ADOPTION AND IMPACT OF SOIL AND WATER CONSERVATION ON CURRENT FOOD INSECURITY AND VULNERABILITY OF FARMING HOUSEHOLDS IN EASTERN ETHIOPIA

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EXTENDED ABSTRACT

Understanding the livelihoods related impacts of soil and water conservation and decision behaviours of smallholder farmers would be a significant step toward improving environmental conditions, while ensuring sustainable and increased agricultural production. Hence, the objectives of this study include: analysis of households' food insecurity and vulnerability to food insecurity and its influencing factors; assessment of factors affecting choice decision of soil and water conservation structure, and evaluation of impact of soil and water conservation adoption on food insecurity and related vulnerability outcomes of farming households. A multi-stage stratified sampling procedure was used to identify a sample of 408 sample households (200 adopters and 208 non-adopters) and also 790 plot-level observations from three districts in eastern Ethiopia. The study used both primary and secondary data. To address the research objectives, the study used descriptive statistics and various econometric models. The logit model results show that food insecurity of farm households was significantly influenced by age of household head, family size in adult equivalent, use of irrigation, adoption of soil and water conservation, and coping strategies. The Three-step Feasible Generalized Least Squares estimation results indicate that age of household head and family size were found to have a negative and significant influence on expected food consumption expenditure. Furthermore, using improved seed, total cultivated land, using soil and water conservation, received credit were significant predictors with positive influence on expected food consumption expenditure. Based on the intensity of their vulnerability, households were grouped as chronic food insecure (24.27 %), transient food insecure (11.77 %), highly vulnerable-food secure (18.38 %), and low vulnerable-food secure (45.59 %). Moreover, the study indicated that 54.01 % of households are vulnerable to food insecurity, which is by higher than the current incidence of food insecurity (36.02 %). The multivariate probit estimation results indicated that out of hypothesized explanatory variables education level, family size income, contact with development agent and erosion problem, livestock ownership, age and sex of household head, number of plots, off-farm activity and received credit were significant factors for farm-level adoption of stone bund, soil bund and bench terracing conservation technologies. Endogenous switching regressions and propensity score matching result indicated that, adoption of soil and water conservation not only positively impacts the per capita food consumption expenditure and net crop value, but also significantly reduced the probability of farmers being food insecure, vulnerability to food insecurity, as well as being transient and chronically food insecure.

DECLARATION

I, Million Sileshi Haile, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted to any other institution.

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DEDICATION

This dissertation is dedicated to my father Sileshi Haile and my mother Birknesh Ayele for nursing me with affection and love and for their dedicated partnership in the success of my life.

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LIST OF ABBREVIATIONS AND ACRONYMS

AE	Adult Equivalent
ATT	Average Treatment effect on the Treated
ATU	Average Treatment effect on the Untreated
CBPWDP	Community Based Participatory Watershed Development Programme
CPI	Consumer Price Index
CSA	Central Statistical Authority
EHZAO	East Hararghe Zone Agricultural Office
EPRDF	Ethiopian People Republic Democratic Front
ESR	Endogenous Switching Regression
FGLS	Feasible General Least Squares
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ISWCP	Integrated Soil and Water Conservation Programme
KBM	Kernel Based Matching
MVP	Multivariate Probit
NNM	Nearest Neighbor Matching
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PCFCE	Per Capital Food Consumption Expenditure
PSM	Propensity Score Matching
RCM	Radius Caliper Matching
SDPRP	Sustainable Development and Poverty Reduction Programme
SWC	Soil and Water Conservation
VEP	Vulnerability as Expected Poverty

VER	Vulnerability as uninsured Exposure to Risk
VEU	Vulnerability as low Expected Utility
VFI	Vulnerability to Food insecurity
VIF	Variance Inflation Factor

CHAPTER ONE

1.0 Introduction

1.1 Background of the Study

Ethiopia is one of the highest performing economies in sub-Saharan Africa with the double digit economic growth since 2005. However, the country ranks 174 out of 188 countries in the 2015 United Nations Human Development Index, and 104 out of 119 in the Global Hunger Index (IFPRI, 2017). According to IFPRI (2015), about 40 % of the population consumes less than the recommended daily calories. The rate of rural poverty is also high with 26% of rural households living below the poverty line of 1.90 USD per day per capita (UNDP, 2018). In this regard, vulnerability to food insecurity and poverty remains a serious problem despite the level of economic growth.

The past trends show limited progress in combating poverty and food insecurity in Ethiopia. Poverty and vulnerability to food insecurity in the country have been increasing at sometimes but declining at other times (Abbi and McKay, 2003; World Bank 2005; Brown and Amdissa, 2007; Gelaw, 2010; Gelaw and Sileshi, 2013). Vulnerability to poverty and food insecurity is high among other reasons due to: natural disaster, erratic rainfall, unstable and hiking food prices, and land degradation (Dercon and Krishnan, 1998; Dercon and Christiaensen, 2007). Land degradation for example, has had significant implication on household poverty and food insecurity (Shibru and Kfle, 1998; Demel, 2001; Paulos, 2001; Berry *et al*., 2003; Shibru, 2010).

As Greenland and Nabhan (2001) reports, land degradation in Ethiopia accounts for eight percent of the global land degradation. This is much more severe in the Ethiopian highlands where 85% of the population lives in rural areas with 90% of these rural populations depending on agriculture as the main means of livelihood (Shibru, 2010). In this respect, more than 2 million hectares of Ethiopia's highlands have been degraded, and hence making it difficult to mitigate soil erosion (World Bank, 2006) and conserve soil-water. This leads to a loss in cereal production averaging 1.2-1.5 tons per hectare in most of the highlands (valued in monetary terms at 76.60 million USD in 2005) (Yenealem *et al.,* 2013). As a result of extensive land degradation, natural resource base deteriorates with time, and this has directly caused food insecurity and vulnerability (Barrett *et al.*, 2002; Gebremedin *et al.,* 2010).

In promoting soil and water conservation (SWC) practices, the Central Government, regional government, donors, and development partners have invested substantially in sustainable use of natural resources with the aim of increasing agricultural production and reducing food insecurity and vulnerability (Kassie *et al.*, 2008). Nevertheless, in the efforts of addressing these problems, the basic paradigm, and approach to SWC have evolved over time (Kerr *et al.*, 2007). Using a national guideline known as Community Based Participatory Watershed Development (CBPWD), the Ethiopian government has transformed its land management policy to a more holistic and landscape-wide approach that goes beyond resource conservation (Shiferaw *et al.*, 2009). In recent years, the overall objective of this approach has been to improve the livelihood of farming households in rural Ethiopia through comprehensive and integrated natural resource development. In this regard, Ethiopia has been implementing different SWC programmes throughout the country.

On the basis of the mentioned above initiatives, it was deemed useful to assess the livelihoods related impacts of these programmes and decision behaviours of smallholder farmers in order to establish lessons learnt for further improvement of the interventions.

This study, therefore, was set to assess farm households' vulnerability to food insecurity among SWC adopters and non-adopters using vulnerability as expected poverty approach. The study accordingly, measured effectiveness and sustainability of the intervention(s) as a basis for further improvement and scaling-up the interventions.

1.2 Statement of the Problem and Justification

The agricultural sector in Ethiopian is largely rain-fed and thereby it is highly vulnerable to the vagaries of weather. Food insecurity in the country is a long-term phenomenon caused by a combination of both natural and man-made factors such as lack of alternative non-farm income, unreliable rainfall pattern, land degradation, lack of access to infrastructure, and modern agricultural inputs and limited access to credits (Wisner *et al*., 2004). In addition, despite substantial efforts by the Ethiopian government and its development partners in reducing food insecurity in the country, both chronic and transitory food insecurity problems persist at the household level (FAO/WFP, 2010).

Land and water degradation in particular have had a significant effect on household food insecurity and poverty status. Empirical evidences show that the aggregate impacts of land and water degradation on food security are generally negative (Shibru and Kfle, 1998; Demel, 2001; Paulos, 2001; Berry, 2003; Shibru, 2010).

Ethiopia loses about 42 tons per ha of topsoil every year (Pender *et al.*, 2001) and the amount of grain lost due to land degradation alone can feed more than 4 million people (Demel, 2001). The available evidence (Berry, 2003; Paulos, 2001) shows that every year, the country loses billions of Birr in the form of soil, nutrient, water, and agro-biodiversity. According to Gebregziabher *et al*. (2016), the annual costs of land degradation related to soil erosion and nutrients loss from agricultural and grazing lands were estimated at about

USD 162 million (about 3% of agricultural GDP) in 2007. Moreover, land and water degradation reduces agricultural productivity and cause food insecurity and poverty to the rural people (Shibru, 2010).

In recognition of these problems, since the Ethiopian People Republic Democratic Front (EPRDF) came to power in 1991, SWC has been a part of the agriculture extension package. Since the beginning of the 2000s, under the SDPRP (Sustainable Development and Poverty Reduction Programme) a framework launched in 2002 and the PASDEP (Plan for Accelerated and Sustained Development to End Poverty) which was launched in 2005, participatory watershed management is recognized by the government. Given this strategy, different sustainable land management programmes have been implemented throughout the country. Further, the country also developed a national guideline known as Community Based Participatory Watershed Development Programme (CBPWDP) in 2005 (MoARD, 2005). Additionally, the integrated SWC implements different conservation technologies (such as Bench terracing, Soil bund, Stone bund, farm forestry, and so on) in selected areas since 2006. The main goal of this approach is to improve the living standards and welfare of the most vulnerable rural households and communities through SWC practices on individual farm plots and communal land, rainwater harvesting, promoting sustainable agricultural practices, and income diversifying agricultural practices.

Notwithstanding all these efforts by the central government, regional government, donors, and development partners, land degradation has remained a serious problem whereas SWC conservation practices remain underutilized (Asfaw and Wolka *et al.*, 2018; Neka, 2017; Kassie *et al.*, 2010; Bekele, 2003).

Thus for a long time, many efforts have been made in implementing the programme in different districts, except for some biophysical data of the conserved land, food insecurity and vulnerability impacts of the interventions have not been well studied. To make an intervention effective in reducing food insecurity, policies should also focus on both current and future food insecurity of rural households'. In terms of agricultural research for development, many studies on food security policy and programme done in Ethiopia have targeted on identifying the current state of food security in terms of who is food insecure and why (e.g. Agidew and Singh, 2018; Jaleta *et al.*,2018; Di Falco *et al.*, 2011; Bogale and Shimelis, 2009). These studies have not gone beyond and attempt to determine who are likely to be vulnerable to food insecurity in the future.

Therefore, this study attempted to fill information and policy gaps and identified lessons learnt for further improvement of the intervention. Thus, the study aimed at generating empirical evidence on the impacts of SWC programme on food insecurity and vulnerability of farming households in Eastern Ethiopia. The results from this study will inform policy makers and development planners in designing effective and sustainable conservation strategies of agricultural land and water resources. The results can also be disseminated to farmers through the extension system to inform decisions on management of land and water resources at the farm-level. Moreover, the findings of this study can be used as baseline information for further similar research or new project interventions.

1.3Study Objectives

1.3.1 Overall objective

The overall objective of this study was to assess the adoption and impact of SWC on the current food insecurity and vulnerability of farming households in Eastern Ethiopia.

1.3.2 Specific objectives

a) To determine the factors affecting household's food insecurity and vulnerability to food insecurity;

b) To determine the factors influencing household's choices of different SWC measures; and

c) To evaluate the impact of SWC adoption on food insecurity and vulnerability among farming households in eastern Ethiopia.

1.4 Hypotheses of the Study

a) The socio-economic and institutional factors have no significant effect on household's food insecurity and vulnerability to food insecurity;

b) The socio-economic, institutional factors and plot characteristics have no significant effect on household choice of SWC measures; and

c) Adoption of SWC has not significantly reduced household's food insecurity and vulnerability to food insecurity in eastern Ethiopia.

1.5 Scope and Limitations of the Study

The study was carried out in three districts of the East Hararghe Administrative Zone namely: Gurugutu, Deder, and Haramaya Districts in Eastern Ethiopia. Soil and water conservation has other on-site and off-site effects, the main aim of the study, however, was to assess the adoption and impact of SWC on current food insecurity and future food insecurity (vulnerability to food insecurity) of farming household.

The study used cross-sectional data, as it was not possible to use other methods such as longitudinal and panel data due to limitation of time, resources and complex research logistics. The impact assessment design for this study lacked the baseline information and the use of control groups would therefore serve as an ideal approach. Impact assessment design flaw is addressed through the econometric approach. Nevertheless, the cross-sectional data collected at one point in time are credibly able to assess adoption and impact of SWC on current food insecurity and vulnerability of farming households.

1.6 Conceptual Framework

The following conceptual framework in Fig 1.1 was constructed based on the empirical research reviewed, understanding from cases related to land degradation, adaptation and mitigation strategies and its impact on livelihood outcomes including household welfare, food security and vulnerability to food security. It is vital to understand the interaction between government policy, livelihood assets, and household investment strategies on SWC conservation and its effect on current and future food security. This understanding would help the evaluation of government policies and strategies particularly for sustainable SWC and associated investments. Furthermore, smallholder farmers attempt to maximize their livelihood benefits based on the existing resources, assets, and the expected shocks that jointly determine the vulnerability situation. These decisions are also conditioned and mediated by the prevailing socio-economic and policy environment, including sub-national and sub-sectoral policy changes and responses to shifts in global and macro policies, transmitted to the local level through policy reforms, institutional changes, and infrastructural investments. These in turn determine the relative input-output prices and access to new technologies and markets at the local level. In some situations, households, the community, and government response to SWC policy may further enhance and supplement individual decision on SWC investment (Shiferaw and Bantilan, 2004).

In addition, the diversity of household assets and the prevailing biophysical and socio-economic environment therefore, jointly determine the SWC strategies available to farmers.

Government policies related to SWC, community response, access to markets, and institutional arrangements create incentives to adopt SWC; it could be improving livelihood opportunities through sustainable use of the natural resource base. Again, positive or negative outcome of the adoption of SWC that may in turn enhance livelihood assets, which are available for production, consumption, and investment decisions in the future.

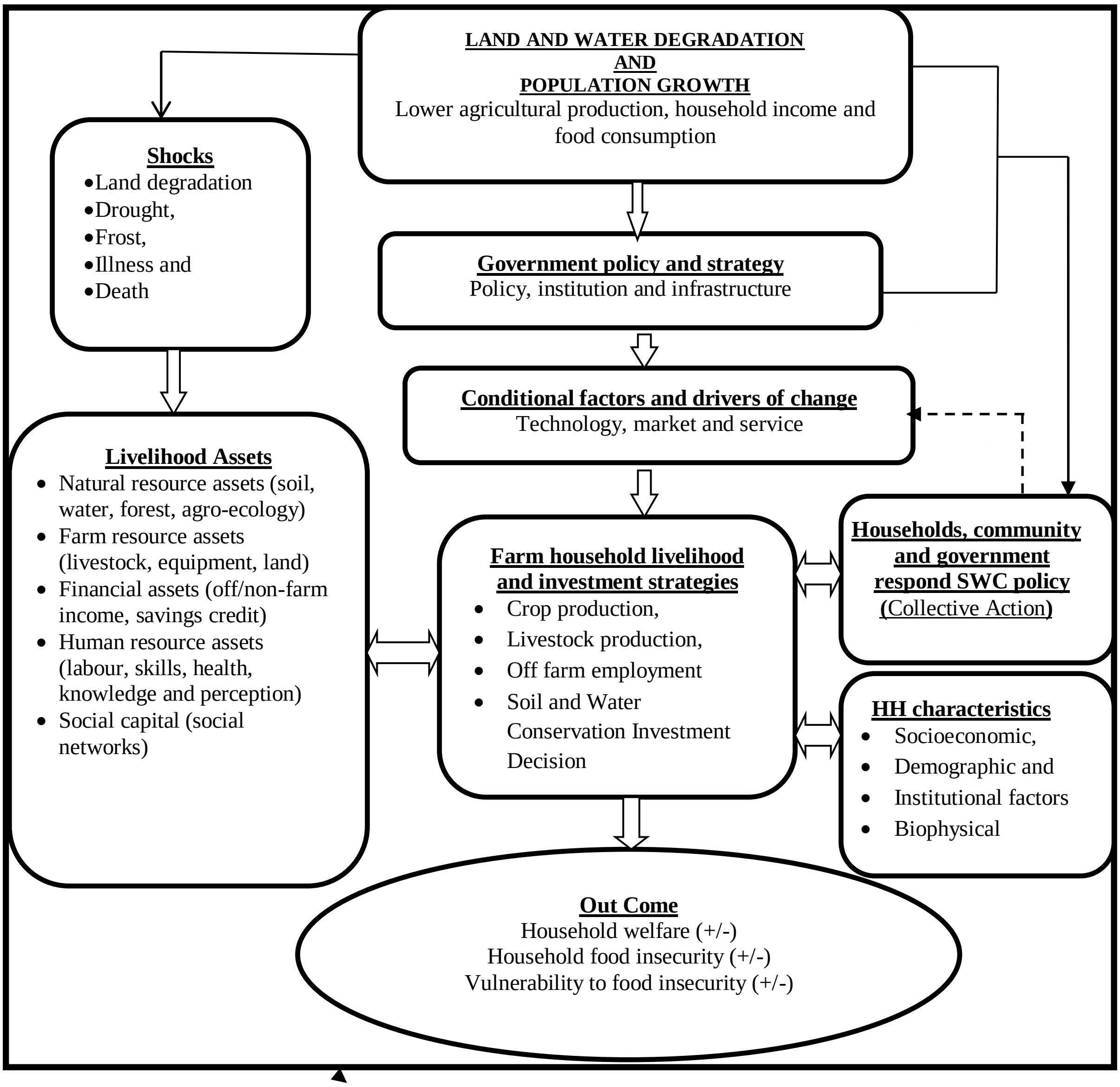

Figure 1.1: Conceptual framework

Source: Conceptual idea adopted from Bekele *et al.* (2009)

1.7 Theoretical Framework

The study adopted the expected utility maximization theory for farmer decision of choosing SWC. The expected utility model describes a decision of making choice whereby an individual has a set of alternative SWC strategies from among a set of discrete measures (Maurice *et al.,* 2014; Kassie *et al.,* 2009; Bekele and Drake, 2003). Mathematically the theory can be presented as follows: the i^{th} individual's decision may, therefore, be modelled as maximizing the expected utility from a given plot by choosing the j^{th} measure from any other alternative measures, including business as usual (i.e. not adopting any measure), i.e.

$$Max_j E(U_{ij}) = f_j(X_i) + \varepsilon_{ij}, \qquad j = 0, \dots, J \qquad (1)$$

Where, $E(U_{ij})$ is the expected utility of alternative *j* to the i^{th} farm household, and f_j is a function of X_i ($X_{i1} \dots X_{in}$), a (*1xn*) is a vector of attributes of the plot, households and farm characteristics that potentially affect the adoption of a given SWC measure. A farmer only chooses alternative *j* from among *J* alternatives is equal to the probability that the expected utility from alternative *j* is greater than the expected utility from any other alternative, i.e.

$$\Pr(C = j) = P[E(Uj) - E(Uk) > 0] \quad \text{or} \quad P[E(Uj)] > P[E(Uk)] \qquad (2)$$

Where C denoted the choice

1.8 Description of the Study Area

1.8.1 Location and physical features

East Hararghe Zone is one of the 18 Zones in Oromia National Regional State. It has a total land area of 2 424 766 hectares (PEDO, 2012).The geographical location of the Zone lies between $7^0 32'$- $9^0 44'$ North latitude and $41^0 10'$- $43^0 16'$ East longitudes (Fig. 1.2). The Zone is located in the Eastern part of Ethiopia, sharing borders with Bale Zone in the south, West Hararghe Zone in the west, Dire Dawa Administration in the north and Somali Regional State in the east and south-east. The capital city of the Zone is Harar, which is located at a distance of 526 kilometres from Addis Ababa.

East Hararghe Zone is characterized by rugged, dissected mountains, deep valley, plateaus, and plains, which are categorized into plateau, lowland and transitional slope with altitude ranging from 500 to 3405 meters above the sea level (PEDO, 2012).

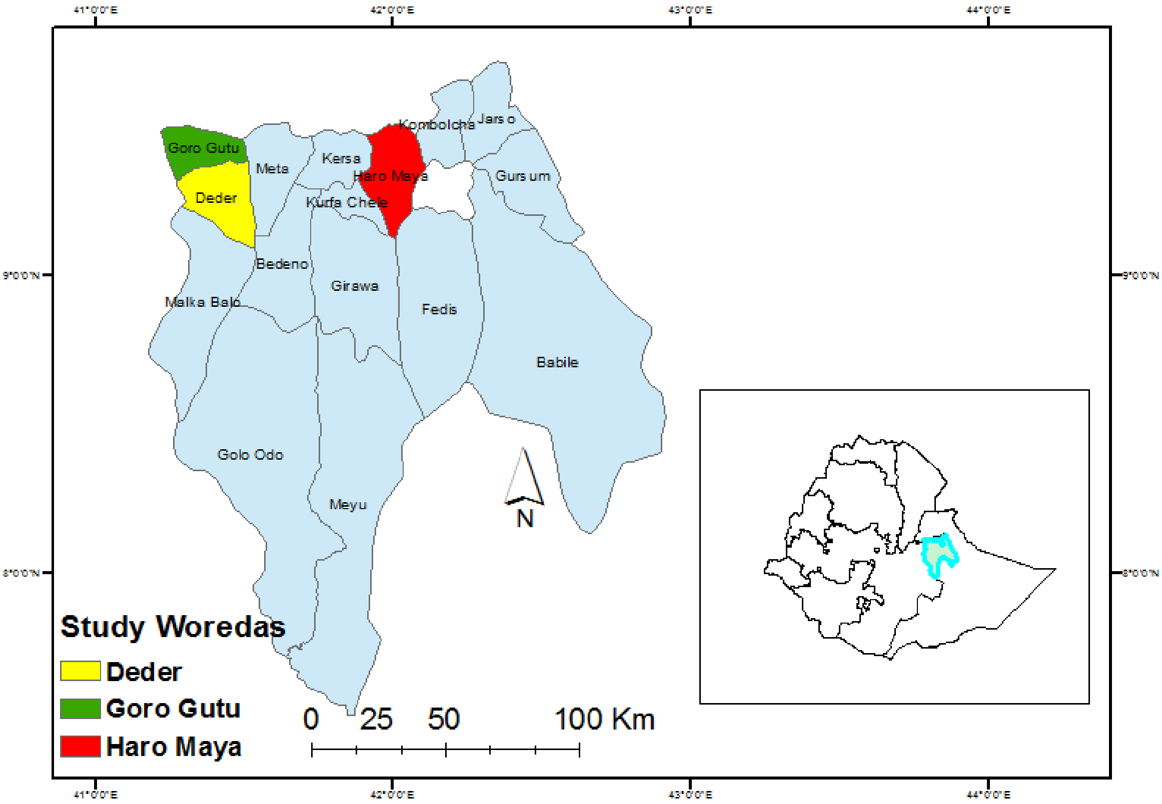

Figure 1.2: **Physical map of Ethiopia and East Hararghe Zone**

1.8.2 Population

As projected in 2013, East Hararghe Zone has a total population of 3 369 639 among these 50.6 % are males and 49.4 % are females. The population density was 139 people per km^2 in 2015. About 90.5 % of the total population of the Zone were of rural inhabitants and 9.5 % being urban dwellers (CSA, 2013). The three largest ethnic groups in the Zone are Oromo (96.43 %), Amhara (2.3 %), and Somali (1.8 %) while the other ethnic groups make up 0.3 % of the total population. About 95 % of the inhabitants are Muslims, and 5 % are Christians (CSA, 2007).

1.8.3 Agro-climatic Zone

According to the East Hararghe Zone's Agriculture and Rural Development Offices (EHZARD, 2012), the zone is characterized by three agro-ecological zones: the semi-arid, semi-temperate, and temperate tropical highlands.

The temperate tropical highlands, known as *dega* constitute 11.4 % of the total area of the zone. The temperate tropical highlands (*dega*) are located at 2 300-3 500 meters above sea level with annual rainfall ranging from 1 200 to 2 000 mm and an average temperature of 10°C to 15°C. This region occupies the western and central highlands of the zone covering a total area of 2 589.14 km^2. The semi-temperate (tropical rainy midlands) part or *woinadega* accounts for 26.4 % of the total area of East Hararghe. This agro-ecological zone is found in the western and central highlands with altitudes ranging from 1 500 to 2300 meters above sea level. The zone has annual rainfall ranging from 600 to 2 000 mm and the mean annual temperature ranging from 15°C to 20°C. The semi-arid (tropical dry or arid) or *kola* comprises 62.2 % of the total area of the East Hararghe. This is characterized by altitudes ranging from 500-1 500 meters above sea level, with an annual rainfall ranging from 400 to 820 mm and the mean annual temperature of 20°C to 25°C. This region is found in the south eastern and northern parts of East Hararghe sharing borders with Somali National Regional State, Bale Zone, and Dire Dawa Administration.

1.8.4 Farming system

The farming system of the East Hararghe zone of Ethiopia constitutes complex production units involving a diversity of interdependent mixed cropping and livestock activities. The cash crops predominantly produced are *khat*[1](*Catha edulis*), coffee, potatoes, onions/shallots, and vegetables. The main staples are sorghum, maize, and sweet potato.

[1]*"This is a shrub, which is grown for its narcotic substances, cathine and cathinone. These are found in the tips of young leaves and are released when they are chewed." (Bogale, 2012)*

The major annual crops grown in the zone are sorghum, maize, groundnuts, potato, wheat, haricot beans, and barley (CSA, 2008). Cereal production in the zone is mostly for home consumption. Only about 5.2 % of the produce in East Hararghe, were sold in 2008 (CSA, 2009). Livestock keeping is also an integral activity of farmers in the study areas and stubble grazing provides most of the animal feed.

Since the majority of the people in the Zone live in rural areas, most of the land is used for agricultural production. According to data from the East Hararghe Zone Agricultural Office (EHZAO, 2012), the average land holding in the Zone is about 0.5 hectare per household. From the total land of 2 424 766 hectares, degraded land constitutes the highest share of 46.7 % followed by shrubs and bush land, and cultivated land constituting 19.4 % and consisting of 19 %, respectively.

1.9 Sampling Procedure and Sample Size

In order to analyse the impact of SWC, sample households who were adopters and non-adopters in SWC were interviewed. The sample size for the study was determined using the Cochran's method (Cochran 1963) as shown in the following equation:

$$n = \frac{z^2pq}{d^2} = 385$$

where *n* is a minimum sample size, *Z* is 1.96 at 95 % confidence level; *p* is smallholder farmers who may adopt in SWC (50 %); *q* is the weight variable and is computed as 1-*p*), and *d* is the desired precision or margin of error, expressed as a fraction of 0.05. Therefore, based on this formula, the sample size was supposed to be 385 farmers but for this study, however, the study collected 420 to cater for incomplete surveys or inaccurate data collected. Finally, the total sample size was 408 farmers (200 from adopters and 208 from non-adopters) after discarded incomplete surveys or inaccurate data.

A multi-stage stratified sampling procedure was used to select districts and specific farming households. The details of the sampling method are as follows. In the first stage, three districts (Deder, Gurugutu, and Haramaya) were selected randomly from the programme intervention area. In the second stage, three *kebeles*[2] were selected purposively from each district based on the problem of land degradation and programme implementation. Then, the households were stratified into two strata (adopters and non-adopters groups). Finally, 208 households that did not adopt any SWC measures from control group and 200 households that did adopt at least one SWC measures from treated group were randomly selected using proportionate probability sampling procedure based on the size of each district and *kebele*. Accordingly, as indicated in Table 1, a representative sample of 408 households (157 households from Deder, 124 households from Gorogutu, and 127 households from Haramaya district) were selected.

Table 1.1: Sample districts, *Kebeles,* and number of sample households

Districts	*Kebeles*	Total number of households	Adopters	Non-Adopters	Total sample
Deder	Chafe Gurumu	1183	28	27	55
	Gaba Gudina	1377	34	30	64
	Walfaa Gabon	817	21	17	38
Gurugutu	Biftu Dirama	688	15	17	32
	Ifa Jalala	1162	29	25	54
	Mauhasa Walfaa	817	16	22	38
Haramaya	Biftu Geda	882	17	24	41
	Amuma	753	15	20	35
	Ifa Oromiya	1097	25	26	51
Total		**8776**	**200**	**208**	**408**

[2]*It is usually named peasant association and is the lowest administrative unit in the country*

1.10 Organization of the Thesis

This thesis is organized into five chapters. The remaining part of the thesis is organized as follows. Chapter Two presents the first manuscript, which focuses on the analysis of households' vulnerability to food insecurity and its influencing factors in the study area. This paper has been accepted by the *Journal of Economic Structure*. Chapter Three focuses on the determinants of the adoption of improved physical SWC practices in eastern Ethiopia. The paper has been published in the *Journal of International Soil and Water Conservation Research*. Chapter Four deals with the impact of SWC practices on household vulnerability to food insecurity in eastern Ethiopia using endogenous switching regression and propensity score matching approach. This paper has been published in the *Journal of Food Security*. Finally, a conclusion of the major findings and recommendations are presented in Chapter Five.

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CHAPTER TWO

2.0. Analysis of Households' Vulnerability to Food Insecurity and Its Influencing Factors in East Hararghe, Ethiopia

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2.1 Abstract

Previous studies on food insecurity in many developing countries, including Ethiopia, have mainly focused on current food insecurity, lacking the ex-ante analysis. An understanding of household vulnerability to food insecurity is critically important to inform the formulation of policies and strategies to enhance food security and reduce vulnerability to food insecurity among smallholder farmers. This paper analyzes vulnerability to food insecurity of farming households using the Vulnerability as Expected Poverty (VEP) approach. The paper is based on cross-section data collected from a sample of 408 households in East Hararghe, Ethiopia, selected using a multi-stage sampling procedure. The Feasible General Least Squares regression results indicate that the age of the household head, family size, access to irrigation, adoption of soil and water conservation, size of cultivated land, and received credit were all significant in determining vulnerability to food insecurity. The log likelihood estimates of the logit regression model indicate that age of household head, adult equivalent, use of irrigation, *adoption of SWC and coping strategy index were significantly influence on current food insecurity. Based on the intensity of their vulnerability, households were grouped as chronic food insecure (24.27 percent), transient food insecure (11.77 percent), highly vulnerable-food secure (18.38 percent), and low vulnerable-food secure (45.59 percent). Overall, about 54 percent of households were categorized as vulnerable to food insecurity. These included households who were food insecure at the time of the survey (36.02 percent) and those who were categorized as transient food secure group (18.38 percent). These findings imply that food insecurity policies and interventions in developing countries should focus not only on households that are currently food insecure but also on those categorized as transient food insecure or households that are more likely to be food insecure in the near future.*

Keywords: Vulnerability as expected poverty; Vulnerability to food insecurity; Food insecurity; Ethiopia

2.2 Introduction

Despite her double digit economic growth rate since 2005, Ethiopia ranks 174th out of 188 countries in the 2015 United Nations Human Development Index and 104th out of 119 countries in the Global Hunger Index classified as suffering from a 'serious' level of hunger (IFPRI 2017). The rate of rural poverty is also high, with 26 percent of rural households living below the poverty line (UNDP, 2018). Stunting and wasting in children younger than five constitute 40.4 and 8.7 percent respectively (IFPRI 2015) which suggests that food insecurity is a serious problem in the country and that many households are vulnerable to it.

Although there are efforts to reduce the prevalence of poverty and vulnerability to food insecurity (VFI), both chronic and transitory food insecurity persist at the household level and millions of people are still vulnerable due to different shocks and stresses. Between the time when the current government (the Ethiopian People's Revolutionary Democratic Front (EPRDF)) came to power in 1991 and 2003, most Ethiopian food security policies have focused on relief and emergency plans. Thereafter, the food security programme was launched in 2003 under the framework of the federal government's food security strategy, and the productive safety net programme formally launched in 2005 in selected chronically food insecure districts. The main goal of these programs is to improve the food security status of chronically and transitory food insecure people through resettlement programs, household asset building programs, as well as complimentary community investment, including public works projects like soil and water conservation (SWC) practices, road construction, and natural resource rehabilitation. However, studies indicate that levels of poverty and vulnerability in Ethiopia remain very high (Dercon and Christiaensen 2011; Dercon et al. 2012; Kumar and Quisumbing 2012; Fentaw et al. 2013; IFPRI 2015; FAO 2016). On average, 32 percent and 40 percent of the Ethiopia's population are undernourished and consume less than the recommended daily calories, respectively (IFPRI 2015). Moreover, the FAO (2016) situation report indicates that more than 10.2 million people needed food assistance in 2016, more than at any other time since 2006.

The prevalence of food insecurity and related vulnerability is generally high in rural parts of Ethiopia, where 79 percent of the population live (World Bank 2018), with rain-fed subsistence farming dominating agricultural production. The level of vulnerability and food insecurity mainly depends on the performance of agriculture (Demeke et al. 2011; Di Falco et al. 2011; Collier et al. 2008). Therefore, household vulnerability and food security largely depends on a combination of both natural and man-made factors, including rainfall patterns, land degradation, population density, climate change, low levels of rural investment, volatile input and grain prices, drought, pest hazard, frost, and flooding (Dercon and Krishnan 1998; Dercon and Christiaensen 2007;WFP 2011;Gelaw and Sileshi 2013). In addition, access to different resources and institutional factors, such as access to land and labor, infrastructure, technologies, credit, and geographic suitability also affect the level of vulnerability and food insecurity though the channels of agricultural production and rural income (Dercon and Krishnan 1998; Gelaw 2010; Bevan 2000).

Furthermore, empirical findings by Dercon and Krishnan (1998); Dercon and Christiaensen (2007); and Capaldo et al. (2010) also show that in many developing countries, like Ethiopia, food security is mostly unstable, fluctuating over time. According to Dercon and Krishnan (2000) and Capaldo et al. (2010), access to adequate food for many households varies over time due to households' proneness to shocks and other risks, such as floods, land degradation, and extreme climate conditions, and their capacity to recover and respond. This implies that the concept of food insecurity is best thought of as dynamic rather than static in nature (Capaldo et al. 2010). It is no surprise that the dynamic nature of food insecurity persists in rural population of Ethiopia where livelihood is derived mainly from agriculture, which is rainfall dependent and highly erratic. As such, it is important to analyze VFI and identify households that are currently food insecure and those likely to be food insecure in the near future. A proper approach to this would be to carry out a more disaggregated analysis of VFI rather than merely categorizing households as either food secure or food insecure. This is particularly important if the aim is to design and implement inclusive food security policies and strategies that are intended to serve different groups.

This also implies that food security studies that aim to inform the formulation and implementation of policies and programs to address VFI should be based not just on the assessment of households’ current conditions but also on the expected situation of access to food in the near future (Capaldo et al. 2010). In addition, although the emphasis is on analyses of dynamic nature of food insecurity for better and effective policy action, most of the past studies have focused on vulnerability to poverty, not food insecurity (Chaudhuri 2003; Scaramozzino 2006). Most food security strategy and programme studies conducted in Ethiopia focus on the evaluation of current food insecurity with respect to who is currently food insecure and why (Bogale and Shimelis 2009; Motbainor et al. 2016;Agidew and Singh 2018; Jaleta et al. 2018.). They do not go further and attempt to determine who are likely to be VFI in the near future.

Therefore, this study analyzes the current food insecurity and VFI of households and its influencing factors using vulnerability as expected poverty (VEP) approach. Then, implications for effective policy intervention that will enhance food security and reduce the VFI in the study areas are drawn.

2.3 The concepts of vulnerability and literature review

In the broad academic literature, vulnerability is a term with a variety of discipline specific implications. The disaster management literature generally associates vulnerability with natural hazards (Alwang et al. 2001), while both human geography and human ecology relate vulnerability to environmental change (Adger 2006). Food insecurity and poverty literature, as well as social risk management literature, define vulnerability in terms of future negative effects on welfare (Mansuri and Healy 2001; Dercon 2001; Holzmann and Jørgensen 2000; World Bank 2000). Others define vulnerability in terms of the level of risk and capacity to recover and respond to it. Thus, not only does vulnerability imply a measure of risk associated with physical, social, and economic aspects, it also describes the ability to cope with different risks and shocks (Chambers 1989; Proag 2014). Accordingly, there are two components of vulnerability: the external side referring to the structural elements that determine sensitivity and risk to exposure (Chambers 1989; Moser 1998; McCarthy et al. 2001), while the internal side concerns the ability of households to respond and cope with stressors and the actions required to overcome them (Chambers 1989; Bohle 2001; Hart 2009).

In the framework of social risk management, vulnerability to poverty was first applied in early 2000s and thereafter, thus increasing awareness about vulnerability in the context of food insecurity (Scaramozzino 2006; Bogale 2012; Sharaunga et al. 2015;Ozughalu 2016). In the context of food insecurity, vulnerability is defined as a household's probability to fall, or stay, below food poverty line within a given period time (Løvendal et al. 2004; Løvendal and Knowles 2005;Capaldo et al. 2010).

Equally important is vulnerability to poverty which can be determined based on the frequency of households transitioning in and out of poverty over a given period of time (Alwang et al. 2001). Households can therefore be considered vulnerable if they remain poor in all the years considered in the study, otherwise they are considered as falling under transient poverty if they are poor or fall below the poverty line for only few times during the years of study (*ibid*).

Overall, vulnerability analysis has two main advantages. First, it is explicitly dynamic; vulnerability analysis does not just focus on the current status, but it is also forward-looking (*ex-ante*). Secondly, it also focuses on a given shock or set of shocks along with the coping strategies that households and communities can adopt to reduce the probability of being food insecure (Scaramozzino 2006; Bogale 2012; Mutabazi et al. 2015; Ozughalu 2016).

The main difference between food insecurity and VFI analysis is that the former summarizes food insecurity as a deficiency of food for a given household or society at a particular point in time, and hence a static measure of welfare that categorizes households as either "food secure" or "food insecure." On the other hand, VFI takes into account the different shocks and risks, such as climate change, land degradation, drought, erratic rainfall, and environmental degradation, that may affect households and society in the future, determining if consumption will move below a given threshold level. Further vulnerability analysis will sort households into four food security statuses: "chronically food insecure," "transitory food insecure," "permanently food secure," and "transitory food secure" (Scaramozzino 2006; Bogale 2012).

It is important to note that, just as there is no unique indicator of food security, there is also no single method to analyze VFI (FAO 2002; Ligon and Schechter 2004; Løvendal and Knowles 2005). The literature shows three principal methods for assessing VFI namely: vulnerability as expected poverty (VEP), vulnerability as low expected utility (VEU), and vulnerability as uninsured exposure to risk (VER) (Hoddinott and Quisumbing 2003; Scaramozzino 2006;Deressa et al. 2009).

VEP focuses on the probability that a given shock or set of shocks will move the well-being of individuals or households below the benchmark (such as below the food poverty line) in the near future (Pritchett et al. 2000; Chaudhuri et al. 2002; Chaudhuri 2003; Christiaensen and Subbarao 2005; Bogale 2012). VEU focuses on the change of utility derived from a certainty equivalent level of consumption (a benchmark) to the household's own expected utility (Ligon and Schechter 2003; Hoddinott and Quisumbing 2003). VER is a measure of the extent to which a given shock or set of shocks impose a welfare loss due to the absence of effective and efficient risk management tools. In addition, this approach is in essence an *ex post* assessment and not an attempt to construct an overall measure of vulnerability (Hoogeveen et al. 2004).

In the estimation, all the three approaches are based on expected mean and variance of household's consumption or income. While VEP can be evaluated using both cross-sectional and panel data, VEU and VER require lengthy panel data. Due to the lack of appropriate panel data, we analyze the VFI of households and examine the factors associated with vulnerability of households to food insecurity using the VEP approach and cross sectional data. However, obtaining a good estimate of household VFI requires consideration of the distribution of food consumption across households and ensuring that the household characteristics at one time capture the time-series variation of food consumption of the household (Chaudhuri et al. 200; Gaiha and Imai 2008).

Previous studies have analyzed vulnerability to poverty as well as food insecurity and its determinants using a variety of econometric tools (Sen 1981; World Bank 2000; Chaudhuri et al. 2002; Chaudhuri 2003; Ellis 2003; Demeke et al. 2011; Bogale 2012; Gelaw and Sileshi 2013; Proag 2014; Bayudan-Dacuycuy and Lim 2014;Sharaunga et al. 2015; Mutabazi et al. 2015;Ogundari 2017).

The findings from these studies attribute food insecurity and vulnerability to various factors. Using the entitlement theory, Sen (1981) for example, associated household food insecurity and vulnerability with the portfolio of current or existing and expected factors of production, including household's own production, assets, and reciprocal arrangements.

Access to production resources and the available adaptation strategies against shocks and risks are the most important factors for shifting the poor households out of poverty and food insecurity (Ellis 2003; Proag 2014). Sharaunga et al. (2015), viewed women's economic empowerment, including economic and physical capital empowerment, as vital in combating food insecurity among rural households in developing countries.

Using a three-stage Feasible General Least Squares (FGLS) Mutabazi et al. (2015) assessed the vulnerability of smallholder farmers in Morogoro region, Tanzania. They found that farmers who perceived climate change as human-induced were less likely to be vulnerable to poverty. In addition, households with stable incomes were also less likely to be vulnerable to external shocks (Alwang et al. 2001; Mutabazi et al. 2015). Other empirical research that has measured vulnerability using income patterns and sources include the studies by Jenkins et al. (2003), Finnie and Sweetman (2003), and Devicienti (2002). There is also a rich body of literature which shows that food insecurity and vulnerability is determined by climate related factor. Demeke et al. (2011) for example, used panel data to estimate the effect of rainfall shocks on smallholders' food security and vulnerability in rural Ethiopia. They found rainfall pattern to be an important factor determining household's food security status over time.

Elsewhere in Indonesia, Chaudhuri et al. (2002) and Chaudhuri (2003) used the VEP approach to analyze VFI based on the country's cross-sectional data. They concluded that the true poverty cost of risk was higher than the observed outcome and there was also a difference between current poverty head counts and vulnerability across different population characteristics. In Ethiopia, Gelaw and Sileshi (2013) found grain price hikes to have significant effects on households transitioning in and out of poverty. Similarly, in the urban slums of Kenya, Kimani-Murage et al. (2014) found prices of staple foods, like maize flour and unemployment to be one of the key factors affecting VFI. Other factors found to determine vulnerability to poverty and food insecurity are gender of household head, income, household size, source of household food (purchased or own produce), geographical location, conflicts, access to remittances, educational level, economic stability, and riskiness of occupation (Bogale 2012;Bayudan-Dacuycuy and Lim 2014; Mutabazi et al. 2015; Ogundari 2017; Azeem et al. 2017).

2.4 Research Methodology

2.4.1 Description of the study area

The study was conducted in East Hararghe, Ethiopia, in August and September, 2017. East Hararghe is located between latitudes 7°32' and 9°44' North and longitudes 41°10' and 43°16' East. The zone is characterized by three agro-ecological zones: the semi-arid (62.20 percent), the semi-temperate (26.40 percent), and the temperate tropical highlands (11.40 percent). This wide range of agro-ecological zones allows the area to produce a variety of products, including cereal crops like sorghum, maize, wheat, and *teff*; vegetables like potatoes, onions, shallots, and cabbage; as well as perennial crops like coffee and *Khat* (*Catha adulis*). Livestock keeping is also an integral activity of farmers in the study area. Among the cereals grown, sorghum and maize constitute the dominant crops, particularly in terms of the size of cultivated land and the number of households growing them. For example, in 2015/16 the land under sorghum and maize crops amounted to 134,708.26 and 49,979.80 ha with average yields of 19.69 and 26.67 qt/ha, respectively. Overall, these were generally much lower than the average national yields of 23.31 and 33.87 qt/ha for sorghum and maize respectively.

Despite the favorable climatic conditions soils, and existence of diverse ecologies, which allow extended crop growing seasons, the East Hararge area is still vulnerable to food insecurity mainly as a result of high population pressures, rampant land degradation deterioration of other natural resources. Recognizing this, the central and regional governments together with other development partners, have implemented different policies and programs intended to reverse this situation. For instance, several food security and productive safety net programs have been introduced and implemented since the early 2000s; yet, food insecurity and VFI still persist.

2.4.2 Sampling technique and data collection

The empirical analysis in this study is based on cross-sectional data from 408 households in East Hararge, Ethiopia. A multi-stage sampling procedure was used to select districts, *kebeles*,[3] and sample households. In the first stage, three districts (Deder, Gorogutu, and Haramaya) were selected randomly from the areas involved in the integrated SWC program. In the second stage, three *kebeles* were selected purposively from each district based on the extent of land degradation and participation in the program. Then households were stratified into two strata (adopters and non-adopters of soil and water conservation). In the third stage, a representative sample of408 households (157 households from Deder, 124 households from Gorogutu, and 127 households from Haramaya district) were randomly selected from both strata using proportionate probability sampling based on the size of each district and *kebele*.

For the household survey, data were collected using a semi structured questionnaire prepared and pretested before the actual survey. The questionnaire was intended to gather different information related to the households' socioeconomic and institutional characteristics, SWC, livelihood shocks and coping strategies, food consumption and

[3] *It is usually a named peasant association and is the lowest administrative unit in the country.*

expenditure, geographic and weather variables, education levels for the head of household, existing social infrastructure, food security programs and related activities.

2.4.3. Econometric modeling strategy

It is important to note that food security and vulnerability analysis primarily requires a method of discriminating the food secure status from the food insecure one or the highly vulnerable status from the low vulnerable one. To determine the food security status of households in the study area, we used the amount of money required to achieve the daily minimum dietary requirement. The government of Ethiopia set the minimum acceptable level of per capita calorie intake per day at 2200 (MoFED 2002). Thus, a household is considered to be food insecure if the amount of money it spends on food and the value of consumption from own produce are not sufficient or nutritionally adequate for a basic diet.

We analyzed the household's VFI using an econometric model proposed by Chaudhuri et al. (2002) and Christiaensen and Subbarao (2005). The model applies the vulnerability as expected poverty (VEP) approach using PCFCE as a measure of household welfare. It also accounts for household risk exposure and coping strategies that may lead a household to fall below a given minimum level of welfare, for example food poverty line. The vulnerability of households during the current period is expressed as:

$$V_{ht} = P(\mathrm{c}_{\mathrm{it+1}} < z) \tag{1}$$

The current vulnerability of a household (V_{it}) is determined by the likelihood that the future household food consumption expenditure (C_{it+1}) will be less than the threshold level (Z). Thus, the estimation of vulnerability involves the determination of the probability distribution of future consumption. Assuming that the probability distribution is log normal, then the estimation of mean and variances of future consumption will effectively determine this distribution.

VEP approach estimates are always a function of the expected mean and variance of household PCFCE. The expected mean of PCFCE is determined by household and community characteristics, while the variance (also known as volatility) in household consumption captures the idiosyncratic shocks that contribute to the difference in PCFCE levels for households that have the similar characteristics (Gunther and Harttgen 2009; Bogale 2012; Echevin 2013).

Following Chaudhuri et al. (2002), Gaiha and Imai (2008), and Günther and Harttgen (2009), we estimate empirically a variant of VEP from the food consumption expenditure function as:

$$ln\, c_i = x_i \beta + \varepsilon_i \qquad (2)$$

Where $ln\, c_i$ represents the log of PCFCE for the i^{th} household, x_i represents an array of household and farm characteristics, selected based on a review of relevant literature, β is a vector of parameters, and ε_i is a disturbance term with a mean of zero and heteroscedastic, and non homoscedastically, the usual regression techniques may yield estimates that are inefficient but not biased in the main parameters of interest. This implies that the variances of the error term vary across households depending onx_i. Then, the squared residuals from equation (2) are regressed on household characteristics (x_i) to generate estimates for the expected variances, specified as:

$$\sigma^2 \varepsilon_i = x_i \theta + \tau_i \qquad (3)$$

Where θrepresents the vector of parameters and τrepresents the error term for estimation of equation (3).

As proposed by Amemiya (1977), Chaudhuri et al. (2002), Chaudhuri (2003), and Christiaensen and Subbarao (2005) the estimates of βandθ can be obtained using the three-steps FGLS. This starts by estimating equation (2) using Ordinary Least Squares (OLS). Thereafter, equation (3) is estimated, using the square of error term from equation (2) as dependent variables. To obtain asymptotically efficient estimates of θ, we re-estimate equation (3) with OLS using predations of equation (2) after weighting each residual by $x_i\theta$ (Chaudhuri et al. 2002). We adopt the approach used by Chaudhuri et al. (2002), Bogale (2012), Mutabazi et al. (2015) to get asymptotically efficient estimates of β by re-estimating equation (2) after using efficient θ and weighted least squares.

$$\frac{\hat{\varepsilon}^2_{OLS,i}}{x_h\hat{\theta}_{OLS}} = \left(\frac{x_h}{x_h\hat{\theta}_{OLS}}\right)\theta + \frac{\tau_i}{x_h\hat{\theta}_{OLS}} \quad (4)$$

The standard deviation of the variance can then be obtained by the following equation:

$$\hat{\sigma}_{\varepsilon,i} = \sqrt{x_i\hat{\theta}_{FGLS}} \quad (5)$$

Finally, equation (2) is transformed, as given in equation 6 to estimateβ.

$$\frac{lnc_i}{\hat{\sigma}_{\varepsilon,i}} = \left(\frac{x_i}{\hat{\sigma}_{\varepsilon,i}}\right)\beta + \frac{\varepsilon_i}{\hat{\sigma}_{\varepsilon,i}} \quad (6)$$

Using the estimates of β and θ, we are able to directly estimate the expected log PCFCE and the variance of log PCFCE for each household as in equations 7 and 8, respectively.

$$\mathrm{E}\,[\ln c_i/x_i] = x_i\hat{\beta} \quad (7)$$

$$\mathrm{V}\,[\ln c_i/x_i] = x_i\hat{\theta} \quad (8)$$

Assuming that consumption is log-normally distributed, each household's VFI at time $t+1$ can be expressed as in equation 9.

$$\hat{V} = \hat{P}(\ln c_i < \ln z/x_i) = \emptyset\left(\frac{\ln Z - \ln x_i\hat{\theta}}{\sqrt{x_i\hat{\beta}}}\right) \quad (9)$$

Where Φ is the cumulative density of the standard normal distribution; $x_i\hat{\theta}$and $x_i\hat{\beta}$ are the expected household food consumption expenditure and the standard error of the regression, respectively, Z is threshold level, and V is the probability that each household

VFI range between zero and one. Chaudhuri et al.(2002), justify a threshold measure that is used to define vulnerable households as those with an estimated vulnerability coefficient above or equal to 0.5. Thus, we classify households as vulnerable if $\widehat{V}$ is above or equal to 0.5 and otherwise, if not vulnerable.

As specified earlier, we used the household food expenditure to determine the current food security status of a household, compared to the daily minimum dietary requirement (food poverty line) set in the literature for Ethiopia. Stated differently, we compared the household dietary intake with the food poverty line for Ethiopia. In addition, we adopted the approach used by Bogale (2012) to determine the food poverty line (threshold), by first picking a 'basket' of the food items typically consumed by the poor. We then determined the quantity of the 'basket,' which was considered as the bundle that meets the predetermined minimum per capital calorie requirement of 2,200 kcal per day according to MoFED (2002). Finally, we used the local prices to estimate both the cost of basket and the value of the food poverty line. Accordingly, the food poverty line was estimated at Birr[4] 2637.86 per annum. In other words, a total of Birr 2637.86 per annum was needed to purchase food that could meet the basic daily food-energy requirements of an adult person. It should be mentioned here that based on sex and age each member of household was assigned a specific adult equivalent figure calculated using standard conversion factors available in the literature.

Based on the CSA (2017)'s report of the country and regional consumer price indices, the study area (Oromia regional state) had a Consumer Price Index (CPI) of 171.4 percent (December 2011 = 100). Thus, we used this CPI to deflate the food poverty line in the

[4]Birr is Ethiopia currency (1USD=23.32Birr).

study taking into account the effect of inflation. Consequently, we adjusted the food poverty line at Birr 1539 per adult equivalent, per year, using the end of 2011 constant price.

To identify the determinants of household food insecurity, a binary logit model was used. The dependent variable for this case was not continuous instead it was binary as such either logit or probit could be used. Both the logit and probit models estimate parameters using maximum likelihood. The probit model assumes normally distributed error term whereas the logit model assumes a logistic distribution of the error term. The logit model is often preferred due to the consistency of parameter estimation associated with the assumption that the error term in the equation has a logistic distribution (Baker 2000; Ravallion 2001). Therefore, the logit model was used to identify the factors associated with household food insecurity status. Accordingly, the binary dependent variable equals 1 when the household PCFCE was less than Birr 2637.86 (for food insecure households), otherwise, 0 (for food secure households).

According to Aldrich and Nelson (1984) andGujarati (2003), the mathematical formulation of logit model is specified as follows:

$$P_i = \frac{e^{z_i}}{1 + e^{-z_i}} \qquad (10)$$

Where, $P_i$is the probability of food insecurity.

The probability that a household is food secure can be specified as:

$$1 - p_i = \frac{1}{1 + e^{z_i}} \qquad (11)$$

Therefore,

$$\frac{P_i}{1-p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} \tag{12}$$

Now equation (12) is simply the odds ratio in favor of food insecurity. The ratio of the probability that the household is food insecure to the probability that it is food secure. Finally, taking the natural log of equation (12) we obtain:

$$L_i = \ln\left(\frac{p_i}{1-p_i}\right) = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n + \mu_i \tag{13}$$

Where L_i is log of the odds ratio, which is not only linear in X_i(vector of household characteristics) but also linear in the parameters;β_i represents vectors of parameter; andμ_i represents an error term.

The reduced form of logit model is written as:

$$zi = ln\left[\frac{pi}{1-pi}\right] = \alpha + \sum \beta_i X_i + \mu_i \tag{14}$$

2.5 Results and discussion

2.5.1 Descriptive Statistics

Based on a desk review of relevant literature (Pritchett et al. 2000; Christiaensen and Boisvert 2000; Bogale et al. 2005;Deressa 2009; Demeke et al. 2011; Bogale 2012; Mutabazi et al. 2015;), we included a range of household and farm characteristics as independent variables in the vulnerability analysis at household level. The summary of descriptive statistics is given in Table2.1.

Table 2.1:Variables specification and summary statistics of household characteristics

Variable	Viable label	Mean	Std. Dev.
lnFCE	Natural log of consumption expenditure per adult equivalent	8.00	0.40
Sex of hh	Dummy of sex of household sex (1=male)	0.87	0.34
Age of hh	Age of the household head in years	40.19	12.73
Education of hh	Level of education in numbers of years	3.65	3.67
Adult equivalent (AE)	Size of household in adult equivalent	4.89	1.65
Dependence ratio	Dependence ratio	1.29	.96
Annual income	Total annual income in birr	16878.67	13263.07
Off-farm Activity	Dummy for participation to off farm activity (Yes=1)	0.46	0.50
Use of fertilizer	Dummy for use to fertilizer (Yes=1)	0.54	0.50
Use of improved seed	Dummy for use to improved seed (Yes=1)	0.51	0.50
Use of irrigation	Dummy for use to irrigation (Yes=1)	0.35	0.48
Cultivated land	Total cultivated land holding	0.29	0.17
Adoption of SWC	Dummy for use to SWC (Yes=1)	0.49	0.50
Total Assets	Total value of assets in birr	24627.73	48081.69
Livestock TLU	Livestock owned (Tropical Livestock Unit)	1.78	1.90
Crop diversification	Number of crop growth	2.46	0.70
Coping strategy index[5]	Coping strategy index	16.46	4.93
Number of Sick	Number of sick person in 1 year	0.36	0.66
Received credit	Dummy for receiving credit (Yes=1)	0.14	0.34
Contact with DA	Number of contacts with extension agent, per month	2.28	2.08

The average age of household heads is 40.19 years. However, the majority of family members are younger than 15 or older than 64 years, meaning that the dependency ratio is very high (averaging 1.29, with a standard deviation of 0.96). Family size, expressed as adult-equivalent, averages 4.82 with a standard deviation of 1.65. However, there are households with as many as 10.85 adult-equivalents. A large total adult equivalency may imply insufficiency in terms of food consumption because large households tend to consume more than small households. This is usually true if the dependency ratio of the household is large (Bogale 2012; Mutabazi et al. 2015). The gender dimension shows that

[5]The Coping Strategies Index is a tool that measures what households do when they cannot access adequate food. Food insecure households may change their diet, which means switching food consumption from preferred to cheaper and even less preferred substitutes, as well as others means like purchasing food on credit, consuming wild foods and immature crops or even seed stocks, favoring certain household members over others or going an entire day without eating food, just to mention few (Maxwell et al. 2003).

households are mainly headed by men, with only 13 percent out of the 408 sampled households being headed women. Although education can equip and enhance access to information and technology, thereby contributing to greater understanding of new technology that can help them reduce food insecurity and vulnerability, 40.69 percent of household heads have never attend formal education. On average, household heads have completed 3.65 years of formal education.

The value of household assets and use of productivity-enhancing inputs (e.g. fertilizers, improved seeds and irrigation water), size of cultivated land livestock holdings, as well as adoption of SWC constituted the important factors in analyzing VFI. On average the study households cultivated 0.29 hectares of land and owned 1.78 TLUs. Furthermore, 54, 51, 35, and 49 percent of households used fertilizers, improved seeds, irrigation water and SWC, respectively. About 13 percent received credits from formal credit institutions and each household was contacted or visited by an extension agent for about 2.28 times a month on average.

Recognizing the importance of crop diversification in smallholder production systems, especially its role of ensuring that farmers do not depend solely on production and revenue from a single crop, we also evaluate the extent to which farmers in the study area diversified crop production. Our descriptive statistics indicate that, on average, households grew 2.48 crops during the last production season of the year under study. Moreover, 46 percent of households participated in off-farm activities. The income generated from off-farm activities backed up the farmers' income and enabled them to smoothen their food consumption pattern.

It is important to highlight the role of family labor in smallholder farming systems as these farms depend predominantly on family labour. However, the number of family labour alone does not tell the whole story as a household may have many sick people who are unable to contribute their labour during a specific period of cropping season. Our analysis of family labour shows that on average, about 0.36 of the household's total adult-labour equivalents were reported sick during the last 12 months before the survey date. We included this information in our model as an idiosyncratic shock.

2.5.2 Empirical result

2.5.2.1 Determinants of households' food insecurity

In order to find out the most important factors underlying household food security status, binary logit model was employed. Thus, household with food consumption expenditure less than food poverty line (Birr 7.224 per day per adult equivalent or 2637.86 per annum per adult equivalent) were considered as food insecure, and were given a value 1, and otherwise given a value of 0.

Table 2.2 presents the results of logit model. Before interpreting the significant variables, it is essential to determine the statistical validity of the model. Our model fitted the data reasonably well [Wald Chi-squared = 73.820, P= 0.000)]. Thus, the hypothesis that all coefficient of independent variables are jointly equal to zero was rejected. The logit model result reveals that a total of 18 explanatory variables were considered in the econometric model, out of which, 5 variables were found to significantly influence the food insecurity status of household.

Table 2.2: Logit model result for determinant of food insecurity

Variable	Coef.	Robust Std. Err.	z	Marginal effect	Std. Err.	z
Sex of hh	0.220	0.342	0.640	0.047	0.070	0.660
Age of hh	0.031	0.011	2.760***	0.007	0.002	2.750***
Education of hh	0.029	0.041	0.700	0.006	0.009	0.700
Adult equivalent	0.486	0.083	5.860***	0.106	0.018	6.010***
Annual income	-3.87e-06	1.e-05	-0.200	-8.49e07	0.000	-0.200
Off-farm Activity	0.224	0.277	0.810	0.049	0.061	0.810
Use of fertilizer	0.009	0.299	0.030	0.002	0.066	0.030
Use of improved seed	-0.420	0.300	-1.400	0.092	0.065	-1.410
Use of irrigation	-0.544	0.273	-1.990**	0.115	0.056	-2.050**
Cultivated land	-0.968	0.894	-1.080	0.212	0.196	-1.080
Adoption of SWC	-0.516	0.265	-1.940*	0.113	0.057	-1.970**
Total Asset	-4.02e-07	3e-06	-0.130	8.82e08	0.000	-0.130
Livestock (TLU)	-0.128	0.090	-1.430	0.028	0.020	-1.410
Crop diversification	-0.053	0.167	-0.320	0.012	0.037	-0.320
Coping strategy index	0.064	0.029	2.190**	0.014	0.006	2.200**
Number of Sick	0.076	0.200	0.380	0.017	0.044	0.380
Received credit	-0.395	0.356	-1.110	0.082	0.069	-1.180
Contact with DA	0.030	0.062	0.480	0.007	0.014	0.490
_cons	-4.466	0.902	-4.950			

Number of obs=408.000 | Marginal effects after logit
Wald chi2(18) =73.820 | y = Pr(gap0) (predict) = .325
Prob > chi2=0.000
Pseudo R2=0.171
Log pseudo likelihood=221.158

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

The log likelihood estimates of the model regression model indicate that age of household head and adult equivalent were positive and significantly influence on food insecurity whereas, use of irrigation, adoption of SWC and coping strategy index were negatively and significant influence current food insecurity status of household.

Age of household head was one of the factors, which positively and significantly influenced the food insecurity of household(P<0.01). Accordingly, age of household head increase the probability to food insecure also increase. This means, the older household family was more like to food insecure than young household head family. The model outcome indicated that age of household head increase by 1, the probability of food insecurity increase by 0.67 percent. This might be due to the fact that, young farm household heads are more likely to adopt new technologies, because they may have more schooling than older farmers and they may have been exposed to new ideas and hence achieve food security.

The results of the logit model reveal that, family size measured by adult-equivalent was positively and significantly affect household food insecurity(P<0.01). The possible explanation is that, most of farm households are operating in small-scale subsistence production system and resources are very limited. As the adult-equivalent increase, this may put much pressure on consumption than it contributes to production. One unit increasing household AE, increase probability of food insecurity by 10.64 percent.

Use of irrigation is another important factor which was negatively related to the dependent variable. The marginal effect result indicates that a discrete change in dummy variable from 0 to 1, the probability of being food insecure decreases by 11.52 percent and it is significant (P<0.05). This implies that, the farmer who used irrigation has a high probability to directly produced consumable food grains and/or diversifies their cropping and supplement moisture deficiency in agriculture. Furthermore, access to irrigation enables rural households to produced more than one time per year and sustains seasonal fluctuation of household food consumption expenditure. Thus, the farmers who used irrigation were less likely to food insecure than other farmers.

Other factor affecting household food insecurity negatively was adoption of SWC. The farmer who adopted SWC was less likely to food insecurity as compare than non-adopter. The possible explanation is that, SWC is keeping soil fertility and moisture content of farm plot and thus increase farm production and productivity. Therefore, it increase purchasing capacity and access of food from own production. The marginal effect result indicates that participation in soil and water conservation is reduced the probability to being food insecure by 11.26 percent.

Coping strategy index also another factor positively related with food insecurity. This implies that the household using different coping when facing hardships such as food insecurity and their reaction to attenuate the consequences. For example change their diet which means switching food consumption from preferred to cheaper and even to less preferred substitutes; increase their food supplies using short-term strategies such as purchasing food on credit, consuming wild foods, immature crops or even seed stocks. Therefore, the household with high coping strategy were more likely food insecure than household with less coping strategy. The model outcome indicated that coping strategy increase by one unit, the probability to food insecurity also increase by 1.14 percent.

2.5.2.2 Households' vulnerability to food insecurity assessment result

In this section, we present and discuss the results of analysis of household VFI and factors that influence VFI. We used the three-step FGLS to predict the probability of a household to fall below the minimum food consumption expenditure and determine the factors affecting the expected food consumption expenditure or VFI. The model showed a good overall fit with most variables performing as expected [i.e. $F(19, 388) = 8.12$, $P<0.001$]. To test for multicolinearity, we used the Variance Inflation Factor (VIF) and Contingency Coefficient for continuous variables and dummy variables, respectively. The results indicated nonexistence of a serious multicolinearity problem (i.e. a mean VIF of 1.46).

Out of the 19 explanatory variables specified in our econometric model, six variables were significantly influencing the expected food consumption expenditure (Table 2.3). The results of the model suggest that future food consumption was decreasing with the age of household head and family size (adult equivalents), and it was increasing with the use of improved seeds, size of cultivated land, adoption of SWC, and access to credits.

The expected food consumption expenditure decreased with family size or adult equivalent ($P<0.01$). The possible explanation is that family size determines the expected food consumption expenditure: when the marginal productivity of household members and their contribution to household income is less than the food consumption expenditure then the share of consumption of each member of the household consumption is expected to decline. Our results of the model, for example, suggest that a unit increase in family size (AE) would reduce the expected food consumption expenditure by 10.70 percent. A similar relationship is also reported by Capaldo et al. (2010) and Ogundari (2017).

The results of analysis also show that the expected food consumption expenditure increased with the size of cultivated land ($P<0.1$). This relationship was not astonishing as land is a basic farming input and binding resource for farm households. It is therefore directly associated with the ability of a household to produce enough produce for consumption and sale, in so doing determining its contribution to household's future food consumption expenditures. The results of our model suggest that, a unit increase in cultivated land would increase the expected food consumption expenditure by 24.33 percent. A similar relationship is also reported by Schröder-Butterfill and Marianti (2006) who indicate that cultivated land is positively related with household food security.

Furthermore, our results of analysis show that, the use of improved seeds was positively and significantly influencing the expected food consumption expenditure (P<0.01). For a discrete change in the use of improved seeds from 0 to 1, the household's future food consumption expenditure would increase by 12.92 percent. Again, this relationship was expected because the use of improved seed potentially contributes to increase in productivity and reduce downward fluctuation in production due to the potential characteristics of improved seeds in resisting pests and diseases, as well as their ability to tolerate adverse weather conditions. The high productivity and production from use of improved seeds would in turn reduce the household's VFI. Jaleta et al. (2018) report a similar relationship: they found access to improved seeds to be significantly associated with household's food consumption in Ethiopia.

As expected, the adoption of SWC practices influenced the expected PCFCE positively (P<0.01). This is consistent with Bogale (2012)'s findings, which indicate a positive relationship between adoption of SWC practices and household future food consumption expenditure in Ethiopia. Using SWC practices tends to reduce soil erosion, while maintaining the fertility status and moisture content of a farm land, thus improving farm productivity and allowing production of a fast maturing crop. In addition, SWC practices may reduce the impact of crop loss caused by flooding and land degradation, in so doing reducing the household's VFI. Our results suggest that the adoption of SWC practices would boost the expected food consumption expenditure of a household by 9.96 percent.

The results of analysis also reveal that the expected PCFCE decreased with the age of household head (P<0.1). The model coefficient suggests that a unit increase in age of the household head would result in a decrease of expected PCFCE by 0.28 percent. We further infer this to the inverse relationship between age and productivity of farmers: as the age of farmers increases, their productivity decreases. Consequently, the decrease in productivity would result in reduced income and diminution of expected PCFCE.

Our results further show that the expected food consumption expenditure increased with access to credits ($P<0.1$). The model coefficient suggests that a unit increase in access to credits would increase the expected food consumption expenditure of a household by 9.39 percent. This also implies that households receiving credits were less likely to be VFI than their counterpart households who did not receive credits. This can be attributed to the fact that access to credit enables farmers to make timely purchase of agricultural inputs, like fertilizer, pesticides, herbicides, and improved seeds, which in turn enhance farm productivity and increase future food availability and consumption expenditure. A similar relationship is reported by Iftikhar and Mahmood (2017) in their study of relationship of agricultural credit with food security.

Table 2.3: Three-step Feasible Generalized Least Squares result for determinant of VFI (N=408)

Variables	Log expected food consumption expenditure			Variance of expected food consumption expenditure		
	Coef.	Robust Std. Err.	t	Coef.	Robust Std. Err.	t
Sex	-0.017	0.065	-0.26	-0.073	0.042	-1.75*
Age	-0.003	0.002	-1.75*	0.001	0.001	0.72
Education	-0.001	0.005	-0.16	-0.001	0.002	-0.25
Adult equivalent	-0.107	0.014	-7.65***	0.002	0.006	0.29
Dependence ratio	1.93E-04	1.82E-04	1.06	1.98E-05	8.57E-05	0.23
Annual income	1.94E-07	2.20E-06	0.09	1.06E-08	9.14E-07	0.01
Off-farm Activity	-0.003	0.039	-0.08	-0.002	0.019	-0.1
Use of fertilizer	0.005	0.045	0.1	-0.004	0.018	-0.23
Use of improved seed	0.129	0.045	2.89***	0.026	0.020	1.28
Use of irrigation	0.057	0.037	1.53	-0.025	0.018	-1.39
Cultivated land	0.243	0.134	1.81*	-0.012	0.071	-0.17
Adoption of SWC	0.100	0.038	2.62***	0.022	0.019	1.13
Total Asset	3.43E-07	3.64E-07	0.94	2.65E-07	1.81E-07	1.46
Livestock TLU	0.015	0.012	1.25	-0.006	0.006	-1.03
Crop diversification	0.008	0.024	0.33	-0.014	0.011	-1.23
Coping strategy index	-0.003	0.004	-0.68	0.001	0.002	0.40
Number of Sick	0.038	0.028	1.39	-0.006	0.014	-0.40
Received credit	0.094	0.057	1.66*	0.020	0.028	0.71
Contact with DA	2.90E-04	0.009	0.03	4.70E-04	0.004	0.12
_cons	8.384	0.122	68.68***	0.162	0.060	2.68***
F(19, 388)=8.12				F(19, 388)=1.51		
Prob > F=0				Prob > F=0.0769		
R-squared=0.3041				R-squared=0.0437		
Root MSE=0.33456				Root MSE=0.1633		

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

It is a common approach to estimate vulnerability to food insecurity using vulnerability as expected poverty, which is very often expressed as a function of expected mean and variance of household consumption. In our study, we estimated the *ex-ante* probability distribution for each household to suffer from food insecurity using the expected mean and variance of household consumption (Gonçalves and Machado 2015).

We then determined the VFI status of each household using a 0.5 vulnerability score as the threshold level (Pritchett et al. 2000). Accordingly, a household was inferred as having low VFI, when the vulnerability score was less than 0.5 and was considered highly VFI when the score was greater than or equal to 0.5. The current food insecurity status of a household was determined using the yardstick of food poverty line. In this regard, a household was considered as food insecure when the PCFCE was less than the threshold level; otherwise the household was inferred as food secure. By considering both the vulnerability status of household and its current food insecurity status, we extended our analysis into several food insecurity and vulnerability categories as shown in Table 2.4.

Table 2.4: Vulnerability and food security status of households

		Food security status				χ2-value	Total	
		Secure		Insecure				
		No.	Percent	No.	Percent		No.	Percent
Vulnerability status	Low-vulnerable	186	45.588	48	11.765		234	57.353
	High vulnerable	75	18.382	99	24.265	57.317***	174	42.647
Total		261	63.971	147	36.029		408	100.00

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

The results indicate that about 45.60 percent of the sample households had stable food security levels. These households were food secure and had low probabilities of being food insecure in the near future (less VFI). On the other hand, about 24 percent of the total households were categorized as food insecure for an extended period of time and were considered as suffering from chronic food insecurity. They had PCFCE values which were below the threshold level with probabilities of being food insecure being greater than 0.5. These were considered as being highly VFI having little chance of escaping from food insecurity in the near future. According to FAO (2008), these households may need a special attention in terms of direct food assistance and access to productive resources which will enable them to improve their productive capacity and help them escape from food insecurity in the near future.

About 11.77 percent of the total households were considered as suffering from transient food insecurity, which means that even if they had current PCFCE values of less than the value food poverty line, they were less likely to fall into food insecurity in the near future and could utterly escape from food insecurity. Moreover, about 18.38 percent of the total households were grouped under the transient food security category, meaning that these households may face a sudden drop in their ability to access adequate and sufficient food, hence fail to maintain good nutritional status in the near future. Those households had access to adequate food but were highly VFI. This implies that they were more likely to become food insecure in the future. About 30 percent of the total household (11.77 plus 18.38 percent) were categorized as having an unstable food insecurity status. Overall, these findings imply that households were recurrently moving into and out of the state of being food insecure which has a particular policy implication, that is, vulnerability to food insecurity should be viewed in a broader manner as not only entailing VFI farmers who are chronically food insecure but also those who are currently food insecure but less likely to be VFI as well as those who are currently food secure but highly likely to be VFI in the near future. In our study these households constituted about 54 per cent of the total households in the study area.

2.6 Conclusions

Access to adequate and sufficient food in many developing countries, like Ethiopia, is unstable. This means that the status of food insecurity of many households in these countries varies over time and is inherently dynamic in nature. This, in turn, implies that food security policies and initiatives should above all be based on a though understanding of the existing categories of VFI. It is important to understand both the group of households who are currently food insecurity as well as those who are expected to be food insecurity in the near future. In this paper we analyze vulnerability of farming households to food insecurity in East Hararghe using the VEP approach. The results indicate that 36.03 percent and 42.64 percent of the total households suffered from current and future food insecurity, respectively. When considering both the current and future food insecurity we found that about 24.26 percent suffered from chronic food insecurity, 11.77 percent from transient food insecurity, and 18.38 percent suffered from transient food security. Furthermore, we find that the age of household head, family size, cultivated land, access to credit, access to improved seed, the use of irrigation, coping strategy and the adoption of SWC practices are all significantly associated with VFI and currently food insecurity status. We recommend that any initiative, policies and strategies to combat VFI should be informed by a thorough understanding of the existing categories of VFI. Equally important is the establishment and strengthening of tailor-made service providers, including institutions that provide agricultural extension and credit services, and supply of affordable inputs to smallholder farmers. Importantly is support the introduction and implementation of SWC practices which aim to enhance productivity and sustainable use of land water resource base.

Authors' contributions

The first author handled the data analysis and discussion of results. Other authors supervised the writing of the manuscript, proofread to ensure quality of the research as well as contributed to the revision of the study for publication. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study can be obtained from the authors based on the request.

Competing interests

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CHAPTER THREE

3.0. Determinants for adoption of physical soil and water conservation measures by smallholder farmers in Ethiopia

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3.1 Abstract

Adoption rates of soil and water conservation measures remain below the expected levels in Ethiopia despite the considerable investments in reducing land degradation and improving soil fertility. This has in turn constituted one of the key research agendas in the country. In particular, this paper underscores the need of investigating the factors that are either hindering or facilitating the adoption of introduced soil and water conservation measures. The adoption of these measures is envisaged to result into improved environmental conditions, and increased sustainable agricultural productivity. The study results presented in this paper are based on cross-section data collected from 408 households in eastern Ethiopia, including field observations of 790 plots selected using a multi-stage sampling procedure. A multivariate probit model was employed to analyse the determinants of adoption of three soil and water conservation measures (stone bund, soil bund, and bench terracing) at a plot level. The study findings reveal that household, socioeconomic, and institution characteristics were the key factors that influenced the adoption of soil bund, stone bund, and bench terracing conservation measures.

Furthermore, there was a significant correlation among the three soil and water conservation measures, indicating that the adoption of these measures is interrelated. In particular, the results show that there is a positive (complementarity) correlation between stone bunds and soil bunds. However, the correlations between bench terracing and stone bunds as well as bench terracing and soil bunds were negative (implying substitutability). These results imply that the Government and other relevant organs that are responsible for reducing land degradation in order to increase agricultural production should both support the establishment and strengthening of local institutions to speed up the adoption of soil and water conservation measures.

Keywords: Adoption; Multiple soil and water conservation; Multivariate probit; Ethiopia

3.2 Introduction

Land degradation is a serious problem across Sub-Saharan Africa. Sixty seven percent of the total land is degraded to some degree with levels of degradation ranging from light to very severe. In East Africa, the severity of land degradation is reported to vary from one country to another. In Ethiopia for example, 25 percent of the total land is degraded. Comparatively, the proportions of land degradation in Kenya and Tanzania is 15 and 13 percent respectively (Kirui and Mirzabaev, 2015). This implies that there is more land degradation in Ethiopia than there is in Kenya and Tanzania. The available evidence (e.g. Pender et al., 2001) indicates that losses of topsoil in Ethiopia amounts to about 42 tons per ha per annum, which is equivalent to 8 percent of the total global loss of top soil from arable lands (Greenland & Nabhan,2001). Soil erosion in Ethiopia is at an average of nearly 10 times the rate of soil formation, with the country's rate of soil nutrient depletion being among the highest in Sub-Saharan Africa (Holden et al., 2005).

According to scholars (e.g. Suttclife, 1993; Bojö and Cassells, 1995) the cost of soil degradation due to inappropriate soil management in Ethiopia is estimated at about USD139 million annually. This cost is about 4 percent of the total GDP of the country's agricultural sector and it includes forest losses and loss of livestock capacity. It is important to note that land degradation adversely affects the productive capacity of land. According to Sonneveld (2002) on a simulation study results, land degradation in Ethiopia has resulted in the loss of agricultural value, which is estimated at about USD7 billion for the period between 2000 and 2010.

Land and water degradation reduce agricultural productivity and contribute immensely to food insecurity and poverty (Shibru 2010). According to Demel (2001), the amount of grain lost due to land degradation in Ethiopia alone could feed more than 4 million people. This is particularly important because land degradation is much more severe in the highlands of Ethiopia where 85 percent of the population lives, relying on 95 percent of the total cultivated land and on 77 percent of the country's livestock population (Bewket, 2007).

One of the ways of addressing soil and water degradation and improve crop productivity is the use of improved Soil and Water Conservation (SWC) measures. The role of SWC measures in improving productivity is widely acknowledged in the literature (see Pender et al., 2001; Kassie et al., 2008;Tenge et al., 2011;Adgo et al., 2013; Abdulai and Huffman, 2014;Amare et al., 2014; Hishe et al., 2017). In the recognition of this reality, the government of Ethiopia has made considerable investments in soil and water conservation (SWC) since the mid-1970s, with a purpose of not just to reducing soil loss but also improving crop yields and livelihood of the rural farmers. In particular, the central government started massive SWC campaigns in 1980s, targeting the low potential (drought prone and highly degraded) parts of the highlands. On the other hand, the Government discouraged farmers from implementing SWC measures in high potential area while encouraging the adoption of alternative improved technologies, such as the use of fertilizers and improved seeds, in order to enhance productivity per unit of cultivated area (Mekuriaw et al., 2018). As such, SWC has been considered as an important part of the agricultural extension package in the country since 1991when the Ethiopian People Republic Democratic Front (EPRDF) came to power. It should however 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 lack of support and awareness among farmers (Shiferaw and Holden, 1998; Wolka, 2014; Haregeweyn et al., 2015; Mekuriaw and Hurni, 2015; Mekuriaw et al., 2018).

Participatory watershed management was recognized at the national level since early 2000s under the framework of national development strategy. This framework triggered the launching of different sustainable land management programs throughout the country. Along with the national strategy, integrated SWC is implementing different mechanical and biological SWC measures (such as Bench terracing, Soil bund, Stone bund, farm forestry, and so on) in the main intervention areas. Similarly, the Government of Ethiopia is running a massive SWC campaign for two months every year in the selected areas since 2011 (Mekuriaw et al., 2018). The campaign aims at encouraging rural farming households to construct SWC structures and change their attitudes towards land degradation and SWC. From 1995 to 2014, the average labour investment in SWC per annum has being increasing in monetary terms and is currently reported to amount to more than USD 1.2 billion per year (Gebreselassie et al., 2016;Adimassu et al., 2018). This amount is much lower than the cost of land degradation (USD 4.3 billion per year).

Notwithstanding all these efforts by the central government, regional government, donors, and development partners, land degradation remains a serious problem and the adoption of SWC measures is generally low.

The low rate of adoption of improved SWC measures is not only peculiar to Ethiopia; it is a common phenomenon in Sub-Saharan Africa as a whole (Bekele 2003;Tenge et al., 2011; Asfaw and Neka, 2017; Wolka et al., 2018). Just as important, its underlying effects on crop productivity, income, and rural livelihoods can not to be overemphasized here. As such, we underline the need for identifying the key factors that prevent farmers from adopting the improved SWC measures, which could improve agricultural production and productivity. Previous studies which focused on this research agenda include Bekele and Drake, 2003,Holden et al., 2004,Hucket, 2010,Shimeles et al., 2011, Barungi et al., (2013), Fentie et al., 2013,Teshome et al., (2016), Asfaw and Neka (2017) andMekuriaw et al., (2018). These studies used different economic models to identify and map different demographics, institutional, socio-economic factors, plot level characteristics, and agro-ecology conditions that influence the adoption of SWC measures. The findings of these studies show that the adoption of SWC measures was influenced by different aspects, including the socio-economic factors, such as sex, age, and education of the household head. Others include household assets, income and land size, livestock holding, engagement in off-farm activities, as well as access credits. On the other hand, other scholars (e.g. Fentie et al., 2013; Teshome et al., 2016; Asfaw and Neka 2017) found out that contact with development agents was a key influential factors.

However, most of these previous studies have assumed the adoption of SWC measures as mutually exclusive with little or no interdependency among them. This implies that farmers can choose only one SWC measure from several of mutually exclusive (independent) options to practice on their single cultivated plot. In other words, each conservation measure does not have complimentary (positive) or substitution (negative) correlation with other conservation measures. This is unrealistic because other studies have already observed that farmers can adopt more than one SWC measures on an individual plot (Tenge et al., 2011; Amare et al., 2014). We therefore argue that SWC measures are not necessarily mutually exclusive and recognize the possibility of farmers to implement more than one SWC measures simultaneously on a single plot. We also acknowledge the possibility of having some potential correlations between the adopted measures. Based on this proposition, we use the case of smallholder farmers in eastern Ethiopia to analyse the factors that jointly influence (facilitate or impede) the adoption of different SWC measures and determine whether these measures complements or substitutes.

3.3 Methodology

3.3.1 Description of the study area

This paper uses data and information gathered from a study, which was conducted in the eastern part of Ethiopia specifically in East Hararge, which is one of the zones in the regional state of Oromia. East Hararghe is located between latitudes 7°32'- 9°44' North and longitudes 41°10'- 43°16' East. The area is characterized by rugged, dissected mountains, deep valley, plateaus, and plains, which are categorized into plateau, lowland, and transitional slope with altitudes ranging from 500 to 3,405 meters above the sea level (PEDO, 2012). The zone is characterized by three agro-ecological zones: the semi-arid, the semi-temperate, and the temperate tropical highlands. Temperate tropical highlands, known as *dega* constitute 11.4 percent of the total area of the zone. The temperate tropical highlands (*dega*) are located from 2,300-3,500 meters above the sea level with annual rainfall ranging from 1,200 to 2,000 mm and an average temperature of 10°C to 15°C. This region occupies the western and central highlands of the zone covering a total area of 2,589.14 km^2. The semi-temperate (tropical rainy midlands) part or *woinadega* accounts for 26.4 percent of the total area of East Hararghe. This agro-ecological zone is found in the western and central highlands with altitudes ranging from 1,500 to 2,300 meters above the sea level. It has annual rainfall ranging from 600 mm to 2000 mm and the mean annual temperature ranging from 15°C to 20°C. The semi-arid (tropical dry or arid) or *kola* comprises 62.2 percent of the total area of the East Hararghe. This is characterized by altitudes that range from 500-1500 meters above sea level, with an annual rainfall ranging from 400 to 820 mm and mean annual temperature that ranges from 20°C to 25°C. This region is found in the south eastern and northern parts of East Hararghe sharing borders Somali National Regional State, Bale Zone, and Dire Dawa Administration.

The farming system of East Hararghe constitutes a complex production system involving a diversity of interdependent mixed cropping and livestock keeping activities. The agro-climatic zone allows the area to produce a variety of agricultural products, including cereal crops such as sorghum, maize, wheat, and *teff*; vegetables like potatoes, onions, shallots, and cabbage; as well as perennial crops like coffee and *khat* (*Catha adulis*).

3.3.2 Sampling technique and data collection

The data used in this paper were gathered from a household survey conducted in the study area during August and September 2017. A multi-stage sampling procedure was used to select the study districts, *kebeles*,[6] and sample households. In the first stage, three districts (Deder, Gurugutu, and Haramaya) were selected randomly from the areas involved in the integrated SWC program. In the second stage, three *kebeles* were selected purposively from each district based on the extent of land degradation and participation in the program.

6 *Kebele is usually named peasant association and is the lowest administrative unit in the country.*

Then households were stratified into two strata (adopters and non-adopters of SWC). Finally, 200 households that adopted at least one SWC measure and 208 households that did not adopt any measure were randomly selected from both strata using proportionate probability sampling based on the size of each district and *kebele*. Moreover, data were collected on plot level leading to 790 observations (400 adopters plots and 390 non-adopters plots), numbers of plots cultivated in the 2016/17 production period.

The sample households were interviewed using a semi structured questionnaire, which was designed and pretested before the actual survey. The questionnaire covered a wide range of questions, which were intended to identify factors that influenced the adoption of SWC measures in the study area. Specifically, the questionnaire was used to solicit information on demographics, socio-economics, and institutional context of the sample households, as well as plot specific characteristics, types of SWC measures adopted, and perception of farmers about land degradation and SWC.

3.3.3 Methods of data analysis

There is evidence that the adoption of a specific SWC measure by smallholder farmers is not mutually exclusive or independent of other measures that are implemented on the same farm plot (Tenge et al., 2011; Amare et al., 2014). However, most economic models that have been used to analyse the adoption of these measures failed to capture the interdependence and relationship between them as well as the potential correlation between unobserved disturbances (error term). For instance, binary logit/probit models are only able to estimate the adoption of a single measure, with only two binary outcomes (Wooldridge, 2002). On the other hand, multinomial models are useful when the bivariate response models involve more than two possible outcomes. In other words, the multinomial models are useful when the outcome variables are unordered and mutually exclusive, and the farmer can choose only a single outcome from among a set of independent alternatives (Young et al., 2009). This means that, the model should pass the *independence of irrelevant alternatives* test. However, various studies have indicated that SWC measures are not mutually exclusive; thus, one must consider the possibility for a simultaneous use of more than a single SWC measure on a single farm plot as well as the potential for interdependence between these different measures (Tenge et al., 2011; Amare et al., 2014).

In this paper, we use a multivariate probit (MVP) regression model to identify factors affecting the adoption of three SWC measures namely; stone bund, soil bund, and bench terracing using a set of demographic, institutional, socio-economic and plot characteristics. The main advantage of this model is that it allows the analysis of potential correlation between unobserved disturbances (error terms) and the correlation between the adoption of each SWC measure (Belderbos et al., 2004; Young et al., 2009). Accordingly, the correlation among the decisions to adopt different measures may be due to technological complementarities or substitutabilities (Belderbos et al., 2004; Wainaina et al., 2016). In this case, estimates of simple binary logit or probit models can be biased and inefficient (Wainaina et al., 2016). Thus, the study employed the MVP model using simulated maximum likelihood with large numbers of random draws (*R=100*) on plot level observations.

The analysis is based on the expected utility maximization theory which suggests that individual farmer i will adopt a specific SWC measure on his or her farm plot if the expected utility from adoption (U_{ij}^{*}) is greater than the expected utility from any other alternative measures, including the business as usual (i.e. not adopting any measure) (U_{ij}), i.e. $y^*{}_{1i} = U^*_{ij} - U_{iJ} > 0$; where,$y^*{}_{ji}$is the net benefit (latent variable) that the farmer can received from adopting jth measure.

In the multivariate probit model, there are multiple binary dependent variables(y_{ji}), and multiple latent variables$(y^*{}_{ji})$. However, in this study, the multivariate model consists of three binary choice equations (i.e. soil bound, stone bound, and bench terracing). Consequently, the model assumes that each binary observed variable takes a value 1 if, and only if, the continuous latent variable is greater than zero:

$$y^*{}_{ji} = X_{ji}\beta_{ji} + v_{ji} \qquad (3)$$

$$y_{ji} = \begin{cases} 1 & if\ y^*{}_{ji} > 0 \\ 0 & \text{otherwise} \end{cases} \ (\mathrm{j = S, A, B}) \qquad (4)$$

where $y_{ji}$is the dependent variable; y^*_{ji} is a latent variable that captures the unobserved preferences associated with the choice of three SWC measures and is influenced by observed characteristics (X_{ij}) and unobserved characteristics captured by the stochastic error term (υ_{ij}); β_{1j} is a vector of parameters to be estimated. The error terms $v_{im\ \ m=1,2,3}$ are distributed multivariate normal with mean of 0 and a variance covariance matrix as given below with values of 1 on the leading diagonal and correlations $\rho_{kj} = \rho_{jk}$as off-diagonal elements.

$$\begin{bmatrix} v_{1i} \\ v_{2i} \\ v_{3i} \end{bmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{21} & 1 & \rho_{23} \\ \rho_{31} & \rho_{32} & 1 \end{pmatrix} \right] (5)$$

Thus, off-diagonal elements show correlation between the different types of SWC measures. In addition, the elements also capture unobserved characteristics that affect the adoption of different SWC measures (Teklewold, 2016; Ahmed et al., 2017).

3.4 Results and discussion

3.4.1 Household and socio-economic characteristics of households

The summary statistics of variables, which were hypothesized to influence the adoption of SWC and included in the MVP model, are provided in Tables 3.1. The specification of these variables was informed by a review of relevant literature (see Holden et al., 2004; Shimeles et al., 2011; Fentie et al., 2013; Ahmed et al., 2017; Asfaw and Neka 2017; Mekuriaw et al., 2018;). These variables include a range of demographic, socioeconomic, institutional, and plot characteristics. The average ages of household heads for adopters and non-adopters were 39.94 and 40.43 years respectively. About 86.80 percent of the heads of the sample households were males. When disaggregated as adopters and non-adopters the male headed households constituted 91.00 and 82.70 percent respectively of the total sampled households. The average family sizes for the adopters and non-adopters were 6.24 and 6.18 respectively. Overall, the household heads in the pooled sample have attended formal education for an average of 3.65 years. However, the study results show that farmers who adopted SWC measures were relatively more educated (with an average of 4.46 years in formal education vis-à-vis only 2.88 years for non-adopters) and the difference was statistically significant at 1 percent probability level. Education was found to be among the most important variables that directly influenced the adoption of SWC measures. Other studies done elsewhere in Ethiopia (Tesfaye et al., 2016; Asfaw and Neka, 2017; Mekuriaw et al., 2018) also confirm that farmers who adopted SWC measures were more educated than those who did not.

The study results also reveal that the value of assets owned by farmers varied with the adopters and non-adopters owning assets worth Birr 29594.80 and 19851.70 respectively. Overall, the units of livestock owned by the sampled households averaged at 1.78 TLUs. Moreover, farmers who adopted SWC measures earned higher annual income averaging at

Birr 20129.33 than the non-adopters who earned an average income of Birr 13753.03. Concerning the institutional variables, about 15.50 and 11.50 percent of the adopters and non-adopters respectively, had received credits from formal credit institutions. On average, farmers had contacted extension agents for 2.28 times per month per household. However, the adopters of SWC measures reported higher frequencies of contact with development agents than the non-adopters. This finding is in line with the findings of several other studies in Ethiopia and other places (see for example in Bogale et al., 2007;Teferi et al., 2015;Teshome et al., 2016; Mango et al., 2017).

Table 3.1: Description of explanatory variables

Variables	Description	Adopters		Non-Adopters		Total Sample	
		Mean	SD	Mean	SD	Mean	SD
Sex of hh	Dummy of sex of household head (1=male)	0.910***	0.287	0.827	0.379	0.868	0.339
Age of hh	Age of the household head in years	39.940	12.545	40.428	12.940	40.189	12.735
Education of hh	Level of education in numbers of years	4.460***	3.631	2.875	3.547	3.652	3.671
Number of plots	Total numbers of plots owned	1.995	0.848	1.889	0.806	1.941	0.827
Family size	Household size	6.240	1.998	6.178	2.074	6.208	2.035
Income	Total household income in Birr	20129.330***	15036.12	13753.030	10416.14	16878.67	13263.07
Off-farm Activity	Dummy for participation in off-farm activities (Yes=1)	0.440	0.498	0.476	0.501	0.458	0.499
Total Asset	Total value of assets in Birr	29594.798**	51561.049	19851.702	44079.070	24627.729	48081.687
Livestock (TLU)	Livestock owned (Tropical Livestock Unit)	1.939	1.825	1.627	1.957	1.780	1.898
Received credit	Dummy for receiving credits (Yes=1)	0.155	0.363	0.115	0.320	0.135	0.342
Contact of DA	Number of contacts with DA, per month	3.035***	2.298	1.559	1.529	2.282	2.078
Distance plot	Average walking distance to farming plots in minutes	13.289	16.250	14.935	15.342	14.156	15.780
Area plot	Total area of plot in Ha	0.156	0.099	0.143	0.106	0.149	0.103

***and ** * significant at the 1 and 5 percent probability levels, respectively

Our analysis of farm plot characteristics has considered various aspects including the average walking distance to the plot, severity of the erosion problem, soil fertility status, plot slope and plot sizes. Farmers who lived close to their farm plots had a location advantage in the sense that they saved time and energy from walking shorter distances before arriving at their plots as opposed to those who spent more time walking to their plots. Overall, the average time farmers spent to reach their farming plots was 13.29 and 14.93 minutes for adopters and non-adopters respectively. The average plot size for the pooled sample was 0.15 ha with adopters having relatively larger plot sizes than the non-adopters. Moreover, nearly 33.50 percent of adopters and 24.61 percent of non-adopters reported to have suffered from very severe soil erosion on their farming plots.

Table 3.2: Farm plot characteristics

Characteristics	Adopters		Non- Adopters		χ^2-value	Total	
	No.	Percent	No.	Percent		No.	Percent
Level of soil erosion							
Less severe	155	38.750	179	45.897		334	42.278
Severe	111	27.750	115	29.487	7.948**	226	28.608
Very severe	134	33.500	96	24.615		230	29.114
Soil fertility status							
Low	84	21.000	99	25.385	7.659**	183	23.165
Medium	227	56.750	183	46.923		410	51.899
High	89	22.250	108	27.692		197	24.937
Plot slope							
Flat	103	25.750	147	37.692	16.660***	250	31.646
Moderate	145	36.250	123	31.538		268	33.924
Steeper	152	38.000	120	30.769		272	34.430

***and ** * significant at the 1 and 5 percent probability levels, respectively

About 23.16, 51.90, and 24.94 percent of the sample plots had low, medium, and high soil fertility status respectively. However, the plots of farmers who adopted SWC measures were relatively less fertile than the plots of non-adopters. The low soil fertility status for the plots cultivated by farmers who adopted SWC measures might have influenced these farmers to adopt SWC measures so as to improve soil fertility, moisture content and hence, productivity of their plots. This finding is not surprising as a substantial proportion of the plots of the adopters were located along steeper slopes (38.00 percent) as opposed to that of non-adopter plots (30.77 percent). Elsewhere in north-western highlands of Ethiopia, Moges and Taye (2017) also reported a similar scenario that most of the adopters' plots were located at higher slopes than that of non-adopters. The results of Chi-square test in Table 3 also support the assertion that soil fertility status and slope were systematically associated with the adoption of SWC measures at 5 and 1 percent significant levels, respectively.

3.4.2 Adoption status of SWC and relationships between measures

The results of descriptive analysis summarized in Table 3.3 for different SWC measures implemented in the study area show that the adopters of SWC measures operated 400 plots and the non-adopters had 390 plots out of 790 plots which were covered by our study. About 93.5 percent of the adopters' plots (374 plots) were under at least one SWC measure. Specifically, the key SWC measures implemented in the study area are shown in Table 4. These include soil bund, stone bund, bench terraces, check-dam, as well as other mechanical and biological conservation measures. The most and widely applied SWC measures are the stone bunds (53.75 percent), followed by the soil bunds (50.50 percent), bench terraces(21.50 percent), and check-dams (3 percent). Others such as *fanyajuu,* cut of drain, and biological conservation are implemented only on about 4.25 percent of the adopters' plots.

Table 3.3: Major SWC measures in the study area

Types SWC	Number	Percent
Stone bund	215	53.75
Soil bund	202	50.50
Check-dam	12	3.00
Bench terraces	86	21.50
Other	17	4.25
Not implement	26	6.50

Most plots (about 62 percent or 231 plots) of the adopters were entailed a single conservation measure. About 33 percent (125 plots) and 3.5 percent (13 plots) comprised two and three SWC measures respectively. Very few plots (about 0.8 percent or 3 plots) contained more than three measures. This indicates that there is simultaneity and interdependence among the adoption decisions of improved SWC technologies measures in the study area.

Furthermore, the conditional and unconditional probability of adopting the three SWC measures as presented in Table 3.4 indicates that the three measures were interdependent. The unconditional probability for a plot with stone bund was 27.21 percent. However, this probability of adoption increased significantly to 57.92 percent and decreased to 10.47 percent for plots with soil bund and bench terracing conservation measures respectively. The unconditional probability for plots with soil bunds was 25.56 percent and this probability increased to 54.42 percent conditional on the adoption of stone bund but decreased to 17.44 percent when farmers adopt bench terracing. This implies that there is a complementary relationship between stone bund and soil bund and substitutability between bench terracing and stone bund/soil band. One of the possible explanations for the two relationships is to do with the relative costs of implementing specific SWC measures. Though more stable, stone bunds and bench terraces are relatively more expensive and labour demanding than the soil bunds (Rolker, 2012; Mishra and Rai, 2014). Soil bunds are relatively less stable, and depending on the type of soil, they may easily become eroded. Because of high costs of implementing stone bunds and terraces, most farmers prefer to combine the two (i.e. soil bunds with stone bunds interspaced) to reinforce their SWC structures (we refer this to complementary relationship). Moreover, where stones are plenty and readily available, farmers would prefer to use stone bunds; and where stones are either scanty or not readily available, farmers would obviously go for soil band or combine soil bunds with stone bunds interspaced. It is important to note that farmer's decision on what type of SWC measure to adopt will also depend on the steepness of the slope. For example, bench terracing is more suited and preferable on steeper slopes while stone bunds and soil bunds are common in plots with less steep slopes.

Table 3.4: Unconditional and conditional adoption probabilities

	Stone band (S)	**Soil band(A)**	**Bench terracing (B)**
$P(Y_k = 1)$	0.2721	0.2556	0.1088
$P(Y_k = 1 \mid Y_S = 1)$	1	0.5442	0.0419
$P(Y_k = 1 \mid Y_A = 1)$	0.5792	1	0.0743
$P(Y_k = 1 \mid Y_B = 1)$	0.1047	0.1744	1
$P(Y_k = 1 \mid Y_S = 1, Y_A = 1)$	1	1	0.0581
$P(Y_k = 1 \mid Y_S = 1, Y_B = 1)$	1	0.0246	1
$P(Y_k = 1 \mid Y_A = 1, Y_B = 1)$	0.0330	1	1

Y_k is a binary variable representing the participation status with respect to choice *K* (*K* = Stone band (*S*), Soil band (*A*), Bench terracing (*B*)

3.4.2 Determinants for adoption of SWC measures

As noted earlier, smallholder farmers who adopted SWC in the study area implemented at least one or more conservation measures. In this paper, we only focus on three specific SWC measures: stone bund, soil bund, and bench terracing because the other conservation measures were adopted by a small number of farmers.

Table 3.5 presents the results of MVP model. Before interpreting the results, it is essential to determine the statistical validity of the model and interdependence of dependent variables. Our model fitted the data reasonably well [Wald Chi-squared = 274.34, P= 0.000)]. Thus, the hypothesis that all coefficients in each equation are jointly equal to zero was rejected. On the other hand, the Chi-square test verified that the adoption decisions among the three SWC measures were not mutually exclusive (independent). According to Young et al., (2009), this confirms that the coefficient estimates obtained from joint estimation are asymptotically more efficient than the coefficient estimates obtained from a single equation when the binary outcome variables are correlated. Accordingly, all the possible pairs of correlation between the error terms were significant at less than one percent probability level, supporting joint estimation. The correlation coefficients between stone bund and soil bund, stone bund and bench terracing, and soil bund and bench terracing were 56.71 percent, -47.61 percent, and -27.29 percent respectively. The positive sign indicates that there was a positive (complementarity) and interactive correlation between stone bund and soil bund, while the negative sign for bench terracing indicates substitutability and interactive correlation with stone and soil bunds.

The results of MVP model reveal that demographic, socio-economic, institutional, and plot characteristics as significantly influencing farmers' choice of adopting SWC measures. Out of the 16 hypothesized variables, 5, 4, and 9 were found to be significantly influencing the adoption of stone bund, soil bund, and bench terracing, respectively.

The adoption of stone bund and soil bund conservation measures increased with the level of education of the household head and the relationship was significant at 5 and 1 percent levels, respectively. Heads of household who attended formal education were more likely to adopt stone and soil bunds than their uneducated counterpart heads of household. This might be because better education is associated with greater access to information and awareness about the severity of soil degradation and its consequences, which, in turn, motivate them to adopt SWC measures. Moreover, educated farmers are also more likely to use appropriate SWC measures than uneducated farmers. Elsewhere in Ethiopia, scholars (e.g. Fentie et al., 2013; Asfaw and Neka, 2017) also found education to be an important factor of accelerating the adoption of SWC measures.

The results of MVP model indicate that the adoption of stone bunds was decreasing with family size and this relationship was significant at 1 percent level. The negative relationship between family size and the adoption of stone bund is not surprising; particularly for households with a high dependency ratio (average dependence ratio was 129.24 percent). Thus, households with a large family size are less likely to choose the stone bund conservation structure than are smaller sized families. This relationship is also reported by Shifereaw and Holder (1998) and Bekele and Drake (2003) who found the adoption of SWC measures decreasing with family size.

Table 3.5: Results of multivariate probit model for choice of SWC measures

Variables	Stone Bund			Soil Bund			Bench terracing		
	Coef.	**B.Std. Err.**	**Z**	**Coef.**	**B.Std. Err.**	**z**	**Coef.**	**B.Std. Err.**	**z**
Sex of hh	0.3124	0.1759	1.78	0.2083	0.1661	1.25	-0.3629	0.1744	-2.08**
Age of hh	0.0018	0.0047	0.39	0.0058	0.0047	1.23	-0.0092	0.0059	-1.55
Level of education	0.0342	0.0169	2.02**	0.0439	0.0163	2.70***	0.0184	0.0200	0.92
Number of plots	0.0321	0.0678	0.47	-0.0491	0.0666	-0.74	-0.2659	0.0908	-2.93***
Family size	-0.0726	0.0278	-2.61***	-0.0201	0.0291	-0.69	0.0275	0.0306	0.90
Income	1.41e-05	5.38e-06	2.62***	9.33e-06	5.17e-06	1.80	4.36e-05	6.49e-06	6.72***
Off-farm Activities	-0.1429	0.1144	-1.25	-0.1255	0.1167	-1.08	-0.6379	0.1544	-4.13***
Total Asset	-8.45e-07	1.25e-06	-0.68	4.75e-07	1.19e-06	0.40	2.69e-07	1.30e-06	0.21
Livestock (TLU)	-0.0565	0.0301	-1.88	-0.0735	0.0323	-2.27**	-0.1691	0.0423	-4.00***
Received credit	-0.0381	0.1435	-0.27	0.0996	0.1440	0.69	0.3028	0.1560	1.94**
Contact of DA	0.1499	0.0248	6.04***	0.1568	0.0248	6.31***	0.0626	0.0300	2.09***
Distance plot	0.0004	0.0032	0.13	-0.0027	0.0033	-0.83	-0.0015	0.0041	-0.36
Erosion problem	0.0575	0.0641	0.90	0.2258	0.0641	3.52***	-0.0471	0.0840	-0.56
Plot soil fertility	-0.0383	0.0775	-0.49	0.0582	0.0757	0.77	-0.0739	0.0947	-0.78
Plot slope	0.2208	0.0628	3.52***	-0.0464	0.0666	-0.7	0.2188	0.0790	2.77***
Area plot	-0.0011	0.0664	-0.02	-0.0008	0.0663	-0.01	-0.1547	0.0748	-2.07***
_cons	-1.6584	0.3805	-4.36***	-1.8366	0.3975	-4.62***	-0.7384	0.4231	-1.75
/atrho21	0.6432	0.0784	8.21***				Multivariate probit (SML, # draws=100)		
/atrho31	-0.5179	0.1033	-5.01***				Log pseudo likelihood = -990.2775		
/atrho32	-0.2800	0.1016	-2.76***				Number of obs=790		
rho21	0.5671	0.0532	10.67***				Wald chi2(42)= 274.34		
rho31	-0.4761	0.0799	-5.96***				Prob > chi2=0.0000		
rho32	-0.2729	0.0940	-2.90***						
Joint probability (success)		0.0097							
Joint probability (failure)		0.5421							

Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(3) = 111.149 Prob > chi2 = 0.0000
***and ** significant at the 1 and 5 percent probability levels, respectively

Contact with extension agents constituted another important institutional factor that was positively influencing the decision to adopt stone bund, soil bund, and bench terracing conservation measures ($P < 0.01$). Farmers who have close contact with extension agents can develop awareness and understanding of the soil erosion problem and become encouraged to adopt improved soil conservation measures (Yirga, 2007; Bogale et al., 2007; Shimeles et al., 2011).

The adoption of stone bund and bench terracing conservation measures also increased with household income ($P < 0.01$). Farm households with high incomes were more likely to adopt SWC measures than were those with low incomes. This result is not astonishing because households with higher incomes can better afford to purchase SWC material and hire additional labour to implement the conservation measures. Furthermore, farmers with high incomes have a higher risk of bearing the capacity of testing new technologies than have those with low income.

The adoption of soil bunds increased with the perception of farmers about the severity of erosion on their farm plots ($P < 0.01$). This implies that farmers who had already perceived their plots to have soil erosion problem were more likely to adopt SWC measures than those who did not. This is because soil bunds were relatively cheaper to construct than the stone bunds and bench terraces. Farmers who perceived to have suffered from soil erosion on their plots would preferably select a cheaper measure.

The study results also indicate that the adoption of soil bunds and bench terraces decreased with the size of livestock holdings and the relationship was statistically significant at 5 and 1 percent respectively. This means that households with larger livestock holdings were less likely to adopt soil bund and bench terracing than were household with smaller livestock holdings. This is because households with larger livestock holdings focused more on livestock than on crop production. In addition, temporal yield gains through the application of manure might have replaced the fertility loss and potential productivity losses due to soil erosion, thus reducing conservation efforts. Similar findings were reported by Shimeles et al., (2011) and Fentie et al., (2013) for rural farmers of Gursum District, and Hulet Eju Enesie District, East Gojjam Zone respectively in Ethiopia.

The likelihood of farmers to adopt bench terracing declined with an increase of plot size ($P < 0.01$). According to Bekele and Drake (2002), larger numbers of plots may imply greater degree of land fragmentation. Then the construction of SWC structures would occupy a large area of land. Large numbers of farm plots are therefore associated with reduced likelihood for farmers to implement bench terracing. Similarly, farmers cultivating larger plots were less likely to construct bench terrace for SWC. This is because large cultivated farm plots require large amounts of SWC construction materials and labour, which make it difficult for subsistence farmers to implement. Moreover, most farmers cultivating large farm plots were relatively older and lacked the labour required for constructing conservation structures.

The results of MVP model also show that farmers who participated in off-farm activities as alternative sources of income were less likely to implement bench terracing ($P < 0.01$). This may be because off-farm activities competed with agricultural production in terms of labour resources making it difficult for farmers to mobilize adequate labour for the construction of SWC measures. On the other hand, farmers may earn more returns from participating in off-farm activities rather than concentrating on on-farm activities, which include among others the construction and maintenance of SWC structures. Thus, farmers engaged in off-farm activities are less likely to choose bench terracing as conservation measure because it is a labour intensive undertaking and competes with other activities over the available capital and labour resources.

Surprisingly, the male-headed households were less likely to adopt SWC measures as opposed to the female-headed households ($P < 0.05$). This could probably suggest that female heads of households were more concerned with produce and ensuring food security for their families than was the case with their male counterparts. Female heads of households therefore felt they had the responsibility of taking actions against land degradation, which reduces crop productivity. Furthermore, the government and other partner NGOs had given female headed households the priority in enabling them construct SWC structure and providing them with other related support. This might have influenced their decision of adopting SWC measures.

The adoption of stone bunds and bench terraces as SWC measures was also significantly influenced by the slope steepness. The steeper the slope of the plot the more likely that the farmer would adopt stone bunds and bench terraces as SWC measures. The is possibly because land degradation is more prominent and severe in steeper than on flat slopes and farmers are therefore more likely to adopt SWC measures that are more stable in plots located at steeper slopes.

Finally, the adoption of bench terracing increased with an increase of access to credits from formal lending institutions ($P < 0.05$). Most subsistence farmers lacked the capital, which is needed in reinvesting in farming, including the financial resources, which are needed for the construction of SWC structures. Hence, access to credit was vital for farmers to make timely purchase of agricultural inputs and invest in SWC structures.

3.5 Conclusions

This paper investigates the determinants of the adoption of improved SWC measures using the primary data collected from eastern Ethiopia. A sample of 790 plots, 400 belonging to adopters of SWC, and 390 plots operated by non-adopters were used. The findings show that at least one type of SWC measures was implemented on 374 plots (equivalent to 92.25 percent of the adopters' plots). Of these, the most widely and intensively used measures were stone bunds (53.75 percent), soil bunds (50.50 percent), and bench terraces (21.50 percent). Others constituted the least used measures, including the check-dam (3 percent) as well as the cut-off drains, *fanyajuu* and biological conservation, which were by practiced only on 4.25 percent of the plots of the adopters. Moreover, the conditional and unconditional probabilities of adoption decisions indicated that there were significant complementarities between stone bunds and soil bunds, as well as a substitutability relationship between bench terracing and stone bunds, and bench terracing and soil bunds. The results MVP model reveal that the adoption of bench tracing conservation measure was positively influenced by household income, farmers' contact with development agents, access to credit and the plot's slope steepness. The adoption of bench terraces was also negatively influenced by sex of the head of the household, the number of plots, the size of the plots, engagement in off-farm activities and the units of livestock owned. Similarly, the adoption of soil bunds was positively and significantly influenced by famers' contact with development agents, the level of education of the head of the household and the perception of farmers towards the intensity of the erosion problem on their plots. Equally important, the adoption of soil bunds was negatively influenced by the units of livestock owned by the household. Furthermore, the adoption of stone bunds was positively influenced by the level of education of the household head, annual income, farmer's contact with development agents and the steepness of the plot's slope, while influenced negatively by family size. Based on these findings, we recommend that efforts of addressing land degradation using SWC structures should focus on strengthening the human and institutional capacity. This should be done through enhancing farmers' education and continuous training and creation of awareness on the effects of land degradation, as well as, the importance of adopting appropriate SWC to control soil degradation and enhance farm productivity. In addition, it is imperative to create credit facilities that are tailor made to address the challenge of access to credits by smallholder farmers.

Conflict of interest

There is no conflict of interest among the authors.

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CHAPTER FOUR

4.0. Impact of Soil and Water Conservation Practices on Household Vulnerability to Food Insecurity in Eastern Ethiopia: Endogenous Switching Regression and Propensity Score Matching Approach

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4.1 Abstract

Governmental and developmental partners invest substantial resources to reduce land and water degradation in order to upgrade agricultural productivity, thus reducing food insecurity and related vulnerability in Sub-Saharan Africa. Understanding the impact of soil and water conservation on food insecurity outcomes would be a significant step toward improving environmental conditions, while ensuring sustainable and increased agricultural production. Therefore, this article analyzes the impact of adopting soil and water conservation on food insecurity and related vulnerability outcomes of farming households using a sample of 408 households selected using a multi-stage stratified sampling procedure from three districts in eastern Ethiopia. Vulnerability as expected poverty (three-step Feasible General Least Squares) is employed to analyze the vulnerability of sample households in the context of food insecurity. In addition, endogenous switching regressions with propensity score matching methods are combined *to obtain consistent impact estimates. The study findings reveal that education and sex of household head, use of irrigation and fertilizer, source of information, and cultivated land are the main factors influencing the adoption of soil and water conservation practices. Moreover, the adoption of soil and water conservation not only positively impacts the per capita food consumption expenditure and net crop value, but it also significantly reduces the probability of farmers being food insecure, vulnerable to food insecurity, as well as being transient and chronically food insecure. Therefore, policymakers and development organizations should consider soil and water conservation as a main strategy to reduce land degradation and improve the livelihoods of the rural farm households.*

Keywords: Soil and water conservation; Endogenous switching regression; Vulnerability to food insecurity; Ethiopia

4.2 Introduction

Ethiopia is one of the fastest growing countries in sub-Saharan Africa, with double digit economic growth in most years since 2005. Between 2000 and 2015, the poverty level fell from 44 to 30 percent of the population (IFPRI 2015). However, the figure remains high and Ethiopia ranks 174 out of 188 countries on the 2015 UN Human Development Index and 104 out of 119 in the Global Hunger Index ratings (IFPRI 2017). IFPRI (2015) also reports that a large portion of the country’s population, about 40 percent, consumes less than the recommended daily calories Agriculture, which employs about 72 percent of the active population in Ethiopia, would have contributed significantly in reducing poverty and food insecurity in the country. However, the levels of poverty and food insecurity remain high, especially in the rural areas of Ethiopia (World Bank 2016).

Food insecurity and poverty in Ethiopia is a long-term phenomenon caused by a combination of both natural and man-made factors; which include among others the limited opportunities for livelihood diversification, unreliable rainfall patterns, land degradation, poor infrastructure, poor access to agricultural inputs, and limited credit facilities (Dercon and Krishnan 1998;Wisner et al. 2004; Dercon and Christiaensen 2011;). Land and water degradation significantly affects household poverty, food insecurity, and related vulnerability. Empirical evidence shows that aggregate impacts of land and water degradation on food security are negative (see Shibru and Kfle 1998;Demel 2001;Paulos 2001; Berry et al. 2003; Shibru 2010).

The available information further indicate that over 25 percent of the land in Ethiopia is degraded at moderate to very severe levels (Kirui and Mirzabaev 2015) and about 0.084 million km^2, or 9.5 percent of the country constitutes one of the most intensively eroded regions in the world (Borrelli et al. 2017). Erosion is more severe in the Ethiopian highland, where 85 percent of the country’s human population lives, along with 77 percent of livestock population, and where there is intensive agriculture (Bewket, 2007). Paulos (2001) and Berrt et al. (2003) estimate losses caused by land degradation and unsustainable land management in Ethiopia to amount to billions of Birr.[7] Accordingly, Ethiopia loses at least three percent of agriculture Gross Domestic Product (GDP) annually; which is equivalent to USD 162 million in 2007 agricultural GDP (Gebreselassie et al. 2016). Moreover, land and water degradation reduces agricultural productivity, thus contributing immensely to food insecurity and poverty (Shibru 2010). It is estimated that,

[7] *Birr is Ethiopia currency (1USD=23.32 Birr).*

the amount of grain lost due to land degradation could feed more than 4 million people annually (Demel 2001).

Due to extensive land degradation, the natural resource base is deteriorating over time, directly resulting in food insecurity and related vulnerability (Barrett et al. 2002; Pender and Gebremedhin 2006; Berhanu et al. 2010). For instance, land and water degradation could affect all dimensions of food security in complex ways (food availability, accessibility, sustainability, and utilization). 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 (Demel 2001;Sonneveld 2002;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 local and national levels (Slaymaker 2002). Under such circumstances, subsistence farmers, who already have high food expenditures, would have to sacrifice further to meet their adequate nutritional requirements and, in addition, be unable to escape food insecurity in the near future (Stocking 2003).

Sustainable use of natural resources at household and community levels may improve the welfare of farming households and help them become food secured while escaping the vulnerability trap. Various studies (Tenge et al. 2011; Amare et al. 2014; Hishe et al. 2017; Keesstra et al. 2018) indicate that Soil and Water Conservation (SWC) practices help the reduced rainfall be transformed into runoff that increases soil fertility and moisture content, also improving soil health and function that maintains and restores the eco-system. In the long run, SWC will improve ecology and environment as well as local climate which is directly and indirectly associated with sustainable agriculture. Thus, adopting SWCcould substantially impact not just crop production, but also the household income of small holder farmers. According to Bogale and Shimelis (2009) and Mozumdar (2012), high production and household income increases the farmers' purchasing power and consumption from own production. Moreover, as argued by Jenkins et al. (2003), Devicienti (2002)andFinnie and Sweetman (2003), households with high income are less likely to be food insecure and less vulnerable to external shocks.

The Ethiopian government has considerable investments in conserving the environment, with its main objective being the improvement of livelihood opportunities through improved environmental conditions that ensures sustainable and increased agricultural production. During the 1980s, the country started SWC campaigns, encouraging the implementation of SWC practices in drought prone and extremely land degraded parts of Ethiopia (Mekuriaw and Hurni 2015). However, as farmers were forced to implement a conservation structure designed by experts, the programme was not effective (Wolka 2014; Haregeweyn et al. 2015; Mekuriaw and Hurni 2015;Mekuriaw et al. 2018). Since the Ethiopian People Republic Democratic Front (EPRDF) came to power in 1991, SWC has been a part of the agriculture extension package.

Since the beginning of the 2000s, under the SDPRP[8] framework launched in 2002 and the PASDEP launched in 2005, participatory watershed management is recognized by the government. Given this strategy, different sustainable land management programs have been implemented throughout the country. Further, the country developed a national guideline known as Community Based Participatory Watershed Development Programme (CBPWDP) in 2005 (MoARD 2005). Additionally, the integrated SWC implements

[8] *"Two successive Poverty Reduction Strategic Papers (PRSP), i.e., the Sustainable Development and Poverty Reduction Programme (SDPRP) launched in 2002 and the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) were instituted in 2005. The two broad strategies of PASDEP is to reduce poverty by stimulating rural growth through agriculture and rural development, and to strengthen public institutions to deliver services" (Gelaw and Sileshi 2013).*

different conservation technologies (such as Bench terracing, Soil bund, Stone bund, farm forestry, and so on) in selected areas. The main goal of this approach is to improve the living standards and welfare of the most vulnerable rural households and communities through SWC practices on individual farm plots and communal land, rainwater harvesting, promoting sustainable agricultural practices, and income diversifying agricultural practices (Gebregziabher et al. 2016). In addition, the programme also promotes and provides training to farmers on how to integrate SWC with livestock fattening, improved poultry and apiculture production, and promotion of fruit tree planting.

Despite these efforts to improve livelihood opportunities, as well as increase farm productivity through improved environmental conditions, the impacts of conservation practices on food consumption expenditure, food insecurity, and related vulnerability outcomes are not yet systematically analyzed. Various studies have examined the impact of SWC on technical efficiency, crop productivity, and household income. A study on the impact of SWC in Rwanda and the Democratic Republic of Congo shows that adopting SWC reduces technical efficiency(Judith et al. 2011). Kassie and Holden (2006)found that SWC in Ethiopia has yielded very low returns, with most smallholder farmers not receiving adequate incentive from their initial investment. In addition, Nyangena and Köhlin (2009), also revealed that plots under SWC practices generate less yields than those without. In contrast, Adgo et al. (2013), in their study of the impact of SWC practices in Ethiopia, found that the adoption of these practices can significantly increase *teff*, barley, and maize productivity. Elsewhere in Zimbabwe, Zikhali (2008), also found that soil conservation technology enhanced productivity. The studies by Bekele (2003) and Yenealem et al. (2013) also found that plots under SWC practices significantly increased crop production compared to those without. In another study, Tesfaye et al. (2016) also confirmed that SWC practices in Ethiopia increased grain productivity, and thus benefiting farm communities.

However, most of these previous studies have focused their analysis on current production and household crop income (e.g., Bekele 2003;Zikhali 2008; Adgo et al. 2013; Yenealem et al. 2013), failing to address the effect of conservation measures on current and expected welfare effects (food insecurity and related vulnerability) as well as other food security categories (transient and chronic food insecurity). To the best of our knowledge, this is the first rigorous paper that examines the association between food insecurity and related vulnerability with adoption of SWC in Africa, in general, and Ethiopia, in particular. Impact assessment provides major inputs for policy makers and planners when designing and developing effective and sustainable conservation strategies to mitigate current and future food insecurity through increased farm productivity. This paper employs the standard Per Capita Food Consumption Expenditure (PCFCE) and the Vulnerability as Expected Poverty (VEP) approaches to measure food security and Vulnerability to Food Insecurity (VFI) for farming households, respectively. This allows us to check the impact of adoption on current food insecurity as well as expected food insecurity after taking idiosyncratic shocks into account. Thus, the empirical premise of this article is to analyze the direction and magnitude of SWC effects on PCFCE, net crop value, food insecurity, and VFI in eastern Ethiopia. Moreover, the paper focuses on further disaggregated food security status categories among adopters and non-adopters, assessing the relationship between SWC adoption and food insecurity along with related vulnerability outcome variables by controlling for the effects of confounding factors.

The article is structured in five sections including the introduction part. The second section presents the sampling and data collection procedure, and a brief description of the study area. The third section describes the empirical methods and approaches used in the study. Specifically, we describe the analytical procedure for carrying out Endogenous Switching Regression (ESR), Propensity Score Matching (PSM), and VFI assessment. The fourth section discusses the results and the fifth section winds up the article by presenting some concluding `remarks and policy implications that emanate from the study.

4.3 Data collection and description of the study area

4.3.1 Sampling procedure and data collection

The study was conducted in East Hararghe, Ethiopia, in August and September, 2017.A multi-stage sampling technique was employed to select districts, *kebeles*,[9] and sample households. In the first stage, three districts (Deder, Gurugutu and Haramaya) were selected randomly from the programme intervention area. In the second stage, three *kebeles* were selected purposively from each district based on the extent of soil degradation and programme implementation. Then, the households were stratified into two strata (control and treated groups). Finally, 208 households that did not adopt any SWC measures from control group and 200 households that did adopt at least one SWC measures from treated group were randomly selected using proportionate probability sampling based on the size of each district and *kebele*(Table 4.1.).

[9]*Kebele is usually a named peasant association and is the lowest administrative unit in the country.*

Table 4.1: Sample districts, *Kebeles* and number of sample households

Districts	*Kebeles*	Adopters Sample	Non-AdoptersSample	Total sample
	Chafe Gurumu	28	27	55
Deder	Gaba Gudina	34	30	64
	Walfaa Gabon	21	17	38
	Biftu Dirama	15	17	32
Gurugutu	Ifa Jalala	29	25	54
	Mauhasa Walfaa	16	22	38
	Biftu Geda	17	24	41
Haramaya	Amuma	15	20	35
	Ifa Oromiya	25	26	51
	Total	**200**	**208**	**408**

For the household survey, a structured questionnaire was designed and pretested before the actual survey. The survey covered a wide range of issues that influence SWC technology adoption, as well as food security and related vulnerability at household levels. The survey collected information on each household's socio-economic and institutional characteristics, SWC practices, different shocks and coping strategies, as well as the available relevant food security programs and activities. Furthermore, information on the types and amount of food consumed by each household from different sources was collected. This 'food basket' was valued at local prices to determined PCFCE of the households and food poverty line.

4.3.2 Description of the study area

The study area (East Hararge) is found in eastern Ethiopia. It is a zone in the regional state of Oromia located between latitudes 7°32' - 9°44' North and longitudes 41°10' - 43°16' East. East Hararghe is characterized by rugged, dissected mountains, deep valley, plateaus, and plains, which are categorized into plateau, lowland, and transitional slope with altitudes ranging from 500 to 3,405 meters above sea level (PEDO, 2012). The zone is characterized by three agro-ecological zones namely the semi-arid (62.2 percent), semi-temperate (26.4 percent), and temperate tropical highlands (11.4 percent). This wide range of agro-climatic zone allows the area to produce a variety of products, including cereal crops like sorghum, maize, wheat, and *teff*; vegetables like potatoes, onions, shallots, and cabbage; as well as perennial crops like coffee and *Khat* (*Catha adulis*). Livestock keeping is also an integral activity of farmers.

East Hararge is highly prone to regular droughts as well as serious land and other natural resources degradation. Thus, the central and regional governments, along with other development partners, promote different policies and programs to reverse this situation. For instance, with the framework of the federal government's CBPWDP, an integrated SWC program, has been implemented since 2006 in selected districts. The main goal of this programme is to improve the livelihoods opportunities of rural communities and reduce food insecurity and poverty through integrated natural resource management (Gebregziabher et al. 2016).

4.4 Econometric modeling strategy

4.4.1 Endogenous Switching Regression (ESR)

When making an accurate impact assessment of SWC adoption on food insecurity and the VFI of farm households, the observable and unobservable characteristics of the adopters (treatment group) and non-adopters (control group) must be captured. However, most impact assessment approaches using non-experimental data (not randomly assigned) fail to capture observable and/or unobservable characteristics that affect adoption and outcome variables. For instance, instrumental variables capture only unobserved heterogeneity, but the assumption is that the parallel shift of outcome variables can be consider as a treatment effect (Kabunga et al. 2012; Shiferaw et al. 2014;Ahmed et al. 2017). In contrast, using regression models to analyze the impact of a given technology using pooled samples of users and non-users might be inappropriate because it gives the similar effect on both groups (Kassie et al. 2010; Kassie et al. 2011b;Ahmed et al. 2017). A methodological approach that overcomes the aforementioned limitations is endogenous switching regression (ESR), which is the most frequently used common method to analyze the impact of a given technology (Kassie et al. 2011a; Di Falco et al. 2011;Asfaw et al. 2012;Kabunga et al. 2012; Abdulai and Huffman 2014; Shiferaw et al. 2014; Ahmed et al. 2017; Jaleta et al. 2018). In this paper, we employ parametric ESR with non-parametric PSM technique to reduce the selection bias and assure consistent results by capturing both the observed and unobserved heterogeneity that influence the outcome variable as well as the adoption decision.

The impact of SWC technology on food insecurity and related vulnerability under the ESR framework follows two stages. 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 outcome variable and adoption of SWC (Shiferaw et al. 2014; Jaleta et al. 2018). The detail of the econometric modeling framework used is specified below.

The study adopts the expected utility maximization theory for farmer adoption of SWC measures. Individual *i* adopts SWC on their farm plot if expected utility from adoption (U_{swc}) is greater than the expected utility from non-adoption (U_{nswc}), i.e. U_{swc} -U_{nswc}>0.

$$I_i^* = \beta X_i + v_i \quad where\ I_i = \begin{cases} 1 & if\ I_i^* > 0 \\ 0 & otherwise \end{cases} \qquad (1)$$

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 observed binary indicator variable that equals 1 if a farmer adopts SWC practices and zero otherwise, while β is a vector of parameters to be estimated.

In this article, adoption is defined if farmers used at least one of the introduced SWC technologies (soil bund, stone bund, and bench terracing) on one of their farm plots. However, according Jaleta et al. (2018), if selection equation (first stage) is endogenous in the outcome equation (second stage), result would be biased and inefficient. Therefore, it is vital to use instrumental variable methods to identify the second stage equation from the first stage equation. The instrumental variable should affect the adoption of SWC but not the outcome variables, such as PCFCE, net crop value, food insecurity, VFI, as well as chronically and transient food insecure. While we acknowledge that the selection of instrumental variables is empirically challenging, we use sources of information (government extension (yes=1) and farmers cooperatives (yes=1)) as a selection instrument. Adegbola (2007) indicates that the source of information is a vital element in influencing adoption of a given agricultural technology through the facilitation of diffusion process by accessing a certain source of information. Falco et al. (2011), Shiferaw et al. (2014) and Di and Khonje et al. (2015) use these variables as instruments to assess the impact of adopting improved seed and adaptation to climate change on household food security and welfare. Thus, these variables are more likely to be correlated with the adoption of SWC but not with the food insecurity and vulnerability outcome variables or correlated with the unobserved. Moreover, we also check the validity of the instrument variable using a falsification test. The test shows that the variable significantly affects the adoption decision but not our outcome variables.[10]

[10] *Instrument variable are jointly statistically significant in the selection equation[$\chi 2$ = 25.30 (p = 0.0000)] but not outcome functions: for example binary food insecurity status of adopter [$\chi 2$ = 1.11 (p =*

The outcome regression equations both for adopters (regime 1) and non-adopters (regime 2) can be written as an endogenous switching regime model:

$$Regimes\ 1: Y_{1i} = \theta_1 Z_{1i} + \varepsilon_{1i,} \qquad if\ I = 1 \qquad (2a)$$
$$Regimes\ 2: Y_{2i} = \theta_2 Z_{2i} + \varepsilon_{2i,} \qquad if\ I = 0 \qquad (2b)$$

where Y_i represents outcome variables (PCFCE, net crop value and a binary outcome variables such as food insecurity, VFI, chronically and transient food insecure status) of smallholder farmer i for each regime (1 = adopter of SWC practices and 0 = non-adopter of SWC practices), Z_i is a vector of farm and socio-economic characteristics of household that affects outcome variables, and θ_i is a vector of parameters to be estimated. The error terms in Equations (1) and (2) are distributes 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_1^2 , σ_2^2, andσ_v^2 are the variance of the outcome function of regimes 1 and 2, as well as the selection equation, respectively,σ_{12}, σ_{1v}, andσ_{2v} represent the covariance of ε_{1i}, ε_{2i}, and v_i. The variance of selection question (σ_v^2) is assumed to be equal to 1 since the coefficients (β) are estimable only up to a scale factor. Maddala (1983), confirm that the covariance of the error terms ($\varepsilon_{1i}$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 error term of the second stage are non-zero because the error term of the first stage (v_i) and second stage ($\varepsilon_{1i}$and ε_{2i}) are associated to each other. The expected value of error terms of question (2a) and (2b) can be expressed as follows:

0.5742)] and non-adopter; [χ2 = 1.04 (p = 0.5937)] as well as the PCFCE for adopters [F = 0.43 (p = 0.6520)] and non-adopters [F = 0.87 (p = 0.4188)]. We also find similar result for other outcome functions (net crop value and binary chronic and transitory food insecurity, VFI).

$$E\left(\varepsilon_{1i}\ \middle|Y_i=1\right)=\sigma_{1v}\frac{\emptyset(\beta X_i)}{\Phi(\beta X_i)}=\sigma_{1v}\lambda_{1i} \qquad (4a)$$

$$E\left(\varepsilon_{2i}\ \middle|Y_i=0\right)=\sigma_{2v}\frac{\emptyset(\beta X_i)}{1-\Phi(\beta X_i)}=\sigma_{2v}\lambda_{2i} \qquad (4b)$$

where$\emptyset(.)$ is the standard normal probability density function, $\Phi(.)$ is the standard normal cumulative density function, while $\lambda_{1i}=\frac{\emptyset(\beta X_i)}{\Phi(\beta X_i)}$ and $\lambda_{1i}=\frac{\emptyset(\beta X_i)}{1-\Phi(\beta X_i)}$ are the inverse Mills ratios (IMR) estimated from the first stage question. Then the variable included in the second stage questions captures both absorbed and unabsorbed heterogeneity in estimation procedure ESR (Jaleta et al. 2018). To address the heteroskedasticity arising from the generated regressors, the standard errors in questions (2a) and (2b) are bootstrapped (Shiferaw et al. 2014; Ahmed et al. 2017; Jaleta et al. 2018).

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) is obtained. Similarly average treatment effect on the untreated (ATU) also can be calculated by comparing the expected values of the outcomes of non-adopter in real and counterfactual scenarios (Khonje et al. 2015). Following Kabunga et al. (2012), Asfaw et al. (2012), Shiferaw et al. (2014), Abdulai and Huffman (2014) and Jaleta et al. (2018) the expected values of the outcomes of both adopters and non-adopters in reality and the counterfactual are given as follows:

Adopters with adoption of SWC (real):

$$E\left[Y_{1i}\ \middle|X,I=1,\right]=\theta_1X_{1i}+\sigma_{1v}\lambda_{1i} \qquad (5a)$$

Non-adopters without adoption of SWC (real):

$$E\left[Y_{2i}\ \middle|X,I=0,\right]=\theta_2X_{2i}+\sigma_{2v}\lambda_{2i} \qquad (5b)$$

If adopted had non-adopted SWC (counterfactual):

$$E\left[Y_{2i}\ \middle|X, I=1,\right] = \theta_2 X_{1i} + \sigma_{2v}\lambda_{1i} \qquad (5c)$$

If non-adopted had adopted SWC (counterfactual):

$$E\left[Y_{1i}\ \middle|X, I=0,\right] = \theta_1 X_{2i} + \sigma_{1v}\lambda_{2i} \qquad (5d)$$

Hence, ATT of adopter is computed as the difference between (5a) and (5c):

$$\begin{aligned} ATT &= E\left[Y_{1i}\ \middle|X, I=1,\right] - E\left[Y_{2i}\ \middle|X, I=1,\right] \\ &= (\theta_1 - \theta_2)X_{1i} + (\sigma_{1v} - \sigma_{2v})\lambda_{1i} \end{aligned} \qquad (6)$$

Likewise, ATU of non-adopters is computed as the difference between (5b) and (5d):

$$\begin{aligned} ATU &= E\left[Y_{1i}\ \middle|X, I=0,\right] - E\left[Y_{2i}\ \middle|X, I=0,\right] \\ &= (\theta_1 - \theta_2)X_{2i} + (\sigma_{1v} - \sigma_{2v})\lambda_{2i} \end{aligned} \qquad (7)$$

According to Shiferaw et al. (2014), Khonje et al. (2015) and Ahmed et al. 2017, ESR models have a very strong exclusion restriction and the falsification test may not be adequate to confirm identification. Thus, results may be sensitive to selection of instrumental variables. Therefore, we also use binary PSM to further robustness check of the results obtains from ESR. PSM helps to adjust for initial differences between treated and control groups by constructing a statistical comparison group that is based on a model of the probability of treatment participation, using observed farm and socio-economic characteristics (Caliendo and Kopeinig 2008; Rosenbaum and Rubin 1983; Winters et al. 2011). Adopters are then matched on the basis of this probability (propensity score) to non-adopters (Rosenbaum and Rubin 1983). The ATT of the SWC can be obtained by comparing the mean outcomes between treatment and control groups (Imbens and Wooldridge 2008; Wooldridge 2002; World Bank 2010). This approach is widely applied in the literature (e.g., Kassie et al. 2010; Dillon 2011;Amare et al. 2012; Manda et al. 2018) and we do not present the detail methodology here. For a detailed specification and the steps of PSM, see Wooldridge(2002),World Bank(2010) and Imbens and Wooldridge(2008).

4.4.2 Vulnerability as expected poverty

We adopt an econometric model for analyzing household vulnerability to food insecurity proposed by Chaudhuri et al.(2002) and Christiaensen and Subbarao (2005). The model follows the VEP approach, using PCFCE as a measure of household welfare. Hence, this paper uses the VEP approach, to the analysis of vulnerability of sample households in the context of food security.

The vulnerability of household during time t is expressed as the probability of the household falling below the minimum food requirements at time t + 1:

$$V_{it} = P(\mathrm{c}_{\mathrm{it+1}} < z) \qquad (8)$$

Where the vulnerability of a household (V_{it}) during time t, $C_{it+1,}$ is the household's PCFCE (welfare indicator) at time t + 1 and z is the threshold level (food poverty line).

The VEP approach, using expected mean and variance of household PCFCE, estimates household vulnerability in the context of food insecurity. According to Bogale(2012) and Günther and Harttgen (2009), the expected mean of PCFCE is determined by the household socio-economic, institutional, and farm characteristics as well as community characteristics, whereas the variance (also known as volatility) in household consumption captures the household and community shocks that influence to differences in PCFCE for households that share the same characteristics (Günther and Harttgen 2009). As proposed by Christiaensen and Subbarao (2005), the stochastic process generating the PCFCE of a farming household i can be expressed as follow:

$$\ln c_i = x_\mathrm{i}\beta + \varepsilon_\mathrm{i} \qquad (9)$$

Where C_i is log of PCFCE level, X_i is represents observable farm and household socio-economic characteristics, β is a vector of parameters, and ε_i is a disturbance term with mean zero and variance of $\sigma^2 \varepsilon_i$ (heteroscedastic). This implies that variances of the error term vary across households depending on farm and household socio-economic characteristics. Then, the variance of the unexplained part of PCFCE, ε_i regressed on household characteristics (X_i) to generate estimates for the expected variances specified as:

$$\sigma^2 \varepsilon_i = x_i\theta + \tau_i \qquad (10)$$

Where θ represents the vector of parameters to be estimated and τ is the error term of equation 10.

However, due to heteroscedasticity, the estimated β and θ is inefficient but not biased. Hence, as Chaudhuri (2000), Chaudhuri et al. (2002) and Christiaensen and Subbarao (2005) suggest, we used Three Step Feasible Generalized Least Squares (FGLS) to obtain that to obtain efficient parameters ($\hat{\beta}$ and$\hat{\theta}$).

The steps involved include, first, an estimation procedure applying the Ordinary Least Squares (OLS) method to equation (9) and estimates the residual. Then equation (10) is estimated by OLS using the squared residuals from the estimation of equation (9) as dependent variables. The predictions from this regression are used to re-estimate equation (10) by OLS after having weighted each residual by $X_i\theta$. The new estimates of θ are asymptotically efficient and are used to weight equation (9), which is re-estimated using weighted least squares to obtain asymptotically efficient estimates of β(Bogale 2012). Finally, we used the FGLS asymptotically efficient of β and θ to estimate the expected and variance of log of PCFCE for each household using the following equation as detailed in (Bogale 2012; Mutabazi et al. 2015).

$$E\,[\ln c_i / x_i] = x_{i\hat{\beta}}$$
$$V\,[\ln c_i / x_i] = x_{i\hat{\theta}} \qquad (11)$$

Assuming that household PCFCE is log-normally distributed, each household's probability of food insecurity at time t + 1 is expressed as:

$$\hat{V} = \hat{P}(\ln c_i < \ln z / x_i) = \emptyset\left(\frac{\ln z - \ln \hat{c_i}}{\sqrt{\hat{\sigma}_i^2}}\right) \qquad (12)$$

Where $\emptyset$ is the cumulative density of the standard normal distribution; $\hat{\sigma}_i^2$ is a variance of standard error of the regression; $\hat{c_i}$ and Z are the expected household PCFCE and threshold level (food poverty line), respectively; and $\hat{v}$ is the probability of each household to fall below the threshold level, with values ranging between zero and one. Chaudhuri et al.(2002), justify a threshold measure that is used to define vulnerable households as those with an estimated vulnerability coefficient of above or equal to 0.5. Thus, we classify households as vulnerable if $\hat{V}$ is above or equal to 0.5 and, otherwise, non-vulnerable.

To determine current household food insecurity status, we use the amount of money required to achieve the daily minimum dietary requirement. The government of Ethiopia set the minimum acceptable level of per capita calorie intake per day to 2200 (MoFED 2002). Thus, a household is considered to be food insecure if the amount of money it spends on food is not adequate to purchase a basic diet that is nutritionally adequate. Accordingly, the amount of money required to achieve the daily minimum dietary requirement (food poverty line) was Birr 2637.86 per annum. The CSA (2017)country and regional level consumer price indices show that the Consumer Price Index (CPI) of the study area (Oromia regional state) was 171.4 percent (December 2011 = 100). Thus, the food poverty line was deflated in order to take into account the effect of inflation.

Therefore, the adjusted food poverty line was estimated at Birr 1539 per adult equivalent, per year, at the end of 2011 constant price. Thus, a household was considered food insecure if PCFCE was less than food poverty line; otherwise food secure.

By combining vulnerability status with the current food insecurity status of household, we extended the analysis into several food insecurity and vulnerability categories among the adopters of SWC practices and non-adopters. Accordingly, currently food secure and less vulnerable households were considered to have a stable food secure status. The currently food insecure and high vulnerable households were considered as chronic food insecure; households are currently food secure and high vulnerable and vice versa are consider as transient food insecure.

4.5 Results and discussion

4.5.1 Descriptive analysis

Before embarking on the impact assessment, it is important to describe the socio-economic, institutional, and farm characteristics of the sample households (Table 4.2). About 91 and 83 percent of adopter and non-adopter households, were respectively male headed. The average ages of household heads were 39.94 and 40.43 years for adopters and non-adopters respectively. However, the majority of family members had ages of less than 15 or greater than 64 years, which means that the dependency ratio was high (averaging at 1.33 for adopters and 1.25 for non-adopters). The average family sizes for adopters and non-adopters were 6.24 and 6.18, respectively. As far as the household head educational status is concerned, 40.69 percent of household heads never attended formal education. Overall farmers who adopted SWC practices were relatively more educated (with an average of 4.46 years in formal education) than their counterpart non-adopter farmers (average of 2.88 years in formal education).

Table 4.2: Description of explanatory variables among adopter and non-adopter

Characteristics	Description	Adopters N=200 Mean	SD	Non-Adopters N=208 Mean	SD	Total Sample N=408 Mean	SD
Age of hh	Age of household head (years)	39.940	12.545	40.428	12.940	40.189	12.735
Education of hh	Level of education (number of years in formal education)	4.460***	3.631	2.875	3.547	3.652	3.671
Family size	Household size (number)	6.240	1.998	6.178	2.074	6.208	2.035
Sex of hh	Dummy of sex of household head (1=male)	0.910***	0.287	0.827	0.379	0.868	0.339
Dependence ratio	Dependence ratio	133.445	96.725	125.194	96.275	129.239	96.466
Cultivated land	Total cultivated land holding	0.317***	0.188	0.263	0.155	0.289	0.174
Numbers of plot	Total numbers of plots owned	1.995	0.848	1.889	0.806	1.941	0.827
Off-farm	Dummy for engagement in off-farm activities(Yes=1)	0.440	0.498	0.476	0.501	0.458	0.499
Use of fertilizer	Dummy for using fertilizer (Yes=1)	0.595**	0.492	0.490	0.501	0.542	0.499
Livestock TLU	Livestock owned (Tropical Livestock Units)	1.939*	1.825	1.627	1.957	1.780	1.898
Information EA	Dummy for access to information from extension agents (Yes=1)	0.850***	0.357	0.659	0.475	0.752	0.432
Information FC	Dummy for access to information from farmers' cooperative (Yes=1)	0.215*	0.412	0.149	0.356	0.181	0.385
Dis. FTC	Average walking distance to FTC (minutes)	29.425	27.962	27.197	22.995	28.289	25.544
Use of irrigation	Dummy for using irrigation (Yes=1)	0.375	0.485	0.322	0.468	0.348	0.477
Erosion problem	Dummy for erosion problem (Yes=1)	0.650*	0.478	0.558	0.499	0.603	0.490
Received credit	Dummy for receiving credits (Yes=1)	0.155	0.363	0.115	0.320	0.135	0.342

***, **, and * significant at the 1, 5, and 10 percent probability levels, respectively

Generally, adopters had larger cultivated land and livestock holdings than the non-adopters. Moreover, nearly 65 percent of adopters and 56 percent of non-adopters indicated that their cultivated land was degraded. Both the adopters and non-adopters relied mainly on rain-fed agriculture, with only 35 percent practicing irrigation and 54 percent using chemical fertilizers. Concerning institutional variables, about 14 percent of the respondents received credits from formal financial institutions. Furthermore, out of the total sample households, 75.20 and 18.10 percent of households accessed information from government extension agents and farmers' cooperatives, respectively, with those adopting SWC having more access to information than non-adopters from both sources.

4.5.2 Food insecurity and vulnerability to food insecurity

Table 4.9 in the appendix presents the three-step FGLS regression results showing explanatory variables that are used to estimate the expected PCFCE and its variance, as well as to show the relationship between explanatory variables with expected PCFCE and its variance. The model outcome reveals that the age of household head and family size, as expressed by adult equivalence, influenced expected food consumption expenditure negatively. Use of improved seeds, size of cultivated land, adoption of SWC practices, and access to credit influenced expected food consumption expenditures positively. The results of vulnerability assessment indicated that about 43 percent of the sample households were vulnerable, with farmers who adopted SWC practices being less vulnerable (31 percent) than those who did not (54 percent). Overall, the PCFCE and expected PCFCE of adopters were higher than that of non-adopters.

The results of net crop value and current food insecurity status for adopters and non-adopters are presented in Table 4.3. The average net crop value was significantly higher (by Birr 4176.66 per ha per year) for SWC adopters than that of non-adopters. Again, the results of analysis of current food insecurity status show that farmers who adopted SWC were relatively less food insecure than their counterpart non-adopters.

Table 4.3: Descriptive statistics of outcome variables among adopters and non-adopters

Outcome variables	Adopters		Non-Adopters		Total	
	N=200		N=208		N=408	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
PCFCE/annum	3453.32**	1405.10	3067.04	1552.5	3256.30	1492.8
Expected PCFCE /annum	3280.82**	684.85	2842.64	537.95	3057.40	651.62
VFI	0.31***	0.46	0.54	.49	0.43	0.49
Food insecurity	0.305***	0.40	0.42	0.49	0.36	0.48
Net crop value	10791.02*	6723.20	6614.36	5356.10	8661.70	6407.90

***, **, and * significant at the 1, 5, and 10 percent probability levels, respectively

By combining vulnerability status with the current food insecurity status of households, we classified food security status of adopters and non-adopters into stable food secure, chronic food insecure, and transient food insecurity. The results of analysis are summarized in Table 4.4.

Table 4.4: Food security status among adopters and non-adopters

Outcome variables	Adopters		Non-Adopters		χ^2-value	Total	
	N=200		N=208			N=408	
	No.	**Percent**	**No.**	**Percent**		**No**	**Percent**
Stable food secure	115	57.500	71	34.135	24.762***	186	45.588
Chronic food insecure	36	18.000	63	30.288		99	24.265
Transient food insecurity	49	24.500	74	35.577		123	30.147

***, **, and * significant at the 1, 5, and 10 percent probability levels, respectively

The results reveal that 57.50 percent of adopters were categorized under the stable food security status, compared with only 34.14 percent for non-adopters. In general, adopters were food secure and had a low probability of falling into food insecurity in the near future (they were less vulnerable to food insecurity). In contrast, about 18.00 percent of adopters and 30.29 percent of non-adopters were food insecure for an extended period of time and were considered to be chronic food insecure. Furthermore, 24.50 percent of adopters and 45.58 percent of non-adopters frequently moved into and out of the state of food insecurity (transient). The Chi-test result indicates that there is a systematic relationship between the household's food insecurity status and the adoption of SWC at the 1 percent level of significant.

These descriptive statistics indicate that households who adopted SWC practices were less prone to food insecurity and vulnerability than their counterpart non-adopter farmers. However, at this level, it is difficult to conclude that adopting SWC practices reduces current and future food insecurity. Thus, an impact assessment is needed to determine if this decrease in food insecurity and VFI is due to SWC adoption, by controlling for the observed and unobserved heterogeneity that affect the adoption decision and outcome variables.

4.5.3 Endogenous switching regression estimation results

The first stage ESR binary probit estimation results are presented in Table 4.5. Our probit model fits the data reasonably well [Wald Chi-squared = 78.2, P= 0.000)]. The model results reveal that household, socio-economic, and institution factors influenced the SWC adoption decisions significantly. Use to fertilizers was positively and significantly associated with adopting SWC. Thus, farmers with access to fertilizer had a higher probability of adopting SWC practices. The adoption of soil and water conservation increased with the level of education of household heads. Household heads who attended formal education have better understanding of the advantages and challenges of adopting SWC practices (Fentie et al. 2013; Asfaw and Neka, 2017). Similarly, male headed households were also more likely to adopt SWC practices than female headed households. The possible explanation is that male headed households have better access to information and the labor required to implement new technology than the female headed households (Bekele and Drake 2006; Mekuriaw et al. 2018).

Farmers with access to information from government extension agents and farmers' cooperatives are more likely to adopt conservation technology. This is because the provision of information helps farmers to become aware of the problem of land degradation and its consequences, while also acquiring new knowledge regarding the new technological measures to address it (Chilot 2007; Bogale et al. 2007; Shimeles et al. 2011). Another factor that significantly and positively influenced the adoption of SWC was the size of cultivated land. Farmers who owned and/or operated larger sizes of cultivated land were more likely to allocate a proportion of land for SWC than those with small holdings of cultivated land. Moreover, ownership operation of large cultivated or land holdings are often linked to rich farmers with relatively big capital, which directly influences the adoption of SWC practices (Paulos et al. 2001).

Table 4.5: Decision of adopting SWC: Probit model

Number of observations	**408.000**		
Wald chi2(15)	**56.58**		
Prob > chi2	**0.000**		
Pseudo R2	**0.108**		
Log pseudo likelihood	**-252.139**		
Variables	**Coef.**	**Robust Std. Err.**	**Marginal Effects**
Sex of hh	0.335*	0.203	0.131
Age of hh	0.007	0.006	0.003
Education of hh	0.067***	0.023	0.027
Family size	-0.043	0.036	-0.017
DPR	0.001	0.001	0.000
Use fertilizer	0.252*	0.146	0.100
Distance FTC	0.002	0.003	0.001
Numbers of plot	-0.010	0.089	-0.004
Use of irrigation	0.149	0.150	0.060
Cultivated land	0.938**	0.462	0.374
TLU	-0.029	0.042	-0.011
Received credit	0.112	0.204	0.045
Information EA	0.685***	0.163	0.262
Information FC	0.437**	0.222	0.172
Off-farm	0.034	0.142	0.013
Erosion problem	0.209	0.143	0.083
_cons	-1.902***	0.438	

***, **, and * significant at the 1, 5, and 10 percent probability levels, respectively

The results of ESR model-based ATT and ATU for the key outcome variables related to the adoption of SWC practices are presented in Table 4.6. As discussed earlier, the main outcome variables considered in this analysis are PCFCE and net crop value in Birr, as well as the binary outcomes like food insecurity, VFI, chronic food insecurity, and transient food insecurity.

The ESR impact results reveal that the adoption of SWC practices reduces the probability of current food insecurity, VFI, transient food insecurity, and chronically food insecurity. On the other hand, the adoption increases PCFCE and net crop value. For farmers who adopted SWC practices but theoretically would have not adopted, then their PCFCE decreased by Birr 205.97 (USD 8.83). This means, for an average family size expressed as adult equivalent of 4.89 per household, the ATT of food consumption expenditure at household level would decrease by Birr 1007.19 (USD 42.19) as a result of not adopting SWC practices. Similarly, if non-adopters would have adopted SWC practices, then their average PCFCE would have significantly increased by Birr 297.084 (USD12.74). Considering the average family size (in adult equivalent) of 4.89, this would translate to Birr 1477.02 (USD 62.30) per household. If SWC adopters had they not adopted, the average probability that they will be food insecure would increase by 10.50 percent. Likewise, if SWC non-adopters had adopted, the average probability of food insecurity would decrease by 12.10 percent. On the other hand, households who actually adopted switching to non-adopted, then the probability of VFI status would have increased by 14.10 percent but deceased by 23.30 percent for non-adopters had they adopted SWC. Moreover, the adoption of SWC practices reduced the probability of chronic food insecurity by 6.80 percent for adopters and 15.60 percent for non-adopters. Likewise, the average probability of transient food insecurity status (shift from food secure to food insecure and vice-versa) for adopters would increase by 17.80 percent, if they had not adopted SWC practices, while if non-adopters had adopted SWC, then transient food insecurity would decrease by 7.50 percent.

In addition to food insecurity and vulnerability outcome variables, we also checked the impact of SWC practices on net crop value. The results indicate that the average net crop value for adopters would drop by 3284.088 (USD140.83) per ha if the adopters would not have adopted. In the same way, if the non-adopters had adopted, their average net crop value would have increased by Birr 2980.135 (USD 127.79) per ha. Therefore, ESR reveals that the adoption of SWC practices in Ethiopia would have not only reduced food insecurity and related vulnerability but also increased food consumption expenditure by increasing net crop value.

The results of second stage ESR, the estimated coefficients of PCFCE, and binary food insecurity and VFI are presented in Table 4.10 of the appendix.

Table 4.6: Endogenous switching regression model result (average treatment effects)

Outcome variables	**Farm household type and treatment effect**	**Decision stage**		**Treatment effect**
		To adopt	**Not to adopt**	
PCFCE	ATT	3451.763	3245.793	205.970**
	ATU	3365.626	3068.542	297.084***
Food security	ATT	0.295	0.400	-0.105***
	ATU	0.299	0.420	-0.121***
VFI	ATT	0.312	0.452	-0.141***
	ATU	0.306	0.539	-0.233***
Transient food	ATT	0.244	0.422	0.178***
insecurity	ATU	0.281	0.356	0.075***
Chronic food insecure	ATT	0.175	0.243	-0.068**
	ATU	0.137	0.293	-0.156***
Net crop value	ATT	10791.02	7506.935	3284.088***
	ATU	9594.495	6614.361	2980.135***

***, **, and * significant at the 1, 5, and 10 percent probability levels, respectively

4.5.4 Binary propensity score matching estimation results

In addition to the ESR model, this study uses the PSM technique to check the robustness of the results obtained from the ESR model. Propensity scores (the probability of adoption in SWC) are estimated using a probit model. Fig. 4.1 shows the distribution of adopter and non-adopter households with respect to estimated propensity scores. The figure illustrates the estimated propensity distribution for treatment and control households. The upper half of the graph refers to the propensity score distribution of treatment groups, while the bottom half shows the control groups. The y-axis refers to the densities of estimated propensity scores.

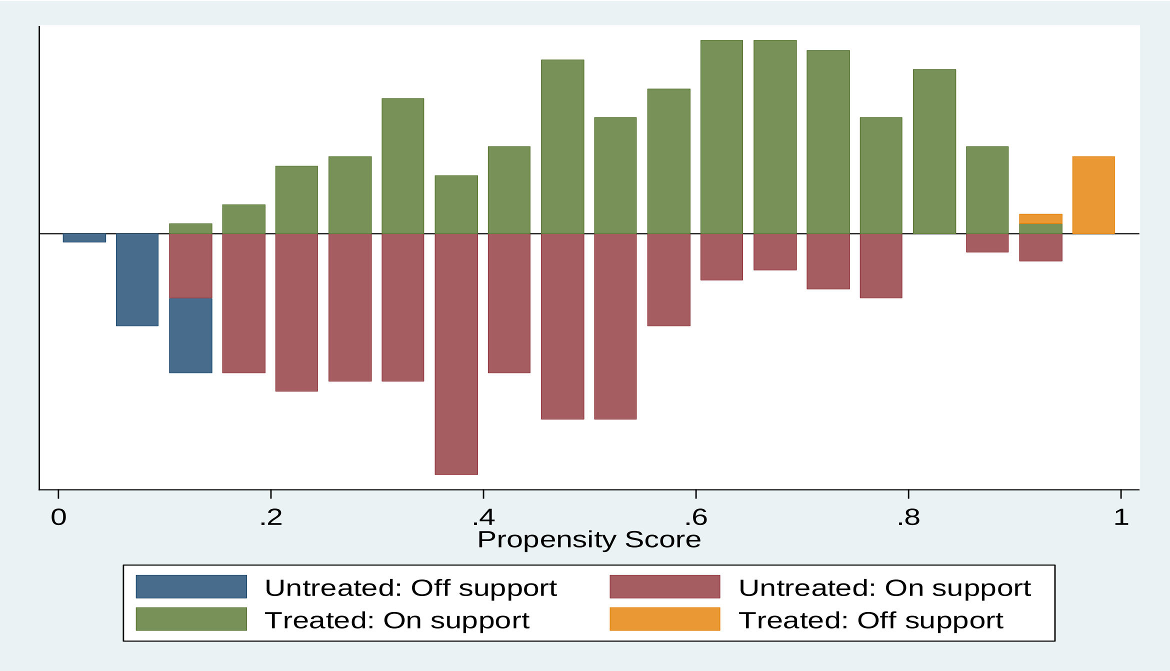

Figure 4.1: Distribution of estimated propensity distribution for treatment and control groups and common support area

A common support condition should be imposed on the propensity score distribution of SWC adopters and non-adopters. The estimated propensity scores vary between 0.1437482 and 0.9463331 (mean = 0.5600339) and 0.0344507 and 0.8960822 (mean =

0.4203612) for the treatment and control groups, respectively. The common support region would then lie between 0.1437482 and 0.8960822. Accordingly, off support sample were discarded from the analysis in estimating the ATT in both groups. Thus, about 90 percent of adopters and non-adopters were in the common support area, showing substantial overlap between the two groups. Table 4.7 presents the balancing tests of each matching algorithm before and after matching. The results show that the mean standardized bias is reduced after matching (4.2 to 5.8 percent) compared to before matching (22.2 percent). Similarly, the Pseudo-R^2 declines substantially, from 10.82 percent to a range of 0.8 to 1.7 percent. The likelihood ratio tests (p-values) indicated the joint significance of all covariates at less than 1 percent probability level before matching, but it was insignificant after matching. Furthermore, the total bias significantly declined in the range of 47.49 to 70.01 through matching. Thus, these tests clearly show that the matching process balances the observed characteristics between treated and control groups after matching.

Table 4.7: Covariates balancing tests before and after matching

Matching algorithm	Pseudo-R^2		LR χ^2 (p-value)		Mean standardized bias		Total % |bias| reduction
	Before	After	Before	After	Before	After	
NNM[a]	0.1082	0.008	61.17 (0.000)	4.63 (0.997)	22.2	4.2	70.01
KBM[b]	0.1082	0.017	61.17 (0.000)	8.93 (0.916)	22.2	5.8	47.49
KBM[c]	0.1082	0.010	61.17 (0.000)	5.67 (0.991)	22.2	5.4	49.87
RCM[e]	0.1082	0.014	61.17 (0.000)	7.32 (0.967)	22.2	5.8	47.73
RCM[f]	0.1082	0.009	61.17 (0.000)	4.63 (0.997)	22.2	4.8	54.38

NNM[a] = One nearest neighbor matching and common support
KBM[b] = Kernel with band width 0.01 and common support
KBM[c] = Kernel with band width 0.025 and common support
RCM[e] = Radius Caliper 0.01 matching
RCM[f] = Radius Caliper 0.025 matching

Table 4.8 reports the ATT, based on PSM technique, using three different matching algorithm techniques (nearest neighbor matching (NNM), Kernel based matching (KBM), and Radius matching methods). The result reveals that, as in the ESR analysis, the adoption of SWC practices resulted in increase in both PCFCE and net crop value, while reducing the probability of food insecurity, VFI, transient food insecurity, and chronic food insecurity. The PSM result reveals that, on average, the adoption of SWC practices increased the households' PCFCE in the range of Birr 232.683 to 352.276 (7.21 to11.51 percent). Similarly, it reduced the probability of food insecurity and VFI in the range of 9.10 to 11.50 percent and 12.90 to 16.60 percent, respectively. The probability of chronic (transient) food insecurity declined in the range of 7.10 to 7.50 percent (16.6 to 18.60 percent), respectively. Moreover, the results show that the adoption of SWC would significantly increase the annual net crop value, from Birr 3127.105 to 3907.255 per ha. It can therefore be concluded that, apart from the slight differences in magnitude between the PSM and ESR estimates, the adoption of SWC had positive impacts on PCFCE and net crop value. It reduced food insecurity and VFI in the study area. In line with this finding, Bekele(2003) Benin (2006), Kassie and Holden(2006),Pender and Gebremedhin(2006) and Kassie et al.(2009), all conclude that investing in SWC measures has positive impacts in terms of mitigating land degradation, while also improving crop production and income, especially in moisture deficit areas.

Table 4.8: Average treatment effects: propensity score matching

Outcome variables	Matching algorithm	Mean of outcome variables based on matched observations		ATT	SE
		Adopters	Non-adopters		
PCFCE	NNM[a]	3457.124	3224.441	232.683*	135.682
	KBM[b]	3412.933	3066.386	346.546*	206.996
	KBM[c]	3454.214	3115.266	338.948*	185.058
	RCM[e]	3412.933	3060.657	352.276*	200.755
	RCM[f]	3454.214	3135.852	318.362*	181.284
Food insecurity	NNMa	0.291	0.383	-0.091*	0.054
	KBMb	0.307	0.418	-0.111*	0.064
	KBMc	0.296	0.410	-0.115**	0.058
	RCMe	0.307	0.413	-0.106*	0.062
	RCMf	0.296	0.409	-0.113**	0.057
VFI	NNM[a]	0.307	0.463	-0.157***	0.055
	KBM[b]	0.312	0.441	-0.129**	0.065
	KBM[c]	0.311	0.448	-0.137**	0.059
	RCM[e]	0.307	0.472	-0.166***	0.054
	RCM[f]	0.311	0.444	-0.133**	0.058
Chronic food insecure	NNM[a]	0.176	0.218	-0.042	0.038
	KBM[b]	0.178	0.215	-0.037	0.042
	KBM[d]	0.179	0.250	-0.071*	0.041
	RCM[e]	0.178	0.221	-0.043	0.041
	RCM[f]	0.179	0.253	-0.075*	0.045
Transient food insecurity	NNM[a]	0.246	0.412	-0.166***	0.053
	KBM[b]	0.254	0.440	-0.186***	0.060
	KBM[c]	0.250	0.426	-0.176***	0.056
	RCM[e]	0.254	0.435	-0.181***	0.059
	RCM[f]	0.250	0.421	-0.171***	0.056
Net crop value	NNM[a]	10776.351	7649.246	3127.105***	677.304
	KBM[b]	10613.861	6706.606	3907.255***	732.947
	KBM[c]	10628.070	7134.457	3493.613***	712.120
	RCM[e]	10613.861	6838.140	3775.721***	724.140
	RCM[f]	10628.070	7266.212	3361.858***	704.070

***, **, and * significant at the 1, 5, and 10 percent probability levels, respectively

4.6 Conclusions and implications for policy

This article analyzes the impact of SWC on food insecurity and vulnerability to food insecurity using primary data collected in eastern Ethiopia. We employ both parametric (ESR) and non-parametric (PSM) methods to reduce the effect of self-selection bias due to both observable and unobservable farm, household socio-economic characteristics as well as to test the consistence of the results, respectively.

The first stage ESR indicates that access to irrigation and fertilizers, education level and sex of household head, access to information, and size of cultivated land were significantly associated with SWC adoption. The results obtained from both the ESR and PSM models were consistent, indicating that the adoption of SWC practices not only generated a significantly positive impact on PCFCE and net crop value, but it also reduced food insecurity and VFI. In fact, the probability of food insecurity and VFI decreases by 10.5 and 14.1 percent, respectively, compared to their counterfactuals. Further, PCFCE and net crop value increased by Birr 205.97 and 3284.088 per ha due to SWC adoption, respectively.

Therefore, it can be concluded that SWC practices significantly contribute to the economic and social development of smallholder farmers by improving average PCFCE and net crop values as well as by reducing food insecurity and VFI. In addition, in countries like Ethiopia, where 40 percent of people suffer from food insecurity and land degradation is severe, SWC practices should be considered as a principle strategy for improving the livelihoods of the rural farm households and preventing land and water degradation. The findings of the study stress that policymakers and development organizations should focus on strengthening human and institutional capacity through enhanced education and continuous training on the effects of land degradation, as well as the use of appropriate

SWC technologies, the use of fertilizer, and rainwater harvesting, in order to increase productivity while restoring the soil and agro-ecosystem health. Furthermore, governmental and developmental partners should give more attention to integrated SWC programs not just to improve environmental conditions and increase agricultural productivity but also improve the food security status of farming households and reduce vulnerability to external shocks.

Table 4.9: Three-step Feasible Generalized Least Squares result for determinant of vulnerability to food insecurity (N=408) (Appendix)

Variables	Log food consumption expenditure			Variance of food consumption expenditure		
	Coef.	**Robust Std. Err.**	**t**	**Coef.**	**Robust Std. Err.**	**t**
Sex	-0.017	0.065	-0.26	-0.073	0.042	-1.75*
Age	-0.003	0.002	-1.75*	0.001	0.001	0.72
Education	-0.001	0.005	-0.16	-0.001	0.002	-0.25
Adult equivalent	-0.107	0.014	-7.65***	0.002	0.006	0.29
Dependence ratio	1.93E-04	1.82E-04	1.06	1.98E-05	8.57E-05	0.23
Annual income	1.94E-07	2.20E-06	0.09	1.06E-08	9.14E-07	0.01
Off-farm Activity	-0.003	0.039	-0.08	-0.002	0.019	-0.1
Use of fertilizer	0.005	0.045	0.1	-0.004	0.018	-0.23
Use of improved seed	0.129	0.045	2.89***	0.026	0.020	1.28
Use of irrigation	0.057	0.037	1.53	-0.025	0.018	-1.39
Cultivated land	0.243	0.134	1.81*	-0.012	0.071	-0.17
Adoption of SWC	0.100	0.038	2.62***	0.022	0.019	1.13
Total Asset	0.000	0.000	0.94	2.65E-07	1.81E-07	1.46
Livestock TLU	0.015	0.012	1.25	-0.006	0.006	-1.03
Crop diversification	0.008	0.024	0.33	-0.014	0.011	-1.23
Coping strategy index	-0.003	0.004	-0.68	0.001	0.002	0.40
Number of Sick	0.038	0.028	1.39	-0.006	0.014	-0.40
Received credit	0.094	0.057	1.66*	0.020	0.028	0.71
Contact with DA	2.90E-04	0.009	0.03	4.70E-04	0.004	0.12
_cons	8.384	0.122	68.68***	0.162	0.060	2.68***
F(19, 388)=8.12				F(19, 388)=1.51		
Prob > F=0				Prob > F=0.077		
R-squared=0.304				R-squared=0.044		
Root MSE=0.335				Root MSE=0.163		

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

Table 4.10: Second stage ESR estimates result (Appendix)

Variables	PCFCE (Birr)				Food insecurity				VFI			
	Adopters		Non-adopters		Adopters		Non-adopters		Adopters		Non-adopters	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Sex	-426.321	260.946	-174.221	444.679	2.061	0.608***	-0.336	0.296	-0.486	0.461	0.434	0.495
Age	-33.564	7.546***	0.639	7.674	0.046	0.011***	0.010	0.008	0.058	0.012***	0.075	0.016***
Education	-30.069	36.222	8.492	35.361	0.082	0.044**	0.013	0.038	-0.126	0.076***	0.016	0.059
Family size	-254.154	47.564***	-356.325	86.037***	0.248	0.065***	0.249	0.060***	1.095	0.144***	1.260	0.161***
DPR	-0.623	1.216	2.584	1.139**	0.002	0.001*	-0.002	0.001	-0.005	0.002*	-0.004	0.002**
Use fertilizer	207.537	208.906	15.590	224.804	0.315	0.255	-0.145	0.237	-1.440	0.355***	-0.701	0.347**
Distance FTC	-2.492	3.252	-4.595	2.490*	0.009	0.004***	0.002	0.003	0.004	0.004	-0.006	0.003*
Numbers of plot	273.262	113.885**	-103.980	115.713	-0.487	0.161***	0.044	0.144	-0.201	0.211	-0.113	0.221
Use of irrigation	38.457	211.661	411.458	192.417**	0.405	0.262	-0.568	0.228**	-0.666	0.318**	-1.500	0.377***
Cultivated land	-584.153	564.800	2397.716	934.104**	1.295	0.671*	-1.345	0.764*	-1.443	0.980	-4.610	1.230***
TLU	34.674	45.871	84.649	46.484*	-0.084	0.072	-0.111	0.053**	-0.289	0.101***	-0.272	0.068***
Received credit	102.810	292.532	413.881	369.584	0.435	0.335	-0.525	0.322	-1.852	0.602***	-1.129	0.427***
Off-farm	330.742	196.487*	-442.868	176.937**	0.426	0.250*	0.152	0.200	-0.043	0.331	0.510	0.300*
Erosion problem	-219.123	237.879	124.210	179.242	0.925	0.286***	0.151	0.204	-0.091	0.407	0.371	0.318
IMR	-643.589	569.941	99.487	411.321	1.807	0.683***	-0.410	0.529	-1.207	0.869	0.646	0.678
_cons	6938.765	1058.708***	4627.157	617.019***	-8.760	1.711***	-1.447	0.552***	-5.360	1.621***	-7.439	1.135
Number of obs.	200		208		200		208		200		208	
F-Value/Wald Chi2	6.62		3.68		65.430		33.010		87.390		76.980	
Prob > F	0		0		0.000		0.005		0.000		0.000	
R-squared/Pseudo r2	0.3146		0.260		0.299		0.139		0.653		0.619	
Root MSE	1207.4		1388.9									
Log pseudo likelihood					-84.949		-121.968		-42.944		-54.653	

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

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CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study assessed the adoption and impact of soil and water conservation on the current food insecurity and vulnerability of farming households in Eastern Ethiopia. Specifically, the study addressed the impact of SWC adoption on current food insecurity and vulnerability to food insecurity, chronically and transitory food insecurity, per capita food consumption expenditure as well as net crop value. Furthermore, the study also analysed households' food insecurity and related vulnerability, and determinants of adoption of multiple SWC technologies.

The results of analysis indicated that, many farm households in the study area suffered from perpetual food insecurity (36.03 % of sample) and persistent vulnerability to food insecurity (about 42.64 % sample). When considering both the current and future food insecurity the study revealed that one-quarter of households were chronically food insecure, while about one-third of households were in dynamic food insecurity status that is they were transient food secure and transient food insecure. Overall, about 54 % of households were categorized as vulnerable to food insecurity. These included households who were food insecure at the time of the survey and those who were categorized as transient food secure group.

The Three-step Feasible Generalized Least Squares estimation results indicate that age of household head and family size were found to have a negative and significant influence on expected food consumption expenditure. Furthermore, using improved seed, total cultivated land, use of SWC, and received credit were significant predictors with positive influence on expected food consumption expenditure. Alternatively, food insecurity status of farm households was significantly influenced by age of household head, family size in adult equivalent, use of irrigation, adoption of soil and water conservation, and coping strategies.

The analysis of the adoption of soil and water conservation measures indicated that there were significant complementarities between stone bund and soil bund, while substitutability between bench tracing and stone bund and bench terracing and soil bund conservation technologies. The results of MVP model reveal that the adoption of bench tracing conservation measure was positively influenced by household income, farmers' contact with development agents, access to credit and the plot's slope steepness. The adoption of bench terraces was also negatively influenced by the sex of the household head, the number of plots, the size of plots, engagement in off-farm activities, and the units of livestock owned. Similarly, the adoption of soil bunds were positively and significantly influenced by famers' contact with development agents, the level of education of the household head and the perception of farmers about the intensity of erosion problem on their plots. Just as important, the adoption of soil bunds was negatively influenced by the units of livestock owned by the household. Furthermore, the adoption of stone bunds was influenced positively by the level of education of the household head, annual income, farmer's contact with development agents, and plot's slope steepness. The adoption of stone bunds was influenced negatively by family size.

The results obtained from both the ESR and PSM models were consistent, indicating that the adoption of SWC practices not only generated a significantly positive impact on PCFCE and net crop value, but it also reduced food insecurity, vulnerability to food insecurity, chronic food insecurity, and unstable food insecurity statuses. Therefore, it can be concluded that SWC practices significantly contribute to the economic and social development of smallholder farmers by improving average PCFCE and net crop values as well as by reducing food insecurity and VFI.

5.2 Recommendations

Based on the empirical findings reported in this research, the following recommendations can be made:

The findings show` that the households which were vulnerable to food insecurity were more (54%) than those that are currently food insecure (36%). Therefore, any design and implementation of food security policies and strategies to reduce food insecurity should also focus on both the current and future access to food by smallholder farmers, and also understanding of the existing categories of food insecurity at household level.

The study findings also reveal that the adoption of soil and water conservation practices significantly contributed to economic and social development of smallholder farmers in the study area. This is achieved through the improvement of the average expenditure on food consumption and net crop value which is in turn improves food security and reduces household's vulnerability to food insecurity and chronic food insecurity. Therefore, SWC measures should be considered as a principle strategy for improving the livelihoods of the rural farm households and preventing land and water degradation.

Contact with development agents was found significantly factors in influence the adoption of conservation measures. Similarly, education of the household heads positively influenced the adoption of stone and soil bunds conservation measures. This implies that the development of human capital is an important factor for increasing the probability of smallholder farmers to adopt SWC measures. Therefore, the government and other concerning bodies should further improve the provision of extension services by employing qualified extension agents who are professional in disseminating suitable SWC measures and changing the farmers' attitude toward land degradation and conservation measures. Moreover, it is important to improve the education level and skills of farming households through extension education and initiated adult education programmes to improve the use of appropriate SWC measures and farm productivity.

The study findings also show that access to credit significantly influenced the expected expenditure on food consumption and the adoption of bench terracing conservation measure. Many, farming households faced difficulties in accessing credits mainly due to requirements by lending institutions. To adopt SWC measures smallholder farmers must have access to adequate financial resources. It is therefore, recommended that the government should established tailor-made financing programme for farmers/smallholder to lend from rural financing while minimising bureaucratic procedures.

The study findings revealed that there was a strong complementarity between stone bund and soil bund, and substitutability between bench tracing and stone bund; and between bench terracing and soil bund conservation technologies. Thus, the study recommend that soil and water conservation practices should be economically, and technically feasible, considering the availability of construction material in order to minimise farmers cost and durability of SWC structure.

Biological conservation measures are the effective methods of SWC, especially since they are available at low in cost and these can be used with other physical conservation measures. In addition, biological conservation measures improve organic matter and increase infiltration as well as roughages that are also important as livestock feed.

However, most of smallholder farmers in the study area used physical SWC measures with only less than 1 % of households using biological conservation measures. It is important to note that any SWC measure should be integrated with livestock rearing by introducing appropriate biological conservation measures complementarities with other measures.

APPENDICES

Appendix Tables

Appendix Table 1: Conversion factors of tropical livestock unit (TLU)

Livestock Category	TLU
Cows	1.000
Oxen	1.000
Heifers	0.750
Calves	0.200
Goats	0.060
Sheep	0.060
Donkey (adult)	0.700
Donkey (young)	0.350
Mature chicken	0.013
Horses or mules	1.100
Camels	1.250

Source: Storck *et al.* (1991)

Appendix Table 2: Conversion factors for Adult -Equivalents

Age group (years)	Male	Female
<10	0.6	0.6
10-13	0.9	0.8
14-16	1.00	0.75
17-50	1.00	0.75
>50	1.00	0.75

Source: Storck, *et al*., 1991

Appendix Table 3: Conversion factors of food items consumed by sample households

Food items	Unit	kilocalorie (kcal)	Proportion of Consumption (%)
Barley	kg	3723	0.00
Maize	Kg	3751	31.45
Sorghum	Kg	3805	31.14
Teff	Kg	3589	0.35
Wheat	Kg	3623	20.37
Irish potato	Kg	1037	1.34
Sweet potato	Kg	1360	0.06
Lentil	Kg	3522	0.18
Beans	Kg	3514	2.89
Peas	Kg	3553	0.50
Onion	Kg	713	0.65
Pepper	Kg	933	0.00
Beef	Kg	1148	0.09
Milk	Kg	737	1.23
Egg	No.	61	0.04
Sugar	Kg	3850	2.74
Butter	Kg	7364	0.00
Edible oil	litter	8964	6.93
Vetch	Kg	3470	0.00
Coffee	Kg	1103	0.04

Sources: Ethiopian Health and Nutrition Research Institute, (1998)

Appendix Table 4: Multicollinearity test for variables in the MVP

Variable	VIF	1/VIF
Annual income	2.16	0.463
Livestock TLU	1.68	0.595
Total Asset	1.53	0.652
Education of household head	1.45	0.690
Number of plots	1.35	0.743
Age of household head	1.33	0.751
Off-farm Activities	1.28	0.781
Area of plot	1.27	0.790
Adult equivalent	1.17	0.853
Sex of household head	1.16	0.865
Erosion problem	1.15	0.866
Plot Slop	1.13	0.883
Use of fertilizer	1.13	0.885
Contact with DA	1.11	0.901
Received credit	1.07	0.931
Distance plot	1.05	0.954

Appendix Table 5: Multicollinearity test for variables in the logit and FGLS model

Variable	VIF	1/VIF
Annual income in Birr	2.34	0.427
Use of fertilizer	1.8	0.554
Livestock TLU	1.77	0.566
Use of improved seed	1.76	0.569
Cultivated land	1.63	0.612
Total Asset	1.61	0.619
Education of household head	1.61	0.622
Age of household head	1.57	0.637
Coping strategy index	1.47	0.682
Off-farm Activities	1.4	0.716
Contact with DA	1.29	0.776
Adoption of SWC	1.29	0.777
Adult equivalent	1.26	0.797
Crop diversification	1.24	0.805
Use of irrigation	1.2	0.835
Received credit	1.18	0.850
Sex of hh	1.16	0.862
DPR	1.12	0.894
Received credit	1.07	0.932

Appendix Table 6: Multicollinearity test for variables in the ESR and PSM

Variable	VIF	1/VIF
Distance FTC	1.671	0.599
Information FC	1.640	0.610
Cultivated land	1.538	0.650
Education of household head	1.526	0.655
Age of household head	1.467	0.682
TLU	1.334	0.750
Numbers of plot	1.313	0.761
Family size	1.254	0.797
Use of irrigation	1.254	0.797
Use fertilizer	1.214	0.824
DPR	1.177	0.849
Sex of household head	1.157	0.865
Off-farm activities	1.139	0.878
Information EA	1.131	0.884
Erosion problem	1.128	0.887
Received credit	1.083	0.923

Appendix Table 7: Contingency coefficient among discrete explanatory variables

	Sex of hh	Use of irrigation	Received credit	Off-farm Activities	Use of fertilizer	Use of improve seed	Adoption of SWC
Sex of hh	1	0.058	0.120	0.018	0.105	0.154	0.122
Use of irrigation		1	0.047	0.032	0.297	0.258	0.055
Received credit			1	0.032	0.026	0.019	0.058
Off-farm Activity				1	0.023	0.081	0.036
Use of fertilizer					1	0.528	0.104
Use improve seed						1	0.069
Adoption of SWC							1

Appendix Table 8: Second stage ESR estimates of PCFCE and food insecurity

Variables	PCFCE (Birr)				Food insecurity			
	Adopters		Non-adopters		Adopters		Non-adopters	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Sex	-426.321	260.946	-174.221	444.679	2.061	0.608***	-0.336	0.296
Age	-33.564	7.546***	0.639	7.674	0.046	0.011***	0.010	0.008
Education	-30.069	36.222	8.492	35.361	0.082	0.044**	0.013	0.038
Family size	-254.154	47.564***	-356.325	86.037***	0.248	0.065***	0.249	0.060***
DPR	-0.623	1.216	2.584	1.139**	0.002	0.001*	-0.002	0.001
Use fertilizer	207.537	208.906	15.590	224.804	0.315	0.255	-0.145	0.237
Distance FTC	-2.492	3.252	-4.595	2.490*	0.009	0.004***	0.002	0.003
Numbers of plot	273.262	113.885**	-103.980	115.713	-0.487	0.161***	0.044	0.144
Use of irrigation	38.457	211.661	411.458	192.417**	0.405	0.262	-0.568	0.228**
Cultivated land	-584.153	564.800	2397.716	934.104**	1.295	0.671*	-1.345	0.764*
TLU	34.674	45.871	84.649	46.484*	-0.084	0.072	-0.111	0.053**
Received credit	102.810	292.532	413.881	369.584	0.435	0.335	-0.525	0.322
Off-farm	330.742	196.487*	-442.868	176.937**	0.426	0.250*	0.152	0.200
Erosion problem	-219.123	237.879	124.210	179.242	0.925	0.286***	0.151	0.204
IMR	-643.589	569.941	99.487	411.321	1.807	0.683***	-0.410	0.529
Constant	6938.765	1058.708***	4627.157	617.019***	-8.760	1.711***	-1.447	0.552***
Number of obs.	200		208		200		208	
F-Value/W.Chi2	6.62		3.68		65.430		33.010	
Prob > F	0		0		0.000		0.005	
R-squ./Pseudo r2	0.3146		0.260		0.299		0.139	
Root MSE	1207.4		1388.9					
Log pseudo likelihood					-84.949		-121.968	

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

Appendix Table 9: Second stage ESR estimates of VFI and transient food insecurity

Variables	VFI				Transient food insecurity			
	Adopters		Non-adopters		Adopters		Non-adopters	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Sex	-0.486	0.461	0.434	0.495	-0.121	0.386	0.246	0.314
Age	0.058	0.012***	0.075	0.016***	0.023	0.010**	0.013	0.009
Education	-0.126	0.076***	0.016	0.059	0.028	0.039	0.073	0.039*
Family size	1.095	0.144***	1.260	0.161***	0.037	0.053	0.108	0.054**
DPR	-0.005	0.002*	-0.004	0.002**	0.001	0.001	-0.003	0.001**
Use fertilizer	-1.440	0.355***	-0.701	0.347**	0.175	0.257	-0.128	0.233
Distance FTC	0.004	0.004	-0.006	0.003*	0.002	0.004	0.000	0.003
Numbers of plot	-0.201	0.211	-0.113	0.221	-0.384	0.168**	0.089	0.140
Use of irrigation	-0.666	0.318**	-1.500	0.377***	-0.013	0.247	-0.323	0.226
Cultivated land	-1.443	0.980	-4.610	1.230***	-0.241	0.789	2.080	0.787***
TLU	-0.289	0.101***	-0.272	0.068***	0.068	0.065	-0.118	0.057**
Received credit	-1.852	0.602***	-1.129	0.427***	-0.337	0.300	-0.198	0.353
Off-farm	-0.043	0.331	0.510	0.300*	0.082	0.217	0.032	0.215
Erosion problem	-0.091	0.407	0.371	0.318	0.239	0.260	-0.119	0.210
IMR	-1.207	0.869	0.646	0.678	0.602	0.618	-0.267	0.539
Constant	-5.360	1.621***	-7.439	1.135	-2.124	1.261*	-2.155	0.599***
Number of obs.	200		208		200		208	
F-Value/Wald Chi2	87.390		76.980		22.95		42.76	
Prob > F	0.000		0.000		0.085		0.000	
R-squ./Pseudo r2	0.653		0.619		0.0913		0.1396	
Root MSE								
Log pseudo likelihood	-42.944		-54.653		-101.187		-116.493	

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

Appendix Table 10: Second stage ESR estimates of chronic food insecure and net crop value

Variables	**Chronic food insecure**				**Net crop value**			
	Adopters		**Non-adopters**					
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Sex	1.732	0.654***	0.054	0.358	-2188.948	1460.212	-174.221	444.679
Age	0.050	0.014***	0.022	0.009**	-5.832	39.968	0.639	7.674
Education	-0.036	0.069	-0.043	0.042	258.040	124.848	8.492	35.361
Family size	0.748	0.152***	0.477	0.090***	-29.561	215.350	-356.325	86.037***
DPR	-0.001	0.002	0.000	0.001	2.761	4.739	2.584	1.139**
Use fertilizer	-0.581	0.339*	-0.335	0.268	1144.146	963.985	15.590	224.804
Distance FTC	0.011	0.004***	0.000	0.003	-16.285	12.339	-4.595	2.490*
Numbers of plot	-0.082	0.204	-0.116	0.171	481.691	490.314	-103.980	115.713
Use of irrigation	0.279	0.341	-0.418	0.259	1628.221	823.181	411.458	192.417
Cultivated land	0.188	0.976	-3.479	0.974***	14627.470	2994.133	2397.716	934.104**
TLU	-0.285	0.111***	-0.036	0.060	1125.050	322.656	84.649	46.484*
Received credit	-0.095	0.501	-0.338	0.402	-1007.179	1060.177	413.881	369.584
Off-farm	0.342	0.349	0.329	0.242	611.841	825.792	-442.868	176.937**
Erosion problem	0.753	0.446	0.403	0.227*	-1216.713	1089.568	124.210	179.242
IMR	0.151	0.900	0.108	0.581	1061.849	1968.908	99.487	411.321
Constant	-10.240	2.606***	-3.376	0.714***	3030.313	4011.065	4627.157	617.019***
Number of obs.	200		208		200		208	
F-Value/Wald Chi2	36.72		43.15		6.62		3.68	
Prob > F	0.001		0.000		0.000		0.005	
R-squ./Pseudo r2	0.5748		0.3302		0.3146		0.2603	
Root MSE					1207.4		1388.9	
Log pseudo likelihood	-40.090		-85.445					

***, ** and * significant at the 1, 5 and 10 percent probability levels, respectively

Appendix: Survey Questionnaire

ADOPTION AND IMPACT OF SOIL AND WATER CONSERVATION ON CURRENT FOOD INSECURITY AND VULNERABILITY OF FARMING HOUSEHOLDS IN EASTERN ETHIOPIA

SECTION 0. HOUSEHOLD IDENTIFICATION

1. Enumerator's Name:______________________	2.[*Date/Month /Year*] ________________	3. Questionnaire Code:_______________
5. District/Woreda:	6. kebele:	
7. Name of the survey respondent:		

SECTION 1.HOUSEHOLD COMPOSITION AND CHARACTERISTICS

1. Total family size of the household ____________ in number.

Name of household member (start with the respondent)	Sex 0. Female 1. Male	Age (years)	Formal Education (years)	Marital Status **Codes A**	Occupation **Codes B**
Codes A 1. Single 2. Married 3.Widowed 4. Divorced/Separated					
Codes B 1. Farming (crop + livestock) 2. Salaried employment 3. Off-farm employment 4. Non-farm employment 5. School/college child 6. Non-school child 7. Herding 8. Household chores. 9. Others, Specify _____________________					

SECTION 2. LAND HOLDING AND UTILIZATION

2.1.Do you have land? ____________1. Yes 2. No

s.no	**Land holding**	***Timad***	**Price per unit**	**Remark**
1	Cultivated land (Own)			
3	Grazing land			
4	Rented in land			
5	Rented out land			
6	Share in land			
7	Share out land			
8	Forest land			
	Total			

*1 timad = 0.125 ha

2.2.Of the cultivated area under crops, how much area (in timad) is under?

1. Chat__________ 2. Maize_________3. Sorghum _________4.Vegetable _________

2.3.How many plot do you have ________________________

2.4.Where did you get the land?

1. Inheritance 2. Goverment 3. Bought from others 4. Other (Specify)______

2.5.Have you obtained land certificate from kebele authority? 1. Yes 0. No

2.6.Do you think that it is necessary to have a land certificate? 1. Yes 0. No

2.7.Have you ever lost your land to kebele authorities due to redistribution or investment activity? When? ______________

1. Yes 0. No

2.8.Do you think that you have enough land for crop production? 1. Yes 0. No

2.9.Do you feel secured in holding land in future? 1. Yes 0. No

2.10. If you do not feel secured, why?

1. I expect land will be redistributed
2. Land belongs to the government
3. I expect my farmland can be taken any time by the government
4. I will no longer stay in farming (stop farming)
5. Others, specify ______________________

2.11. What do you expect in your landholding after five years from now?

1. Increase 2. Decrease 3. Remain the same

SECTION 3. HOUSEHOLD ASSETS

3.1.Asset on values

Asset Name	Number of items owned	When did the last purchase made by the household (in Ethiopian Calendar)?	Average per unit price during the last purchase (Birr)
Ox-cart or Horse –cart			
Generator			
Machetes/Sickle			
Axe/ Hoes			
Spade			
Computer and accessories			
Sprayer			
Wheel barrow			
Refrigerator			
Sewing machine			
Bicycle			
Tractor			
Bajaj			
Other motorized vehicles			
Radio/radio cassette			
Mobile phone			
Television			
Other, specify			

3.2.Housing

Type of building **(Code A)** Residential = 1, Livestock pen = 2, Food Store = 3, Other = 4, Specify	No. Rooms	Walling material **(Code B)** Bricks (mud) = 1, Stone = 2, Wooden & mud = 3, Bamboo & mud = 4, wood only=5	Roofing material **(Code C)** Grass = 1, Corrugated Tin = 2, Tiles = 3, Other = 4, No roofing=5	Flooring material **(Code D)** 1=Mud 2=Cement 3=kerbed	Total cost of constriction

SECTION 4. LIVESTOCK PRODUCTION

4.1.Livestock ownership and marketing for the household in general during the last 12 months.

Animal type and livestock products	**Stock /quantity during 2009 E.C**	**How much was sold during 2009 E.C**	**Units price**	**Total revenue household received (Birr) during 2009 E.C**	**Total Cost of Production (birr) during 2009 E.C**					
					Feed \Fodder	**Labour (hired)**	**Veterinary care**	**Artificial insemination**	**Mineral**	**Others**
Cows										
Oxen										
Heifers										
Calves										
Goats										
Sheep										
Donkeys										
Mature chicken										
Horses or mules										
Beehives										
Camels										
Livestock products sold										
Eggs										
Honey										
Fresh cow milk										
Fresh camel milk										
Fresh goat milk										
Butter / Cheese/Yoghurt										
Hide/ Skins										
Dung/Manure-wet/dried										

4.2.How do you judge the trend of livestock holding per household in the last 5 years?

1. Declined 2. Increased 3. Remain the same

4.3.Do you face oxen shortage during your farming practices in last production period?

1. Yes 0. No

4.4.If yes, how did you cope up with such shortage?

1. Pairing with others 2. Using oxen of relatives 3. Hiring oxen 4. Exchanging labour for oxen

4.5.What is/ are the main feed source (s) in your area?

1. Grazing 2. Hay 3. Improved forage 4. Others___________

4.6.How pasture lands are owned in your area? 1. Individually 2. Communally 3. Both

4.7.Do you have any enclosed area for forage production? 1. Yes 0. No

4.8.If you have your own pasture land, what kind of method you use?

1. Cut and carry 2. Open access 3. Others, specify ____________

4.9.If there is communal grazing land in your area, what is the trend of it since the last ten years? 1. Decreasing 2. Increasing 3. Remain the same

4.10. If the answer is decreasing, state the major reasons?

1. Expansion of farm land 2. Forestation 3.Expansion of settlement 4. Others ____

4.11. Is there shortage of animal feed in your area? 1. Yes 0. No

4.12. If yes, what are the causes?

1. Drought 2. Population pressure and expansion of cultivation land

3. Livestock population pressure and over grazing 4. Over grazing land

5. Land degradation 6. Others, specify__________________

4.13. For what purpose do you use animal dung?

1. As manure 2. Fuel wood 3. No use 4. Others, specify _____________

SECTION 5. CROP PRODUCTION

5.1. Crop production and annual income

Crop	Area of land (Timad**)**	Production (kg)	Consumption (kg)	Quantity sold (kg or kg equivalent)	Unit price	Seed (kg)	Current stock (kg)

5.2.Perennial crops and annual income

No	Type of perennial crop	Number of trees	Unit measurement	Amount produced	Quantity sold (if any)	Unit price	Total value

5.3.Do you use irrigation? 1. Yes 0. No

5.4.If yes, what type of irrigation?

1. Surface irrigation 2. Drip irrigation 3. Sprinkler irrigation 4. Side roll irrigation 5 Manual irrigation using buckets 5. Others_______________________

5.5.What are the sources of irrigation water in your area?

1. Rivers 2.Lakes 3.Water springs 4.Rain 5.Other (Specify) ________

5.6.When do you mostly use to irrigate your land?

1. Early morning 2. Early afternoon 3.Late in the afternoon 4.At night

4. Other (Specify) __________

5.7.How do you irrigate your land?

1. Using pump 2. Direct furrow from rivers/lakes 3. Collect and pump from pit (water harvest) 4. Other (Specify) _________________

5.8.How many times you irrigate your land? ________days/week

5.9.Which type of crop do you grow using irrigation?

1. Vegetable 2.Fruit 3. Annual crops 4. Khat 5. Others, specify__________

SECTION 6 PLOT CHARACTERISTIC

Would you please specify your farm plot level characteristics?

No	Description	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
6.1.	Plot status 1=owned 2= rented in 3= rented out 4=Shared					
6.2.	Distance from home in walking minutes					
6.3.	Do you think land degradation is a problem for your plots 1. Yes 0. No					
6.4.	If yes, how do you perceive the level of soil erosion in your farm plots? 1. Very severe 2. Severe 3. Less severe					
6.5.	If yes, how do you perceive the soil fertility status of your farm plots? 1. Highly fertile 2. Medium 3. Low					
6.6.	If yes, how much of your plot affected by erosion in (hectares)?					
6.7.	If yes, what features of the plot lead you to believe that such problem exists? 1.Yield decline 2. Soil depth decreased 5. Fertility decline 3. Soil colour changes 6.Stone rock exposed 4. Water holding capacity deteriorated					
6.8	How long did you feel the problem of soil erosion on your plots?					
6.9.	How do you perceive the soil depth of your farm plots during the last five years? (trend of soil fertility) 1. Increased 2. Decreased 3. No change					
6.10.	How is the slope of your farm plots? 1. Gentle 2. Moderate 3. Flat					
6.11.	How do you perceive the severity of fertility decline of your farm plots? 1. Very severe 2. Severe 3. Less severe					

SECTION 7 INPUT FOR CROP PRODUCTION

No	**Description**		**Plot 1**		**Plot 2**		**Plot 3**		**Plot 4**		**Plot 5**	
7.1.	Area of the plot (in hectare)											
7.2.	Types of major crops grown											
7.3.	Seed in KG and Birr	1. Improved										
		2. Local										
7.4.	Fertilizer (in kg and in Birr)	DAP										
		UREA										
7.5.	Manure in kg and Birr if bought											
7.6.	Field chemicals in kg/lit	Pesticide										
		Herbicide										
		Fungicide										
7.7.	Labor cost in man-days and Birr											
7.8.	Yield (in kgand in Birr)											

SECTION 8 SOIL AND WATER CONSERVATION

1.1.	When did you hear about SWC	
1.2.	Do you use improved SWC on your farm land 1. Yes 0. No	
1.3.	If yes, since when?	
1.4.	Which soil and water conservation practices do you use? 1. Stone bund 2. Soil bund 3.Cut-off drain 4. Check-dam 5. Terraces *6. Fanyajuu* 7.Planting of trees 8. Grass strip	
1.5.	Improved soil and water conservation technologies built in meter or No	
1.6.	If no, did you use before? 1. Yes 0. No	
1.7.	If yes, when did you dis-adopte?	
1.8.	Why? 1. Space that it occupies 2. Occurrence of rodents 3. No effect on soil and water conservation 4. Structures were built without my knowledge and willingness	
1.9.	How do you perceive the soil depth of your plot since you applied soil and waters conservation on it? 1. Increased 2. Decreased 3. No change 4. I do not know	
1.10.	How do you compare the problem of soil erosion in your farm plots after conservation structures were built? 1. Aggravated 2. Reduced 3. No change 4. I do not know	
1.11.	Which problems do you face related to soil and water conservation **Code B:**1. Sources of rodents 2. Difficult to implement 3. Not effective to reduce soil erosion 4. Difficult to turn oxen 5. Reduce land size 6. Require large labor 7. No problem	

8.12. Did you have plots where conservation structures were built by food/ cash for work or by any other community participation in the past? 1. Yes 0. No

8.13. If yes, what is the present condition of the structures?

1. Partially removed 2. Completely removed 3.Reconstructed 4. Retained

8.14. If you removed, which type of structures did you remove?

1. Stone bund 2. Soil bund 3.Cut-off drain 4. Check-dam 5.Terraces *6.Fanyajuu* 7.Planting of trees 8. Grass strip

8.15. Why did you remove the structures?

1. Space that it occupies 2. Occurrence of rodents 3. No effect on soil and water conservation 4. Structures were built without my knowledge and willingness

8.16. Are you participating in any other village level natural resource management activities? 1. Yes 0. No

8.17. If yes, specify ________________________________

8.18. If you are participating in conserving communal lands, what did you contribute?

No	Activities	1. Yes 0. No
1.	Labour for terrace construction	
2.	Labour to establish enclosure	
3.	Labour for soil/stone bund constriction	
4.	Gully stabilization (check-dams)	
5.	Preventing own livestock from entering protected areas	
6.	Practice seasonal grazing arrangement	
7.	Others, specify	

8.19. If you are using conservation measures, why do you use in your plots?

1. To conserve soil 2. To conserve water 3.Both 4. Others, specify

8.20. Did/are you use/using traditional conservation measures? 1. Yes 0. No

8.21. If you were/are using traditional conservation measures, what factors do you consider in constructing such structures?

1. Land size 2. Soil characteristics 3.Labor availability 4. Soil fertility status
5. Steepness of the slope 6. Return from conservation measures 7. Others, specify

8.22. What are the factors that limit the height and width of traditional conservation measures?

1. Intensity of rainfall 2. Plot size 3. Slop of the plot 4. Crop type
5. Availability of labour 6. Availability of construction materials 6. Others

8.23. In your opinion, which type of SWC measure is effective in your farm plots?

1. Traditional type 2. Improved type

8.24. If 1 Why? ____

8.25. If 2 Why?____

8.26. If you did not use improved soil and water conservation measures in all your plots, why?

1. Lack of extension service (advice) 5. Lack of inputs (resources)
2. No problem of land degradation 6. Inappropriateness of technology
3. Shortage of labour 7. I don’t have access to the technologies
4. Lack of interest 8. It reduces farmland 9. Others, specify

8.27. In your view, what were the reasons for the failure of conservation activities, if any?

S.N	Reasons	1. Yes 0. No
1.	Lack of community participation in planning	
2.	Withdrawal of incentives for labour contribution	
3.	Community lacks skills in undertaking activities	
4.	Interruption of input supplies (seedlings, equipments)	
5.	Community lacking awareness on outcomes of such activities	
6.	Inappropriateness of technology	
7.	Others, specify	

8.28. What other conservation measures are you using to improve the fertility of you land?

1. Mixed cropping 2. Inorganic fertilizer 3. Farm yard manure
4. Crops residual 5. Crop rotation 6. Others, specify

8.29. Is there any social forest in your area? 1. Yes 0. No

8.30. What are the major causes for the disappearance of forest/trees in your community?

1. Bringing forest land in to agriculture (intensive cultivation) 2. Settlements
3. Livestock grazing and fodder 4. Human consumption for fuel and other necessities

8.31. What are your sources of fuel?

1. Fuel wood 2. Dung 3.Crop residue 4. Electricity

8.32. Is there a shortage of fuel wood in your community? 1. Yes 0. No

8.33. if yes, which source of fuel do you use?_________________________________

8.34. What is the average time you take in collecting fuel? _________________ (in min)

8.35. Are you ready to continue in conserving your land? 1. Yes 0. No

8.36. How many man-days for SWC during last year?_______ how much do you pay?________ (in Birr)

8.37. Which family members participate in soil and water conservation works?
1. Men__________% 2. Women __________%
3. Children_________% 4. None of them participate
8.38. In which SWC activities do your female family members participate?
1. Transporting construction materials 2. Constructing the structures
3. Tree planting 4. Others, specify
8.39. If females do not have participation in SWC activities, what is the reason?
1. The work is too heavy to females 2. They are busy in home activities
3. Others, specify
8.40. In which farming activities do your female family members participate?
1. Land preparation 2. Ploughing 3.Hoeing 4. Weeding
5. Harvesting 6. Trashing 7. Others, specify

SECTION 9. INSTITUTIONAL SUPPORT

9.1. Has your household received any type of extension service?
1. Yes 0. NO
9.2.If yes, who provides you the extension service?
A. Development agents (DAs) B. NGOs C. Researchers D. All E. Others_______
9.3. If yes, what type of advice did you get?
1. Application of seeds and fertilizer 5. Land preparation
2. Improved seed and sowing 6. Weeding /intercultural operations
3. Application of herbicides and insecticide 7. Harvesting
4. Soil and water conservation practices 8. Others, specify________
9.4.How often you have been visited by DAs last year per month?___________________
9.5. How do you describe the contact you have with soil and water conservation experts (DAs) or other agents? 1. None 2. Limited 3. Good 4. Very good
9.6.If you did not receive extension advice on the above conservation measures, why?
1. Possessed the required information
2. No need for service (not interested)
3. Availability of contact farmers in the area
4. Number of DA nearby
5. Poor extension service
6. Didn't hear about it

9.7. Have you been/or are you participating in any of the SWC related projects in your area? 1. Yes 0. No
9.8. If yes, in which project/s?
A. MERET B. PSNP C. Gtz D. ASSP E. ILRI F. None of the projects
9.9.If yes, for how many years?_____________________
9.10. Is credit service available in your area? 1. Yes 0. No
9.11. If yes, what are the sources? 1. Microfinance institutions 2. BoA 3.NGOs 4.Local money lenders 5.Farmers' association (Union) 6. Others, specify___
9.12. Did you receive credit in 2007-2009? 1. Yes 0. No
9.13. If you have received how much_____________________
9.14. Have you been trained about credit, interest rate and commitment so far?
1. Yes 0. No

9.15. How do you perceive the contribution of these institutional supports to invest on conservation technologies? 1. Very important 2. Important 3. Less important

9.16. Access to infrastructure services

S.NO.	Infrastructure	Distance in Minutes
1.	FTC	
2.	Cooperative	
3.	DA office	
4.	Weather road	
5.	Nearest market	
6.	Farmers Union	
7.	Financial services	
8.	Main market	
9.	Drinking water	

9.17. Where is your output marketed?

1. At farm level 2. Local market 3. Woreda market 4. Through cooperative 5. Others

9.18. To whom did you sell your output?

1. Local consumers 2. Local assemblers 3. Urban traders
4. Cooperative center 5. Others, specify____________________

9.19. Where do you buy farm inputs & other commodities?

1. Local market 2. From cooperatives 3.Both 4. Others, specify ____

9.20.. What is the means of transport to marketplace for your output?

1. Carrying by own 2. Using pack animal 3. Using Lorries 4. Others, specify

9.21. What are your basic sources of marketing information?

1. Radio 2. Merchants/traders 3. Development Agents
4. Friends /relatives/neighbours 5. Local market

SECTION 10. FOOD EXPENDITURE

10.1. Household expenditures on food items in the **LAST MONTH**. (Here, wife and/or person involved in purchases should be the principal respondent/s).

Item No	**Food type**	**Own harvest/stock**		**Purchased**			**Receivable in kind, gift, aid...**		
		Amount	**Unit**	**Amount**	**Unit**	**Total expenditure**	**Amount**	**Unit**	**Source**
1	**Cereals**								
1.1	Maize								
1.2	*Teff*								
1.3	Wheat								
1.4	Sorghum								
1.5	Millet								
1.6	Other ----------								
2	**Pulses**								
2.1	Fababean								
2.2	Lentils								
2.3	Chick pea								
2.4	Horse beans								
2.5	Haricot beans								
3	**Oil crops --------**								
3.1	Niger seed								
3.2	Linseed								
4	**Animal products**								
4.1	Milk/cheese/butter								
4.2	Beef								
4.3	Chicken								
4.4	Eggs								
5	**Coffee**								
6	**Sugar**								
7	**Salt**								
8	**Cooking oil**								
9	**Spices (pepper,...)**								
10	**Vegetables and root crops**								
10.1	Potatoes								
10.2	Green leaf								
10.3	Sweet potato								
10.4	onion								
10.5	Other ----------								
12	Stimulants & alcohols								
12.1	*Chat*								
12.3	*Araqi*								
13	Others -------------								

10.2. Food consumption score

1. Over the last seven days, how many days did you consume the following foods?		2. In the past 30 days, how frequently did your household resort to using one/more of the following strategies in order to have access to food? **Codes (1)** 1…never 2…seldom (1-3 days per month) 3…sometimes (1-2 days per week) 4…often (3-6 days a week) 5…daily	
Items	No. Days	Items	**Codes (1)**
Cereals *(Maize, Teff, Wheat Sorghum, Millet)* and tubers *(potatoes, sweet potatoes)*		Skip the whole without eating	
Pulses and nuts (*beans, lentils, peas, peanuts, etc.)*		Reduce the amount of food	
Vegetables		Reduce number of meals a day	
Fruits		Borrow food/rely on help from friends	
Meat and fish (*Beef, goat, poultry, pork, eggs and fish*)		Rely on less expensive/preferred food	
Dairy products *(milk, yoghurt, cheese, other milk's products)*		Purchase/ borrow food on credit	
Sugar, honey		Eat wild food/ hunt/ fish	
Oil, fat, butter		Reduce adult food so children can eat	
		Rely on casual labour	

SECTION 11. HOUSEHOLD OTHER INCOME

11.1. Do you or your family under take some additional income generating activities (off Farming and non -farm activities) in the year 2008/09 1. Yes 0. No

11.2. If yes list the income earned from off -farm and non - farm activities

S/N	**Non -farm income Sources of income**	**Number of people engaged**	**Number of days worked in a month**	**Income per working day**	**Total annual income from off farm activity**
1	Wage				
2	Selling local drink				
3	Petty trading				
4	Selling fire wood				
5	Handicraft				
6	Herding				
7	Pension payments				
8	Ceramic				
9	Carpenter				
10	Rent from assets				
11	Trading				
12	Clothes making				
13	Hired in other farm				
14	Remittance				
15	Other				

SECTION 12 MAJOR SHOCKS

Since September 2008 has your family been affected by any of the following events?	**Rank three most significant shocks**	**In which month(s) did these three occur**	**How is the impact measure?**	**Estimate the value of loss due to the event (Birr)**	**What did you do to cope?**	**How long did it take to get back to normal again**
1. Drought						
2. Flooding						
3. Pest/disease that affected your crops						
4. Frost that affect your crop						
5. Pest/disease for livestock						
6. Sick person (numbers of sick__)						
7. Death of adult members (numbers of death___)						
8. Fire outbreak						
9. Rise in food prices						
10. Rise in input prices						
11. Social conflicts						
12.Other, specify_____________						