaw and Mulugeta Neka (2017), Adjepong *et al*. (2019), and Agere Belachew *et al*. (2020). They reported that more access to training has a positive relationship with the adoption of SWC structures. However, the finding is in contradiction to the finding of Fikru Assefa (2009). He reported that training has a negative correlation with the adoption of soil or stone bund and tree plantations.

Average plot to home distance: As hypothesized**,** the average distance of plots from the homestead in minutes of walking was found to have a negative effect on the adoption of SWC structures. This variable is found statistically significant at a 5%($P<0.05$) significant level. According to the Probit model result, as the average plot to home distance increase by one more minute of walking, the probability of adopting SWC structures falls on average by 0.41% ceteris paribus. As the average plot to home distance increases, it takes more time, energy, and labor to construct and maintain SWC structures. This result is similar to the finding of Berhanu Gebremedhin and Swinton (2003), Habtamu Ertiro (2006), Kessler (2006), Yitayal Anley *et al*. (2007), Tiwari *et al*. (2008), Fikru Assefa (2009), and Daniel Asfaw and Mulugeta Neka, 2017).

Average plot area in hectare: The average plot area in hectares, affects the decision to adopt SWC structures positively. Households with larger average plot area have a high probability of adopting SWC structures. As the average size of plots increases by 1 hectare, there will be an increase in the decision to adopt SWC structures by 30.32% at a 10% ($P<0.1$) significant level. The possible justification is that constructing SWC structures is expected as it takes a wider area to be landed. Due to this, households with smaller average plot area have less chance of adopting SWC structures. This finding is in line with the findings of Million Sileshi *et al*. (2019), and Agere Belachew *et al*. (2020).

Slope of the plot: According to the Probit model result, the proportion of flat slopped plots found to have a negative and statistically significant effect on the adoption of SWC structures at a 1% ($P<0.01$) level of significance. A one percent increase in the proportion of flat-sloped plots on average results in a 0.94% decrease in the probability of adopting SWC structures ceteris paribus. This implies that a household with more flat slope plots has less probability of adopting SWC structures possibly because flat slopped plots will be less vulnerable to run-off and soil erosion. In other words, farmers with less proportion of flat slopped plots (or more proportion of gentle and steep slope plots) are forced to construct SWC structures and more probability of adopting SWC structures. This result is in line with the result found by Wagayehu Bekele and Drake (2003), Amsalu and de Graaff (2007), and Agere Bela chew *et al*. (2020).

Plot ownership: As expected, this variable was found to have a positive and significant effect on the adoption of SWC structures at a 1% ($P<0.01$) level of significance. According to the Probit model result, a one percent increase in the proportion of owned plots increases the probability of adopting SWC structures on average by 1.37%, ceteris paribus, possibly because owned plots have more security than rented-in and shared-in plots to invest in long term SWC activities. A household can feel more comfortable to construct SWC structures on owned plots than on non-owned plots. However, households may become reluctant to construct SWC structures on non-owned plots since they are not confident enough whether he could use these plots for a longer period or not, as other individuals own these plots. Tenge *et al*. (2004) also reported that tenure ownership affects the adoption of SWC structures positively.

Position of plots from watershed: The position of plots from the nearest watershed affects the adoption of SWC structures significantly. In line with the prior hypothesis, the proportion of downstream plots affects the probability of adopting SWC structures positively at a 1% ($P<0.01$) level of significance. Specifically, a one percent increase in the proportion of downstream plots increases the probability of adopting SWC structures on average by 0.57%, ceteris paribus, possibly because downstream plots may be more susceptible to run off and hence need to have SWC.

4.5. Impact of SWC Structures on Households' Food Security

The main objective of this study is to analyze the impact of adopting SWC structures on households' food security status. The endogenous switching regression (ESR) model was employed to answer this objective. In the first regime of the endogenous switching regression model, the researcher estimated the determinants of the adoption decision of households' as discussed in Section 4.4. above The second stage of the ESR model is used to estimates the effect of different variables on different food security measurements (households dietary diversity score (HDDS), food consumption score (FCS), food insecurity experience scale (FIES), and food security scale (FSS)) for both adopters and non-adopters of SWC structures.

The selection equation after the participation equation includes all the variables in the participation equation and instrumental variables to improve identification. The instrumental variables used in the model were an average plot to home distance, average plot area in hectare, and percentage of flat slopped plots. Based on the falsification test these variables were found to affect the adoption of SWC structures significantly but have no direct effect on food security, suggesting that the variables meet the criteria to be an instrumental variable.

From the ESR model result, we have different factors affecting the food security measurements for both adopters and non-adopters of SWC structures. The model result is indicated in Appendix Table 1 below.

Treatment effects for both the adopters and non-adopters of SWC structures are executed after estimating the effect of different explanatory variables on the proxy outcome variables of food security. The expected HDDS, FCS, FSS, and FIES under actual and counterfactual conditions are reported in Table 4.8 below. The ATT is the difference in the average outcome variable between the observed and counterfactual of adopters of SWC structures. It is simply the effect of the intervention or treatment on the treated group. The value of ATT was found to be significant for all the outcome variables. ATU is the difference in the average outcome variable between the observed and counterfactual of non-adopters (if they had adopted) of SWC structures. It is simply the effect of treatment or intervention on the untreated group. As reported in Table 4.8 below, ATU is also significant for all outcome variables. The transitional heterogeneity effect helps us to determine whether the impact of SWC structures is smaller or larger for adopter and non-adopter households relative to the counterfactual scenario, given by the difference between the ATT and the ATU for each outcome variable. The transitional heterogeneity effect was found to be significant for all outcome variables.

In Table 4.8 below, Cells (a) and (b) in each food security measurement represent the expected HDDS, FCS, FSS and FIES observed in the sample. The expected HDDS and FCS for farmers that adopted SWC structures is higher than the group of farmers that did not adopt. However, the expected FSS and FIES for adopter farmers is less than non-adopter farmers expected FSS and FIES. Meanwhile, this simple comparison can be misleading to attribute the difference in HDDS, FCS, FSS, and FIES to the adoption of SWC structures. Cells (c) and (d) represents the expected value of HDDS, FCS, FSS, and FIES for the counterfactuals for the adopters and non-adopters respectively. The values (e) and (f) in each outcome variable represent the base heterogeneity for adopters and non-adopters of SWC structures respectively. The heterogeneity effect is the difference between the base heterogeneity of adopters and the base heterogeneity of non-adopters.

As indicated in Table 4.8 below, the average treatment effect on HDDS and FCS for the adopters of SWC structures is 7.316 and 18.707 respectively. This implies that adopters of SWC structures increase their HDDS and FCS by 7.316 and 18.707 points respectively because of adopting SWC structures. For non-adopters of SWC structures, the average treatment effect on HDDS and FCS is 0.631 and 4.016 respectively. The results suggest that if non-adopters of

SWC structures had adopted SWC structures, their HDDS and FCS could have increased by 0.631 and 4.016 points respectively. The transitional heterogeneity effect is positive in terms of HDDS and FCS. This implies that the impact of SWC structures on HDDS and FCS is significantly greater for farmers who did adopt compared to those that did not adopt SWC structures.

The average treatment effect on FSS and FIES for the adopters of SWC structures is -4.462 and -0.221 respectively. This implies that there is 4.462 and 0.221 points decrease in FSS and FIES of adopters of SWC structures, respectively due to adopting SWC structures. Likewi se, for non-adopters of SWC structures, the average treatment effect on FSS and FIES is -0.322 and -0.527 respectively. The results suggest that non-adopters of SWC structures would have 0.322 and 0.527 points less FSS and FIES, if they had adopted SWC structures. The transitional heterogeneity effect is positive in terms of FIES. This implies that the impact of SWC structures on FIES is significantly greater for farmers who did adopt compared to those that did not adopt SWC structures. However, the transitional heterogeneity effect is negative in terms of FSS. This implies that the impact of SWC structures on FSS is significantly greater for farmers who did not adopt compared to those that did adopt SWC structures.

Table 4. 8. Impact of SWC structures on HDDS, FCS, FSS, and FIES: treatment, and heterogeneity effects Source: Own analysis from survey data, 2020

Outcome variables	**Treatment effect category**	**Decision stage**		**Treatment effect**
		To adopt	**Not to adopt**	
HDDS	ATT	(a) 7.345	(c) 0.029	(I) 7.316***
	ATU	(d) 7.090	(b) 6.459	(II) 0.631***
	HE	(e) 0.255	(f) -6.43	(III) 6.685***
FCS	ATT	(a) 41.810	(c) 23.103	(I) 18.707***
	ATU	(d) 44.662	(b) 40.646	(II) 4.016***
	HE	(e) -2.852	(f) -17.543	(III) 14.691***

FSS	ATT	(a) 1.736	(c) 6.198	(I) -4.462***
	ATU	(d) 2.660	(b) 2.982	(II) -0.322***
	HE	(e) -0.924	(f) 3.216	(III) -4.140***
FIES	ATT	(a) 4.278	(c) 4.499	(I) -0.221***
	ATU	(d) 4.236	(b) 4.763	(II) -0.527***
	HE	(e) 0.042	(f) -0.264	(III) 0.306***

*** Significant at 1 % level of significance

Note: (e) = (a)-(d), (f) = (c)-(d), (I) = (a)-(c), (II) = (d)-(b), (III) = (e)-(f)

The estimated impact results of this study are consistent with previous studies (Million Sileshi *et al*., 2019; Sita *et al*.,2018) who found that investing in SWC structures has a positive impact on crop productivity, income, and food security, especially in moisture deficit areas.

Chapter 5. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1. Summary and Conclusion

This study analyzes the impact of SWC structures on households' food security by using survey data in West and East Belesa *Woredas*. This study majorly aimed at analyzing the impact of SWC structures on households' food security and specifically aimed at analyzing the determinants of households' SWC adoption decision and assessing the impact of SWC structures on households' dietary diversity, food consumption expenditure, food insecurity experience, and Food security scale. HDDS, FCS, FIES, and FSS were the proxy outcome variables used to measure food security.

A multi-stage sampling technique was used to select sample *kebele*s and sample households. 546 households through were the source of primary data and Woreda and *kebele* level reports were the sources of secondary data. Data management and data analysis were executed using STATA version 15 software. A binary probit model and ESR model were used to analyze the determinants of households' SWC adoption decision and the impact of SWC structures on households' food security.

Out of the total sample households, 284 households were adopters and the remaining 262 households were non-adopters of SWC structures. Soil bund, stone bund, stone-faced soil bund, and terracing are the structures adopted by households on their farm. This implies that SWC structures adopted are more of physical SWC structures.

Among adopters of SWC structures, 15(5.28%), 59(20.77%), and 210(73.95%) households were in low, medium, and high dietary diversity category respectively; 12(4.22%), 59(20.77%), and 213(75.00%) households were in the poor, borderline and acceptable category of food con sumption respectively. Also, 114(40.14%), 83(29.23%), and 87(30.63%) households were in the food secure, moderate food-insecurity experience, and severe food-insecurity experience category respectively, and 159(55.99%), 111(39.08%), 1(0.35%) and 13(4.58%) households were food secure, food insecure without hunger, food insecure with hunger, and food insecure with severe hunger respectively. Whereas, from non-adopters, 21(8.01%), 71(27.10%), and 170(64.89%) households were in low, medium, and high dietary diversity group respectively; 18(6.87%), 63(24.05%), and 181(69.08%) households were in the poor, borderli ne and acceptable category of food consumption respectively. Besides, 80(30.53%), 84(32.06%), and 98(37.41%) non-adopter households were in the food secure, moderate food insecurity experience, and severe food insecurity experience category and 62(23.66%), 175(66.79%), 21(8.02%) and 4(1.53%) households were food secure, food insecure without hunger, food insecure with hunger, and food insecure with severe hunger respectively.

This implies that adopters of SWC structures are in a better position in terms of food security measured in HDDS, FCS, FIES, and FSS compared to non-adopters of SWC structures.

According to the binary probit model result, age of the household head, livestock holding, household size, amount of non-farm and off-farm income, frequency of SWC training, the average distance between homestead and plots, plot slope, plot ownership, and position of the plot from watershed affects the households' SWC adoption decision significantly. This implies that these variables are the determining factors for households' on-farm adoption of different SWC structures.

Adopters HDDS and FCS increase by 7.316 and 18.707 points because of adopting SWC structures. The FSS and FIES of households decrease by 4.462 and 0.221 points because of the adoption of SWC structures. In addition to this, non-adopters of SWC households HDDS and FCS could be increased by 0.631 and 4.016 points if they had been adopting SWC structures. Additionally, the FSS and FIES of non-adopter households could be decreased by 0.322 and 0.527 points if they had been adopting SWC structures. Based on this we can conclude that SWC structures are contributing significantly to the improvement in the food security status of households by improving the dietary diversity and consumption frequency; by decreasing the food insecurity level and food insecurity experience of the households.

5.2. Recommendations

Under this sub-section, the following recommendations are drawn based on the study results:

Based on this study, the most widely used and adopted structures are more physical structures. However, it will be better if these physical structures are supported by biological methods.

In this study, the frequency of SWC training affects the adoption of SWC structures positively. Therefore, it is better to extend the training to a wider scope. The concerned body has to give much attention to providing SWC training in a wider scope.

The age of the household head was found to affect the adoption of SWC structures positively. Considering this, the *Woreda* bureau of agriculture and natural resources and other relevant stakeholders should focus on older farmers and those having the relatively better farming experience to scale-up the structures and benefit younger and relatively less experienced farmers through a trickle-down effect and sharing the experiences. Young and less-experienced farmers should deserve equal, if not more, attention in the process of adoption and diffusion of improved structural SWC structures.

The proportion of flat-sloped plots and the adoption of SWC structures were found to have a negative relationship. Households are adopting SWC structures on plots with gentle and steep slope plots. However, since the area is semi-arid, it is better to use water-conserving structures not only for gentle and steep plots but also for flat slopped plots in addition to the adopted SWC structures. This needs the creation of awareness towards farmers about moisture conservation.

As the average plot area in hectare increases, the adoption of SWC structures increases significantly. Based on the study result households adopted SWC structures more on larger area plots than small area plots. Thus, programs working on SWC should focus on larger area plots as a point of entry to extend the structures to small area plot owners. Rather than leaving a small area plot without SWC structure when even needed, it is recommended to use suitable SWC structures that can take only a small area to construct it.

The increase in the average distance between plots and homestead decreases the adoption of SWC structures. Households' more adopt SWC structures on the nearest plots than too far plots. Since constructing SWC structures on too far plots needs more time, energy, and labor as the structures may need continuous maintenance. Therefore, development planners and implementers should consider the issue while program planning and implementation to realize the required result. Implementing long-lasting SWC practices like plantation on distant plots to reduce the energy, labor, and time cost that can be incurred to maintain the structure frequently is recommended.

According to this study result, the adoption of SWC structures has a statistically significant and positive impact on the households' food security status. Both ATT and ATU were significant implying that those households' who adopted SWC structures are better in food security as compared to their counterfactual and those households' who did not adopt SWC structures will be better off if they could adopt SWC structures. Therefore, more have to be done to motivate adopters to continue adopting SWC structures and to bring non-adopters to adopt SWC structures through extension agents and Medias.

5.3. Further Research Areas

This study was dealing with the impact of SWC structures on households' food security using household level analysis. It will be better if the impact of SWC structures on the productivity of major crops and food security is studied by using plot-level analysis. In addition to this, further research is needed on the impact of different sustainable land management (SLM) practices on different outcome variables like crop productivity, income, and food security.

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7. APPENDICES

Appendix Table 1. Parameter estimates of the impact of soil and water conservation structures on households' dietary diversity score (HDDS).

Variables	Adopter	Non-adopter
SEX	0.2901706	0.1707461
	(0.3219676)	(0 .2176425)
AGE	0.0023136	-0.0161426*
	(0.0115808)	(0 .0087602)
EDUC	0.4161996	-0.1228358
	(0.3290101)	(0.2249545)
HHSIZE	0.0527171	0.014603
	(0.0823664)	(0.0737066)
LIVES	0.0338431	0.1898323 ***
	(0.065366)	(0.0457613)
Farm size	0 .0991448	0.0163872
	(0.1431043)	(0.1041983)
Farm income	0.0000382 **	0.0000326**
	(0.000018)	(0.000015)
NONFARM	3.90e-06	8.27e-06
	(0 .0000423)	(0 .0000163)
CREDIT	-0.0000483 *	-0.0000311*
	(0.0000255)	(0.0000179)
EXTN	0.0162868	0.011061
	(0 .0167587)	(0.0124537)
Market distance	-0.0069025**	-0.0028378
	(0 .0027422)	(0.002009)
Cons	6.634291**	3.165805 ***

	(2.76869)	(0 .6967763)

Number of obs = 546	Log likelihood = -1592.1502
Wald chi2(11) = 54.88	LR test of indep. eqns. : chi2(2) = 6.90**
Prob > chi2 = 0.0000	

Appendix Table 2. Parameter estimates of the impact of soil and water conservation structures on households' food consumption score (FCS).

Variables	**Adopter**	**Non-adopter**
SEX	0.8767877	1.439771
	(1.628744)	(1.729206)
AGE	-0.0003611	-0.1646319**
	(0.0587504)	(0.0691174)
EDUC	1.118633	-0.5989666
	(1.676201)	(1.792253)
HHSIZE	-0.1022337	-0.6142682
	(0.4170713)	(0.4918844)
LIVES	0.0446702	0.1545421
	(0.3323503)	(0.4013636)
Farm size	1.696852**	0.5558512
	(0.7280689)	(0.9334214)
Farm income	6.59e-06	0.0000827
	(0.0000913)	(0.0001069)
NONFARM	0.000051	0.0003211 **
	(0.0002157)	(0.0001298)
CREDIT	-0.0002257*	0.0000262
	(0.0001293)	(0.0001367)
EXTN	0.0524157	0.1742209

	(0.085496)	(0.1059959)
Market distance	-0.0050858	-0.0143221
	(0.0139914)	(0.0162971)
Distance from FTC	-0.0775389*	-0.0874908*
	(0.0467043)	(0.0467712)
Constant	41.89408***	38.96677***
	(5.139294)	(4.93826)
Number of obs = 546	Log likelihood = -2496.4232	
Wald chi2(12) = 21.85	LR test of indep. eqns. : chi2(2) = 4.96*	
Prob > chi2 = 0.0392	Prob > chi2 = 0.0838	

Appendix Table 3. Parameter estimates of the impact of soil and water conservation structures on households' food insecurity experience scale (FIES).

Variables	**Adopter**	**Non-adopter**
SEX	-0.6966907*	-0.3612199
	(0.3898432)	(0.3630607)
AGE	-0.0154849	-0.0039217
	(0.0140609)	(0.0142782)
EDUC	0.4512286	0.236404
	(0.4012332)	(0.3790692)
HHSIZE	-0.0759149	0.1706509
	(0.0998501)	(0.1049997)
LIVES	-0.100817	0.0778696
	(0.0795338)	(0.0834282)
Farm size	-0.3625903**	-0.7038148***
	(0.1742557)	(0.1979994)
Farm income	2.22e-06	-0.000064***

	(0.0000218)	(0.0000226)
NONFARM	-0.0000434	-0.0000517*
	(0.0000517)	(0.0000268)
Amount of credit	-3.75e-06	-1.59e-06
	(0.000031)	(0.0000288)
EXTN	0.0031292	-0.0249446
	(0.0204848)	(0.0222527)
Market distance	0.0000946	0.0046481
	(0.0033637)	(0.0033941)
Distance from FTC	0.0189277*	0.0178583*
	(0.011255	(0.0098103)
Constant	6.173216 ***	5.200165***
	(1.482381)	(1.216656)
Number of obs = 546	Wald chi2(12) = 46.19	
Log likelihood = -1680.8361	Prob > chi2 = 0.0000	

Appendix Table 4. Parameter estimates of the impact of soil and water conservation structures on food security scale (FSS).

Variables	**Adopter**	**Non-adopter**
SEX	-0.4232557*	-0.329357
	(0.217437)	(0.2057023)
AGE	-0.0109509	-0.0016597
	(0.0078325)	(0.0078964)
EDUC	0.1130578	0.0819412
	(0.2234266)	(0.2165541)
HHSIZE	-0.1192185**	-0.0523296
	(0.0555879)	(0.0602973)

LIVES	-0.0379819	0.0247406
	(0.0442658)	(0.0466232)
Farm size	-0.261273***	-0.0419077
	(0.0970261)	(0.108394)
Farm income	-0.0000145	-0.0000386***
	(0.0000122)	(0.0000129)
NONFARM	-7.06e-06	0.0000129
	(0.0000287)	(0.0000145)
Amount of credit	-0.0000218	-0.0000182
	(0.0000173)	(0.0000162)
EXTN	-0.0182833	-0.0110716
	(0.0113892)	(0.0128612)
Market distance	-0.0000396	-0.0021399
	(0.0018534)	(0.0018657)
Distance from FTC	0.0010926	0.0135433**
	(0.006203)	(0.0058384)
Constant	4.260891***	5.54877***
	(0.6235373)	(0.6051347)

Number of obs = 546 Wald chi2(12) = 23.10

Log likelihood = -1380.0217 Prob > chi2 = 0.0269

LR test of indep. eqns. : chi2(2) = 15.21***

Note: ***, **, * are significant at 1%, 5% and 10% level respectively; Standard errors are given in the parenthesis.

Appendix Table 5. Scale value and food security category for household dietary diversity score (HDDS).

scale value	Codes	Food security category
≤ 3	1	Low
4-5	2	Medium
≥6	3	High

Source: FAO (2010).

Appendix Table 6. Scale value and food security category for food consumption score (FCS).

Scale value	Code	Food security category
0-21	1	Poor
21.5-35	2	Borderline
>35	3	Acceptable

Source: WFP (2008)

Appendix Table 7. Scale Values and Food Status Categories for the food security scale.

Households with Children			Households without Children		
Number of Affirmative Responses (Out of 18)	Scale Value	Food Security Status Category	Number of Affirmative Responses (Out of 10)	Scale Value	Food Security Status Category
0	0.0	0	0	0.0	0

1	0.7	0	1	0.9	0
2	1.6	0	2	2.0	0
3	2.3	1	3	2.8	1
4	2.8	1	4	3.6	1
5	3.3	1	5	4.3	1
6	3.8	1	6	5.0	2
7	4.3	1	7	5.7	2
8	4.7	2	8	6.5	2
9	5.2	2	9	7.5	3
10	5.6	2	10	8.2	3
11	6.0	2			
12	6.4	2			
13	6.8	3			
14	7.3	3			
15	7.8	3			
16	8.4	3			
17	9.2	3			
18	10.0	3			

Source: Bickel *et al*. (2000)

Appendix Table 8. Correspondence between Scale Values and Food Security Status (FSS).

Scale Value	Code	Food security category
0.0 to 2.2	0	Food secure
2.3 to 4.6	1	Food insecure without hunger

4.7 to 6.7	2	Food insecure with moderate hunger
6.8 to 10.0	3	Food insecure with severe hunger

Source: Bickel *et al*. (2000)

Appendix Table 9. Correspondence between Scale Values and Food insecurity experience scale (FIES).

Scale value	Code	Food security category
0-3	1	Food secured
4-6	2	Moderate food insecure
7-8	3	Severe food insecure

Source: Wambogo *et al*. (2018)

Appendix Table 10. Conversion factors used to calculate Tropical Livestock Units (TLU).

Animals	TLU-equivalent
Calf	0.25
Heifer and Bull	0.75
Cows and Oxen	1.00
Donkey young	0.35
Donkey adult	0.70
Sheep and Goat	0.13
Mule	1.00

Source: Ghirotti (1993)

Test of econometric problems

Heteroscedasticity test (estat hettest)

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Ho: Constant variance

Variables: fitted values of adoption

chi2 (1) = 0.74

Prob > chi2 = 0.3885

Omitted variable test (ovtest)

Ramsey RESET test using powers of the fitted values of adoption

Ho: model has no omitted variables

F(3, 529) = 0.21

Prob > F = 0.8867

STRUCTURAL SURVEY QUESTIONNAIRE

Survey on the impact of adopting soil and water conservation on households' food security in East and West Belesa *Woreda*s, Ethiopia

General Identification information

Start time ………………

Date of data collection…………

Name of the enumerator………..

Welcome, my name is…….. we are conducting a baseline survey on farm households located in West and East Belesa *Woredas*. Utilize the outcome from this survey will for care project implementation. The information given to us is fully confidential.

Respondent's identification code….

Research site: *Woreda* --------------------------, *Kebele* ---

Name of the respondent:--, Mobile Number ---------------

Background information of the households

Sex of the respondent: 1) Male 2) Female

Age of the respondent: --.

Marital status: 1) Married 2) Single 3) Widowed 4) Divorced

The educational level of the household head: 1) Literate 0) Illiterate;

if literate the formal education in grade: ------

The total number of household members? Male--------Female----------Total------

How many of the total household members are under age 10? Male…….. female…….

How many of the total household members are between the age of 10-13? Male… Female……

How many of the total household members are between the age of 14-16? Male… female…….

How many of the total household members are between the age of 17-50? Male….. female…..

How many of the total household members are above the age of 50? Male….. female……

1. What is the major occupation of the household head:

1. Farming (crop, livestock, etc.)
2. Seedling business (production and selling)
3. Petty trade (kiosk, retailing during market days)
4. Handicrafts
5. Selling of local beverages (tela, arekie, tea, etc.)
6. Building construction (carpenter, plasterer, etc)
7. Guard
8. Daily laborer
9. Religious leader
10. Student
11. No occupation
12. Other (specify)

The number of years a household head is working on farming?

2. Land ownership and distribution

No	Types of land	Own land (Timad)	Rented in land (Timad)	Rented out land (Timad)	Shared in land (Timad)	Shared out (Timad)
1	Cultivated land(farmland)					
2	Fallow land					
3	Grazing land					
4	Forest land					
5	Others					
6	Total					

3. Livestock holding of the household and income

No	Type of livestock	Number of livestock owned	Number of livestock sold over the last 12 months	Income earned from sold (Birr)
1	Oxen			
2	Cow			
3	Bulls			

4	Calve			
5	Heifer			
6	Horse			
7	Mule			
8	Donkey			
9	Goat			
10	Sheep			
11	Chicken			

How much income did you get from the sales of livestock products (egg, milk, butter, and cheese) in the past 12 months in Birr?

How much income did you get from the sale of crops in the past 12 months in Birr?

How much income did you get from the sales of vegetables and fruits in the past 12 months in Birr?

How much income did you get from the sale of eucalyptus in the past 12 months in Birr?

How much income did you get from the sale of chat in the past 12 months in Birr?

How much income did you get from the sale of honey and other products in the past 12 months in Birr?

4. Non-farm and off-farm activities

Did you engage in non-farm and off-farm income-generating activities? Yes/No

If yes, in which activity did you engaged?

1. Petty trade 2. Daily labor 3. Fore wood collection 4. Handicrafts 5. Weaving 6. Remittance income 7. Grain trading 8. Livestock trading 9. Tannery 10. Pottery 11. Animal drawn cart 12. Other, specify

How much money did you earn from the activity per year in Birr?

5. Credit access and utilization

Is it possible for you to get credit in case you need it? Yes/No

Did you take credit during the last 12 months? Yes/No

If yes to the above question, how much did you take?

Where did you get the credit in the past 12 months?

1. ACSI 2. Banks 3. Cooperative 4. Local lender 5. Friends 6. Family 7. Other, specify

What was the purpose of the credit you took?

6. Access to infrastructures and extension services

Do you have access to information from extension agents?

The average frequency of extension contact per year?

Do you have access to information from farmers' cooperatives? Yes/no

Do you have a radio? Yes/no

If yes to the above question, have you followed radio programs related to soil and water conservation? Yes/no

Have you participated in soil and water conservation training in the past 12 months? Yes/no

If yes, the average frequency of SWC training per year?

How far is your home from the market where output is sold in minutes of walking?

How far is your home from the agricultural extension office in minutes of walking?

How far is your home from the farmers' cooperative in minutes of walking?

How far is your home from the farmers' training center in minutes of walking?

7. Perception of farmers

Did you perceive the risk of soil erosion? Yes/no

Do you think that soil and water conservation is important? Yes/no

8. Description of farm plots and plot-level questions

How many agricultural plots do you hold?_______________ Plots

How would you characterize the plots as at 2011/12 season

Far m and	Plot number

	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	15	16
Plot ownership																	
Area of the plot (Timad)																	
Distance From hom estead (minutes)																	
The slope of the plot																	
The location from the watershed																	
Type SWC																	
The age of SWC measure(yr s.)																	
Who constructe d the structure																	
Frequency of mainten ance of the																	

structure per year																		

Codes:

Plot ownership: 1= owned, 2= rented in, 3= rented out, 4= sharecropped in, 5= sharecropped out

Farmers perceived slope of the plot: 1.flat 2. Gentle slope 3. Steep slope

Location of the plot from the nearest watershed: 1=high 2=medium 3=low

Soil and water conservation method on the plot: 0. none, 1. Terraces, 2. Grass strips, 3. Trees on boundaries, 4. Soil bunds, 5. Stone bunds, 6. Diversion ditch 7. Waterway 8. Stone-faced soil bund 9. Trench 10. Other (specify) ____

9. FOOD SECURITY QUESTIONS

A. Household Dietary Diversity Score (HDDS)

No.	12 Food groups	Did you or any member of the family consumed any food made from/with…?	Over the last 24 hours 1. Yes 2. No	Over the last 7 days 1. Yes 2. No
1.	Cereals	Teff, barley, wheat, maize, sorghum, finger millet, oats (Aja'), rice,		
2.	Roots and tubers	Beetroot, carrot, onion, potato, sweet potato, garlic, taro (godere)		
3.	Vegetables	Lettuce, head cabbage, Ethiopian cabbage, tomatoes, green peppers, swiss chard		
4.	Fruits	Avocado, banana, guava, lemon, mango, orange, papaya, pineapple		
5.	Meat and poultry	Beef, lamb, goat, poultry, or any other organ meat		
6.	Egg	Egg		
7.	Fish and seafood	Fish		
8.	Pulse, legume, nuts	Faba bean, field pea, haricot bean, chick-pea, lentils, grass pea, soya bean, fenugreek, mung bean		
9.	Milk and milk products	Cheese, yogurt, milk, and other milk products		
10.	Oil/fats	Oil, fat, or butter		

11.	Sugar/honey	Sugar, honey		
12.	Miscellaneous	Any other foods like condiment (e.g. spice, salt), coffee, tea, chat, ...etc		

B. Household food consumption questionnaire

Ask whether any of the household members consumed the following food items of each group and go for the number of days they consumed, please put 7 if the sum of the frequency of the food items consumed is more than 7.

NO	Food Groups	Food items	How many days in the past one week your household ate							
1	Main staples	Any foods from wheat, barley, maize, rice, sorghum, teff, millet, pasta, and other cereals?	0	1	2	3	4	5	6	7
2	Pulses	Any foods of Beans, Peas, soybean, groundnuts, lentils haricot beans, and others?								
3	Vegetables	Any foods of Vegetable leaves and others?								
4	Fruits	Any Fruits? (Apple, mango, papaya, avocado, wild fruits, and others)								
5	Meat and fish	Any Beef, goat, sheep, poultry, eggs, and fish?								
6	Milk and milk products	Any Milk, yogurt, and another diary								
7	Sugar	Any sugar and sugar products, honey?								
8	Oil	Any oils, fats, and butter?								
9	Condiments	Spices, tea, coffee, salt, fish powder, small amounts of milk for tea.								

C. Household food security scale

For the following food security/insecurity questions, please put the appropriate responses in the code column. If the response to Q1 is the option “1 or 2” and “never true” for Q2-Q6, questions Q7-Q16 will be omitted. And the second level screening: If it is not screened previously and their response to Q7 is “never” true and “No” for Q8 to Q11, Questions Q12-Q16 will be omitted.

No	Questions	Response options	Code
1	Which of these statements best describes the food eaten in your household in the last 12 months?	1. we always have enough to eat and the kinds of food we want 2. we have enough to eat but not always the kinds of food we want 3. Sometimes we don't have enough to eat 4. Often we do not have enough to eat.	
1.1	If sometimes or often not enough to eat, please tell me a reason why you do not always have enough to eat?	1. Not enough money for food 2. Too hard to get to the store 3. No working stove available 4. Not able to cook or eat because of health problems	
1.2	If enough food, but not the kind we want, please tell me a reason why you do not always have the kinds of food you want or need?	1. Not enough money for food 2. Too hard to get to the store 3. On a diet 4. Kinds of food we want not available 5. Good quality food not available	
2	In the past 12 months, did you or any of the HH member would run out of food before you get money to buy more, how often did this happen?	1. Often (>6 months) 2. Sometimes (3-5 months) 3. Never true	
3	In the past 12 months, did you or any of your HH member food just did not eat last, and you did not have money to get more, how often did this happen?	4. Often (>6 months) 5. Sometimes (3-5 months) 1. Never true	
4	In the past 12 months, did you or any of the HH member could not afford to eat a	6. Often (>6 months) 7. Sometimes (3-5 months) 1. Never true	

	balanced meal, how often did this happen?		
5	In the past 12 months, did you relied on only a few kinds of low-cost food to feed the children because of a shortage of money to buy food, how often did this happen?	8. Often (>6 months) 9. Sometimes (3-5 months) 1. Never true	
6	In the past 12 months, did you feed children unbalanced meal because you could not afford the balanced meal, how often did this happen?	10. Often (>6 months) 11. Sometimes (3-5 months) 1. Never true	
7	In the past 12 months, did your children could not eat enough food, because you just could not afford enough food, how often did this happen?	12. Often (>6 months) 13. Sometimes (3-5 months) 1. Never true	
8	In the last 12 months, did you or other adults in your household ever cut the size of your meals or skip meals because there was not enough money for food?	0= No (skip Q9) 1= Yes	
8.1	If yes, to Q. 8, how often did this happen?	1. Almost every month 2. Some months but not every month 3. In only one or two Months	
9	In the last 12 months, did you ever eat less than you felt you should because there was not enough money to buy food?	1= yes 0= No	
10	In the last 12 months, were you ever hungry but did not eat because you could not afford enough food?	1= yes 0= No	

11	In the last 12 months, did you lose weight because there was not enough food?	1= yes 0= No	
12	In the last 12 months, did you or other adults in your household ever not eat for a whole day because there was not enough money for food?	1=yes 0=No (skip Q13)	
12.1	If yes, to Q. 12, How often did this happen?	1. Almost every month 2. Some months but not every month 3. In only one or two months	
13	In the last 12 months, did you ever cut the size of any of the children's meals because there was not enough money for food?	0= No 1= Yes	
14	In the last 12 months, did any of the children ever skip meals because there was not enough money for food?	0=No (skip Q15) 1= No	
14.1	If yes, to Q. 14, How often did this happen?	1. Almost every month 2. Some months but not every month 3. In only one or two months?	
15	In the last 12 months, were the children ever hungry but you just could not afford more food?	0= No 1= Yes	
16	In the last 12 months, did any of the children ever not eat for a whole day because there was not enough money for food?	0= No 1= Yes	

D. Food insecurity experience scale questions

All the questions below should be asked for the last 12 months (start like during the last 12 months…..).

No	Questions	Yes	No
1	Was there a time when you were worried you would run out of food because of a lack of money or other resources?		
2	Was there a time when you were unable to eat healthy and nutritious food because of a lack of money or other resources?		

3	Was there a time when you ate only a few kinds of foods because of a lack of money or other resources?		
4	Was there a time when you had to skip a meal because there was not enough money or other resources to get food?		
5	Was there a time when you ate less than you thought you should because of a lack of money or other resources?		
6	Was there a time when your household run out of food because of a lack of money or other resources?		
7	Was there a time when you were hungry but did not eat because there was not enough money or other resources for food?		
8	Was there a time when you went without eating for a whole day because of a lack of money or other resources?		

BIOGRAPHICAL SKETCH

I was born in Bahir Dar Zuria *Woreda* of Amhara region on August 13, 1988, E.C. I attended my elementary school education at Alhuay primary school. Then I attended my secondary and preparatory education at Merawi secondary and preparatory school. After completing my preparatory education, I joined Bahir Dar University College of Agriculture and Environmental Science in 2007 E.C. After a one-year stay in Bahir Dar University, I was selected by Arava International center for agricultural training (AICAT) to participate in an internship in Israel. I got both practical and theoretical training during my stay in Israel about their agriculture especially drip irrigation and I got an international diploma in General Agriculture. After I finished my stay in Israel, I come back and continue my study in 2009 E.C. I got my Bachelor of Science (BSC) degree in Agricultural Economics with great distinction in 2010 E.C and I started studying for MSc. degree in 2011 E.C in Agricultural Economics.