ADAPTATION STRATEGIES BY SMALLHOLDER FARMERS TO INCREASE CROP PRODUCTION UNDER THE CHANGING CLIMATIC CONDITIONS THE CASE OF GOZAMIN DISTRICT, EAST GOJAM, ETHIOPIA

M. Sc. THESIS

ALEMAYEHU TADELE DERSEH

HAWASSA UNIVERSITY, WONDO GENET, ETHIOPIA

NOVEMBER, 2019

ADAPTATION STRATEGIES BY SMALLHOLDER FARMERS TO INCREASE

CROP PRODUCTION UNDER THE CHANGING CLIMATIC CONDITIONS THE CASE OF GOZAMIN DISTRICT, EAST GOJAM, ETHIOPIA

ALEMAYEHU TADELE DERSEH

A THESIS SUBMITTED TO THE SCHOOL OF GRADAUTE STUDIES, HAWASSA UNIVERSITY, WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CLIMATE SMART AGRICULTURAL LAND SCAPE ASSESSMENT

NOVEMBER, 2019

THESIS APROVAL SHEET I

This is to certify that the thesis entitled “Adaptation Strategies by Smallholder Farmers to Increase Crop Production under the Changing Climatic Conditions at Gozamin District, East Gojam, Ethiopia” submitted in partial fulfillment of the requirement for the degree of Master of Science with specialization in Climate Smart Agricultural landscape assessment at Hawasa University, WGCF-NRS, and is a record of original research carried out by Alemayehu Tadele Derseh, under my supervision, and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the courses of this investigation have been duly acknowledged. Therefore, I recommended that it can be accepted as fulfilling the thesis requirement.

Professor Tsegaye Bekele	________________	______________
Name of Advisor	Signature	Date

THESIS APROVAL SHEET II

Submitted by

Alemayehu Tadele	______	______
Name of student	signature	date

Approved by

1. Professor Tsegaye Bekele	______	______
Name of Advisor	signature	date

Dept's Graduate Committee

4. ______________	______	______
Name of Chairperson,	signature	date
Faculty of Graduate Committee		
5. ______________	______	______
Name of the Dean,	signature	date
School of Graduate studies		

ACKNOWLEDGEMENTS

Thanks to the almighty God for his generosity and making things possible in my life.

I am indebted to my advisor Professor Tsegaye Bekele who gave me unlimited professional support and advice during all the stages of undertaking this thesis work. He also gave me comments and suggestions for improvement and provided me with unreserved support at various levels starting from title selection.

Special thanks to Dr. Adefires Worku for his editing the manuscript and relevant comment to improve the thesis paper. I greatly appreciate Mr. Tefera Tadesse who provided me a laptop computer and financial support. I acknowledged Dr. Gebirelibanos Gebiremariam for his assistance on econometric model selection and data analysis.

I would like to extend my heartfelt thanks to MRV project and the Norwegian government for providing me this chance and financial support both for thesis work and for maintenance payment offered during my stay in Wondo Genet College of Forestry and Natural Resources.

I gratefully acknowledge my family members Abeba Tadele (my sister), Tale Tadele (my brother), my mother Anchinesh Tamir for giving me advice, moral support and encouragement to study and change my life. I am lucky to have such a loving wife Senait Zegeye with incredible endurance, patience, understanding and supporting my lovely child Yeabsira.

Finally, I wish to acknowledge with immense gratitude all those who have made this study possible.

DEDICATION

This thesis is dedicated to my parents, Tadele Derseh and Anchinesh Tamir, who brought me up and gave me the value of education, and my wife Senait Zegeye, my child Yeabsira and my sister Abeba Tadel, I will always love you and remain grateful to you.

DECLARATION

I, the undersigned, hereby declare that this is my original research work and all sources of materials used are duly acknowledged. This work has not been submitted to any other educational institution for achieving any academic degree awards.

Alemayehu Tadele

TABLE OF CONTENTS

Page

LIST OF ABBREVIATIONS

CRGE	Climate Resilience Green Economy
CSA	Central Statistical Agency
DAs	Development Agents
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GARDo	Gozamin agriculture rural development office
GHG	Greenhouse Gases
Ha	Hectare
HH	Household
KII	Key Informant Interview
m.a.s.l	Meter above Sea Level
MNL	Multinomial Logit Model
MOA	Ministry of Agriculture
MVP	Multivariate Probit Model
NGO	Non Governmental Organization
RKA	Rural Kebele Administration
STATA	Statistical software package
SWC	Soil and Water Conservation
VIF	Variance Inflation Factors

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ADAPTATION STRATEGIES BY SMALLHOLDER FARMERS TO INCREASE CROP PRODUCTION UNDER THE CHANGING CLIMATIC CONDITIONS THE CASE OF GOZAMIN DISTRICT, EAST GOJAM, ETHIOPIA (October, 2019)

Alemayehu Tadele
Mobile: +251-913 28 16 50, Email: alemayehu.tadele@gmail.com

ABSTRACT

Agricultural production is the main source of income for most rural communities in Ethiopia. Currently climate change and variability is emerging as a major threat to agricultural crop production by smallholder farmers in the Gozamin district, Northern Ethiopia. The farmers in the study area depend on rain-fed agricultural activities on relatively small farms. The general objective of the study was to evaluate the adaptation strategies by smallholder farmers' to increase crop production under the changing climatic conditions at Gozamin District, East Gojam Zone, Ethiopia. Specific objectives were to identify existing adaptation strategies to improve crop production; and identify factors that affect the choice of crop production adaptation strategies under the changing climatic conditions at Gozamin district. The study used quantitative and qualitative research techniques. Three representative sample kebeles, namely Enerata, Wonka and Desa Enesie from dega, woyna dega and kola kebeles respectively were selected from three agro-ecologies using simple random sampling procedures. Simple random sampling technique was used to select 132 households from three selected kebels. Multivariate probit model was used to identify factors that determine crop production adaptation strategies. The result of the study showed that different crop production adaptation strategies were undertaken by the smallholder farmers in the study area to minimize the impact of climate change and variability related hazards. The likelihood of households to adopt use of fertilizer, crop diversification, irrigation, and improved seeds were 75.8%, 53%, 39.4% and 72.8% respectively. Tree plantation and soil and water conservation practices were also used as a climate change and variability adaptation methods. The result also revealed that the joint probability of using all crop production adaptation strategies was 23.5% and the probability of failure to adopt one of the crop production adaptation strategies was 13.6%. The major sources of income in the study area were on-farm activities mainly from sale of crops. Off-farm and non-farm activities were also other sources of income for some of the sample households in the district. Multivariate probit model results also confirmed that Agro-ecology, climate information, education level, sex, age, farm income, off/non-farm income, extension, credit used and distance to market have a significant impact on the adoption of crop production adaptation strategies. Generally, future policies should focus on the smallholder farmers' technical capacity through adult education system and on updated extension services in line with the prevailing climatic condition, improving irrigation facilities, credit facilities, road accessibilities, farm and off-farm income earning opportunities, and use of new crop varieties that may be more suited to the local environment.

Keywords: A*daptation strategies, climate change and variability, crop production, multivariate probit model,* s*mallholder farmers.*

1 INTRODUCTION

1.1 Background of the Study

Agriculture is an important sector worldwide, significant for livelihoods of a majority of poor in the developing world. This sector is one of the most vulnerable and sensitive to climate change and variability (Patrick Madulu, 2014). Climate change is expected to exacerbate the problem which will have profound impact on crop yields and on the livelihoods of rural communities (Georgis K., 2015). As a result of climate change up to 122 million more people worldwide may live in extreme poverty by 2030 (FAO, 2017).

Agriculture dominates Ethiopia′s economy (Alemu and Mengistu, 2019). Climate change and variability could impose a heavy burden on the poor smallholder farmers (Getachew Teferi *et al.*, 2018). Ethiopia is highly vulnerable to climate change, variability and extreme climate events due to its low level of socio-economic development, inadequate infrastructure, lack of institutional capacity and a higher dependency on natural resources. Climate related hazards in Ethiopia include drought, floods, frost, strong winds, high temperatures, lightning, and others (Tadesse Woldemariam, 2015). According to Mussa, (2015) annual decrease in crop production over the past 10 years, due to pests and diseases, uneven distributed low rainfall and extended drought periods.

Climate-Resilient Green Economy (CRGE) strategy has prioritized for agricultural sector initiatives such as, intensify agricultural activities through usage of improved inputs and better residue management, create new agricultural land in degraded areas for irrigation and introduce lower-emission agricultural techniques by selecting crop cultivars to the promotion of organic fertilizers (CRGE, 2011).

The agricultural production systems in the country mainly depend on rain fed agriculture using little or sometimes no modern inputs, intensive and diversified agricultural activities on relatively small farms (Patrick Madulu, 2014, Georgis K., 2015). Smallholder farmers adopt several agricultural innovations in their agricultural production practice. Their adoption behavior is influenced by a set of factors such as individual characteristics, institutional settings, and biophysical characteristics of the farm they manage as well as unanticipated shocks (Gebremariam and Tesfaye, 2018, Tesfaye Samuel, 2016). However, during the last decade, the impact of climate change increases the experience for implementing adaptation actions (Patrick Madulu, 2014). Improving and strengthening human capital through education, outreach programs, extension services at all levels will improve capacity to adapt to climate change impacts (Akinnagbe and Irohibe, 2014, Mary Nyasimi *et al*., 2017). But low income farmers may be able to invest on low cost technologies for adaptation to climate change (Arun Khatri, *et al*., 2017).

The major adaptation strategies used by smallholder farmers include crop rotation, use of improved seeds and new crop varieties, fertilizer application, irrigation, mixed cropping, adjusting sowing dates (Wondimagegn and Lemma, 2016), use of soil and water conservation techniques and engaging in non-farm income activities (Mussa, 2015), predicting the timing of the onset of the rainy season; and soil fertility and plant health related strategies (John *et al*., 2013). However, developing more effective climate change adaptation strategies from the government need provision of necessary resources such as credit, new technology, information and extension services (Wondimagegn and Lemma, 2016). Improving productivity of the main crop activities are likely better options to adapt to climate change (Bagamba *et al*., 2012). Therefore, this study has identified different climate change crop production adaptation strategies and subsequently examined the determinants of farmers' adoption of adaptation strategies to climate change and variability by smallholder farmers to increase or improve crop production in Gozamin woreda.

1.2 Statement of the Problem

Today climate change and variability have emerged to be major threat on agriculture, food security and livelihood of millions of smallholder farmers (EIAR, 2015; Guodaar, L. *et al*., 2019). Because most smallholder farmers have limited capacity to adapt to climate change, given their low education levels, low income, limited land areas, and poor access to technical assistance, market and credits (Menike and Keeragala, 2016). Currently Population increases and the associated demands for food, water and other agricultural products will bring additional pressures (Mari Gjengedal, 2016).

Agricultural productivity growth is vital for economic and food security outcomes (Michler *et al*., 2019). Crop production is highly vulnerable to climate change effects because it is dependent on rain fed agriculture. Rainfall inconsistencies are common problems and creating a serious threat to smallholder farmers (Arega and Molla, 2018) because variation on the onset and cessation of rain, heavy rains and unpredictable floods (Balama, *et al*., 2013) pests and diseases and extended drought periods causes decrease of crop production (Mussa, 2015). The impact of climate change on agriculture production differs from one area to another (Menike and Keeragala, 2016). Adaptation of off-farm and non-farm activities is another method of reducing the effect of climate change and variability through diversified source of income (Arega and Molla, 2018; Guodaar, L. *et al*., 2019).

Agricultural production and farmers' incomes in Gozamin woreda is affected by on-going climate variability. Many smallholder farmers produce crops on marginal lands (e.g., steep hillside slopes, poor soils or areas prone to flooding or water scarcity) and live in areas with low-quality infrastructure that further hampers their access to markets, technical assistance or government support. Because of this farmer's crop productivity reduced and continues their life in subsistence farming. As compared to the potential irrigation practice by using spring, river and ground water is very small. Negative impacts of climate change and variability can be reduced through adaptation practices.

There were limited earlier studies conducted on climate change variability and crop production adaptation strategies of smallholder farmers in the study area. Hence, considering this knowledge gap, the study assessed the adaptation strategies of smallholder farmers to increase or improve crop production under the changing climatic conditions in Gozamin woreda. Moreover, the study investigated the different adaptation strategies and factors that determined crop production adaptation strategies by smallholder farmers in the study area.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of the study was to evaluate the adaptation strategies of smallholder farmers' with the aim increase crop production under the changing climatic conditions at Gozamin District, East Gojam Zone, Ethiopia.

1.3.2 Specific Objectives

The specific objectives of the study were

1. To identify the existing/ implemented adaptation strategies which improve crop production for smallholder farmers under the changing climatic conditions in the study area.
2. To identify factors that determines the adoption of crop production adaptation strategies by smallholder farmers under the changing climatic conditions in the study area.

1.4 Research Questions of the Study

1. What are climate change and variability in crop production adaptation strategies implemented by smallholder farmers to increase crop production in the study area?
2. What are the factors affecting the choice of crop production adaptation strategies under the changing climatic conditions by smallholder farmers in the study area?

1.5 Scope and limitation of the study

The study was focused on different adaptation strategies implemented by smallholder farmers to improve/increase crop production under the changing climatic condition in Gozamin district East Gojam zone of Amhara region. Currently, climate change is affecting smallholder farmers' crop production in the study area. Adaptation is essential to address the unavoidable impacts of climate change. The capacity to adapt the current climate change and variability by smallholder farmers is limited. However, farmers in the study area try different crop production adaptation strategies to cop up this change.

Gozamen district has 25 rural kebele administrative. For this study, 3 rural kebeles were selected randomly from different agro-ecologies to evaluate different adaptation strategies. This was done due to lack of time, budget, and to increase the quality of the study. Totally 132 household heads were selected randomly from this kebeles.

1.6 Significance of the Study

The study assessed the major climate change adaptation strategies implemented by smallholder farmers to increase crop production and identify different factors affecting farmers' preference/choice of adaptation measures to reduce exposure to climate variability. This study will be essential for policy makers, the local government, the regional government and other stake holders or beneficiaries who are working on climate change and variability adaptation and crop production practices. The study will also be important as general literature to the next work who will like to conduct detail and comprehensive studies.

2 LITRATURE RIVIEW

2.1 Definitions

Adaptation is defined by Echnoserve, (2014) is “the ability to respond and adjust to actual or potential impacts of changing conditions in ways that moderate harm or take advantage of any positive opportunities that the climate may afford”.

Adaptation to climate change is defined by Echnoserve, (2014) is “the process through which people reduce the adverse effects of climate variability on their health and well-being, and take advantage of the opportunities that their climatic environment provides. The term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change”**.**

Adaptive capacity is also defined by Echnoserve, (2014) is “the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. Thus, the adaptive capacity of a system or a community describes its ability to modify its characteristics or behaviors so as to cope better with changes in external conditions”**.**

Climate variability is variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. It is defines as “Climate varies over seasons and years instead of day-to-day like weather. Some summers are colder than others. Some years have more overall precipitation." Scientists think of climate variability as the way climate fluctuates yearly above or below a long-term average value" (Dinse K., 2010).

Seasonal variation is defined as the presence of variations that occur at specific regular intervals less than a year, such as weekly, monthly, or quarterly. Seasonal fluctuations in a time series can be contrasted with cyclical patterns, e.g. seasonal variation in rainfall, temperature, etc (https://en.wikipedia.org/wiki/Seasonality).

2.2 Impact of climate change and Variability on crop production

Climate change is a global challenge that has a particularly strong effect on developing countries where adaptive capacity is low and their agriculture is highly dependent on climatic factors (Sujata Manandhar *et al*., 2011). The results from annual and decadal precipitation and temperature, annual precipitation is decreasing while temperature is slightly increasing (Parvin *et al.*, 2019). Climate is a resource in itself, but it affects the productivity of other critical resources, such as crops and livestock, forests, fisheries and water resources when business as usual continues (Tadesse Woldemariam, 2015). According to Patrick Madulu, (2014) stated world agriculture as a major part of the livelihood of 40% of the world's population and occupies 40% of total land area; 90% of farms worldwide have a size of less than 2 hectares. Crop production is the main source of livelihoods, and has significantly been affected by climate change and variability (Guodaar, L. *et al*., 2019; Lalego *et al*., 2019). The key hazards brought by potential extreme volatility are droughts, floods new insect pests, new vector-borne diseases and soil erosion. The worst impacts are caused by droughts (Echnoserve, 2014; Tadesse Woldemariam, 2015).

2.2.1 Environmental Impact on crop production

Natural resource degradation is one of the most serious environmental problems in Ethiopia (Echnoserve, 2014). Declining soil fertility, low crop production and crop failure resulting from climate variation are major problems facing smallholder farmers (John, *et al*., 2013; Mussa, 2015). Climate change reduces the amount of water in the environment that can be sustainably withdrawn for irrigation during the driest months (Parvin *et al*., 2019). Ethiopia has many different agro-ecologies and farming systems that vary within short distances. It needs site specific research results to plan and develop sustainable agricultural production at the smallest administrative units (Georgis K., 2015)

2.2.2 Social Impact on crop production

Africa is already under climate stresses which increase vulnerability to further climate change and reduce adaptive capacity. This is affecting food production with its resultant effect on widespread poverty (Akinnagbe and Irohibe, 2014). In addition to this the growing population creates additional demand on resources (Parvin *et al*., 2019). Resource limitations and poor infrastructure limit the ability of most smallholder farmers to engage in adaptation measures as a response to changes in climatic conditions. Health factors also determine the ability of the available labor force to work on different farm activities (Weldlul Ayalew, 2016). Climate change jeopardizes the achievement of the vital goals for human development. The increasing impacts of the changing climate threaten to undercut and possibly reverse the progress that has been made in the fight against hunger and malnutrition in recent years (FAO, 2017). During the last century a decrease and variability of precipitation has led to recurrent shortfalls in agricultural production claiming tens of thousands of human and animal lives (Georgis K. 2015). Ethiopia has experienced 16 major national droughts since the 1980s, along with dozens of local droughts. Recently in 2015 10 million peoples, in 2017 5 million peoples were food insecure, as a result of drought caused by climate change induced EL Nino (Alemu and Mengistu, 2019).

2.2.3 Economical Impact on Crop production

Patrick Madulu, (2014) taking from (Howden, *et. al*., 2007) stated that Agriculture is an extremely essential economic sector globally and for the developing countries where it is believed to provide livelihoods for around 70 percent the rural poor. Globally, from 5 million hectares of land estimated to be 1.5 million hectares used for crop production and animal husbandry occupying 3.5 million hectares. Smallholder producers in developing countries have limited resilience and difficult to adopt practices that support improved climate change adaptation practices (FAO, 2017).

Agriculture plays a major role in Ethiopia’s economy, contributing 41% of GDP, 85% of employment and 75% of export commodity value. Under an extreme scenario of higher temperatures and increased intensity and frequency of extreme events, the negative impacts of climate change by 2050, could cost Ethiopia 10% or more of its GDP (Tadesse Woldemariam, 2015). To develop climate resilient systems in Ethiopia, understanding past and projected impacts of climate change on agriculture is important (Georgis K., 2015).

2.3 Crop production Adaptation Strategies

Climate change and Variability adaptation can be anticipatory, where systems adjust before the initial impacts take place, or it can be reactive, where change is introduced in response to the onset of impacts (Echnoserve, 2014). Smallholder farmers are engaging in various economic activities to diversify their income sources because of changes in the climate, markets and high living costs and demand for personal and household needs (FAO, 2017). The results of Arun Khatri *et al*., (2017) study indicate that low income farmers are more likely to prefer site specific integrated nutrient management, integrated pest management, laser land leveling compared to rainwater harvesting, contingent crop planning and crop insurance. Agro-forestry systems involve the growing of woody perennials and annual crops together in a sustainable manner and it is increasingly practiced in degraded areas as climate change and variability adaptation (Kassam *et al*., 2018). Increasing the vegetation cover has been proposed as a strategy to cope with increased temperatures triggered by climate change, and to mitigate the negative impacts on human health (Reyes-Paecke *et al*., 2019). Tree planting practice on farm lands owing to the lucrative economic gains and its low susceptibility to moisture stress. The wide spread land use change or conversion of farm land into eucalypts woodland however needs to be seen with caution as land is a scarce resource in eastern and western Gojam (Weldlul Ayalew, 2016).

The agricultural measures such as the use of improved crop varieties, planting trees, soil conservation, crop diversification, changing planting dates, use of fertilizer and irrigation are the most widely used adaptation strategies (John, *et al*., 2013; Akinnagbe and Irohibe, 2014; Menike and Keeragala, 2016). There is also the need for governments and non-governmental organizations to invest in climate-resilient projects (Wondimagegn and Lemma, 2016). Increasing food production, enhancing livelihood outcomes with less vulnerability and reducing poverty gives high emphasis to show climate resilience (Guodaar, L. *et al*., 2019).

2.3.1 Irrigation Agriculture

The challenges of climate change will have to be met through adaptation options. Climate change is expected to intensify the existing risks, particularly in regions where water scarcity is already a concern. Agriculture requires water which is an increasingly scarce resource. Irrigated agriculture is protected to some extent from natural variability by hydraulic infrastructure (Iglesias and Garrote, 2015). Climate change and variability adaptation plans have prioritized water saving to prevent the devastating consequences of drought (Reyes-Paecke *et al*., 2019). Irrigation was a viable method that can help improve crop production in places with poor rain, high drought, or dry spell. Farmer's dugouts, dams, and wells near their farms or homes for irrigation could help in vegetable gardening, thereby supplementing farm yield (Fagariba *et al*., 2018). Use of irrigation as a strategy helped farmers cultivate crops without concern for rain. It is regarded as an effective measure to increase water accessibility to farmers to improve production (Guodaar, L. *et al*., 2019). Irrigation enhances agricultural yields and stabilizes farmer incomes, but over exploitation has depleted groundwater resources. Groundwater level declines are a global problem, solutions are necessarily local and site specific (Deines *et al*., 2019).

2.3.2 Crop diversification

Crop diversification used to maintain productivity under climate change through unreliable rainfall and drought. In fact, when intercropped with maize, legumes help to produce larger quantities of better quality organic matter inputs (such as nitrogen and soil organic carbon) leading to greater productivity benefits compared with mono-cropped maize plots in western Tanzania (FAO, 2016). Crop diversification is the practice of cultivating more than one crop varietys belonging to the same or different species in a given area in the form of rotations and or intercropping (Fadina and Barjolle, 2018). Farmers used crop diversification (mixed cropping, intercropping and dividing farm lands into varying crops) as an adaptation strategy to reduce the adverse effect of climate change in western Ethiopia (Seid Sani *et al*., 2016). Multiple crop species with different root systems and canopies in the given land dissipate climate risks. Mixed farming, agro-forestry and intercropping are more beneficial and adapted than mono cropping (Maharjan, 2019). Crop diversification is a strategy that maximizes the use of land, water and other resources and avoids risk and uncertainty due to climatic and weather variability (Piya *et al*., 2019; Teklewold, H. *et al*., 2019). Intercropping of potatoes with different crop varieties is identified as one of the adaptation strategies in eastern Ethiopia (Sisay Diriba *et al*., 2019). The result of Kassem *et al*., (2019) also found farmers who pursued different farming activities (vegetables, fruits, animal production, crops, food processing enterprises, etc.) are thought to be less vulnerable to climate change. In Belay *et al*., (2017) study reported that crop diversification was practiced by more households in the Central Rift Valley of Ethiopia. Similarly, the study by Lalego *et al*., (2019) found that mixed cropping is one of the effective adaptation mechanisms farmers use to overcome the impacts of climate change and variability on crop production in Southern Ethiopia. Diversifying crops have different but positive response to climatic shocks, pests and diseases (Maharjan, 2019). The most preferred strategies by smallholder farmers in southern Ghana were crop diversification, application of agrochemicals, and mixed cropping (Guodaar L. *et al*., 2019).

2.3.3 Soil Fertilizer

In areas of high rainfall, climate change can cause land degradation (Teklewold *et al*., 2018). Land degradation as a result of climate change is declining production and productivity of smallholder farmers (Seid Sani *et al*., 2016). Land degradation and soil fertility decline are critical problems in Ethiopia which aggravate poverty and food insecurity (Wondimagegn and Lemma, 2016). Degraded ecosystems no longer perform the basic ecosystem functions, such as water infiltration and maintenance of water cycles (Kassam *et al*., 2018). Adaptation strategies considered by small holder farmers across agro-ecologies and adaptive capacity are influenced by fertility of the soil and resource endowments (Weldlul Ayalew, 2016). Use of fertilizer inputs are singly important, better complementarities are derived from fertilizer and other adaptation practices (Teklewold *et al*., 2018). Application of chemical fertilizer was identified by a majority of smallholders as an adaptive strategy (Guodaar L. *et al*., 2019). The use of organic fertilizer is one of the most important sustainable agricultural practices, since it harmonizes agricultural production with the natural environment by improving soil permeability and water holding capacity as well as soil chemical properties (such as N, P, K) and other fundamental mineral nutrients. The productivity of chemical fertilizer is higher than that of organic fertilizer, at least in the short run. On the other hand, organic fertilizer appears to be more effective in reducing soil erosion and maintaining soil productivity in the long run (FAO, 2016).

2.3.4 Soil and water conservation (SWC) practices

Soil conservation practice is another climate change adaptation strategy pursued by smallholder farmers in western Ethiopia (Seid Sani *et al*., 2016). In Humid, high altitude and hilly areas, most farmers having farm plots with steep slopes are exposed to moving water caused by recurrent flooding that erodes the precious top layer of soil containing essential soil nutrient for crop production (Bedeke *et al*., 2018). Declining soil fertility resulting from climate change and other factors (e.g., soil erosion) are major problems facing smallholder farmers (John *et al*., 2013). Soil and water conservation techniques reduce soil loss from farmers' plots, preserving critical nutrients and increasing crop yields (Wondimagegn and Lemma, 2016). SWC measures also often provide benefits to neighbors and downstream water users by mitigating flooding, enhancing biodiversity, and reducing sedimentation of waterways (FAO, 2016). In addition to this rainwater enters the soil complex readily, because soil organic matter improves soil structure, since rates of infiltration usually exceed the rates of rainfall (Kassam *et al*., 2018). Stone bunds used for moisture conservation through reduction of runoff and allow more water to infiltrate (Mazvimavi *et al*., 2014).

2.3.5 Improved seeds

Smallholder farmers have introduced new crops and crop varieties; adopted crops and crop varieties, which are drought resistant, short maturing and high yielding verities of crops are among the adaptation options used by smallholder farmers across the agro-ecology to both perceived changes in temperature and precipitation and they have also stopped cultivation of some crops as well as crop varieties (Frehiwot Assefa, 2016; FAO, 2017). Improved seeds could improve food security by improving crop productivity (FAO, 2016). In John, *et al*., (2013) Improved varieties or breeds strategy enhance the smallholder farmer' crops or livestock resilience to climatic shocks. In the study of Sisay Diriba *et al*., (2019) said that improved potato varieties are important to increase yield and addresses food security problem in eastern Ethiopia. Similarly, Alam, *et al.,* (2017) also found farmers adopting new rice and wheat varieties as part of their response to the changing climatic conditions.

2.4 Constraints of Climate Change and variability Adaptation Strategies

The major constraints to apply agricultural adaptation strategies in Africa has been lack of knowledge, expertise and data on climate change issues; a lack of specific climate change institutions to take on climate change work and needs better institutional framework in which to implement adaptation options (Akinnagbe and Irohibe, 2014). Crop production is constrained by a number of problems including erratic rain fall/moisture stress, lack of plowing oxen, lack of money to buy agricultural inputs, lack of land and poor soil fertility, and problem of weeds and insect. In the face of unpredictable climatic condition these challenges affect food security of the farming community (Weldlul Ayalew, 2016). Adaptation faces various informational and resource constraints and advanced adaptation measures are only implemented by large or educated farmers (Muhammad Abid, 2016). Constraints claimed by smallholder farmers' involved inadequate working facilities, human population growth and lack of cohesion and unity among community members (Mussa, 2015).

2.5 Implemented Activities to Fill Adaptation Gaps

Actions to address climate change adaptation gaps include: training, research activities, specific institutional frameworks, incentives, etc. Furthermore, improving and strengthening human capital, through education, outreach, and extension services, improves decision-making capacity at every level and increases the collective capacity to adapt climate change (Akinnagbe and Irohibe, 2014). Adaptive capacity by smallholder farmers depends on access to resources that could help in responding to threats and exposures (i.e., access to low-rate loans, accessible services such as health care and sanitation, irrigation systems and water storage, etc.) (Echnoserve, 2014). It is also designing policies for smallholder farmers to improve climate change adaptation barriers (Wondimagegn and Lemma, 2016).

2.6 Conceptual Framework

This study was focused on assessing and identifying adaptation strategies by smallholder farmers' under the cause of climate change impacts and their interaction between different stakeholders to reduce this impact and farmers to adopt and used different climate change crop production adaptation strategies. This chain of interaction shows us to increase crop production by copping/adapting the current situation with minimum or reduced climate variability impact and government intervention actions for ultimately to come up with recommendation for what to do with these adaptation strategies. There was a need to evaluate the interrelationship and interactions of various factors revolving around the Adaptation strategies by smallholder farmers of the rural community.

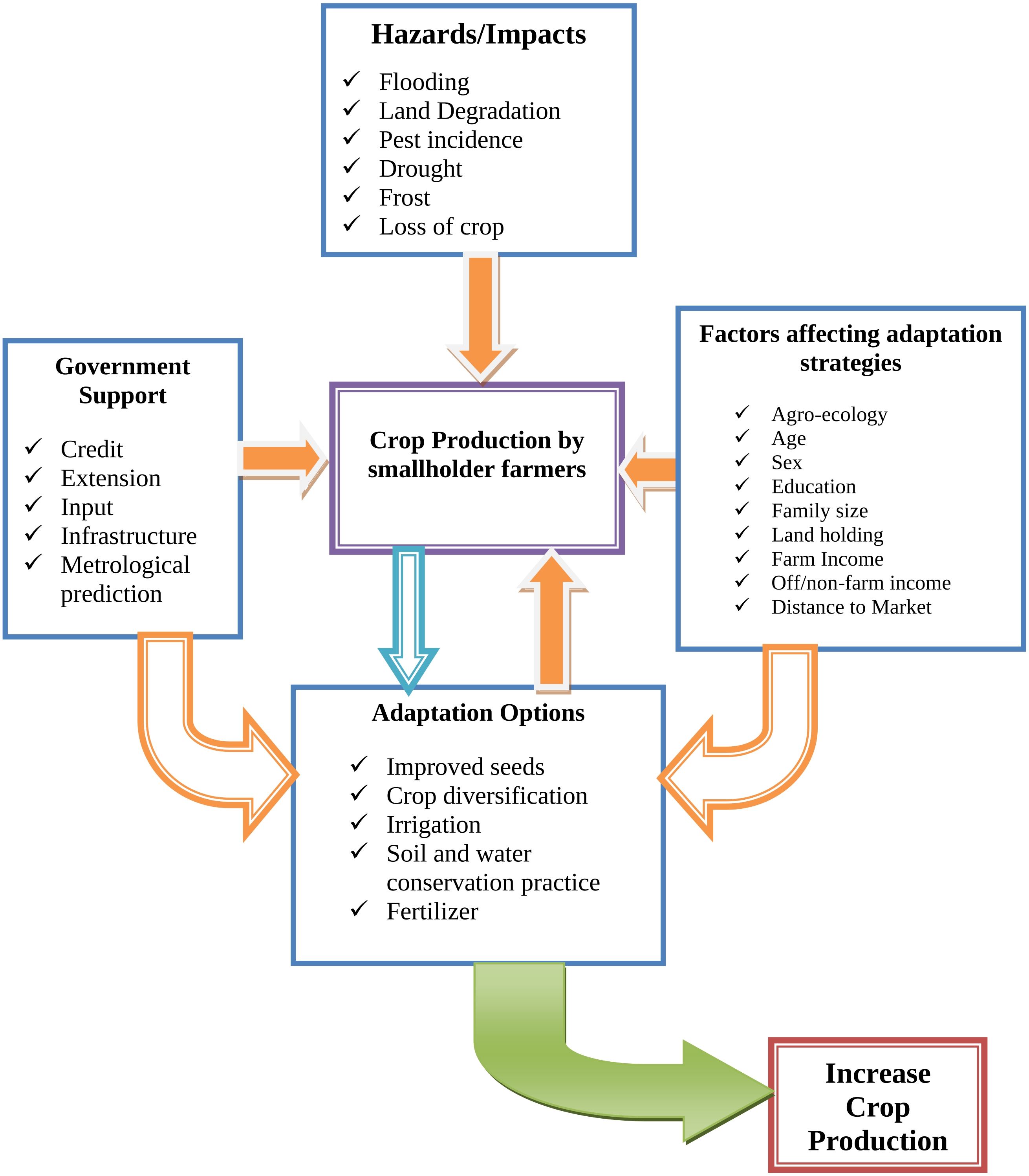

Figure 1: Conceptual Framework (own prepared).

3 MATERIALS AND METHODS

3.1 Description of the study area

Gozamin Woreda is found in Amhara regional state in East Gojam zone of north central part of Ethiopia. The Woreda hosts the administrative seat of East Gojam zone, which is 270 km far from the regional capital Bahir Dar and 299 km far from Addis Ababa. The woreda shares boundary with Machakel located to the west, Bibugn and Debay Telat lies to the north, Awabel and Baso Liben located to the east and finally Guduru woreda to the south. The geographic location extends from 10˚10'0" and 10˚30'0" North latitude and 37˚35'0" and 37˚45'0" East longitude respectively. The study area comprised of 25 rural kebele administrations with total area of 117,379.849 hectare (GARDo, 2018). Major rivers which drain in the Woreda, include Chemoga, Dijil, and Kulech.

3.1.1 Population Number of the Study Area

Population number of Gozamin woreda based on the Central Statistics Agency of Ethiopia 2007 census 66,348 male and 66,535 female totally 132,883 (CSA, 2010).

3.1.2 Soil type of the study area

According to the FAO soil classification, there are five major types of soil in the Woreda include Eutric Nitisols (reddish brown), Acrisols (red), Vertisoils (black), Cambisols (brown) and Phaeosoms (gray/black). From these soil types Eutric Nitosols is the dominant soil type in the Woreda (GARDo, 2018).

3.1.3 Agro-climatic condition of the study area

According to Gozamen agriculture rural development office document, from the total area of the district 74%, 16%, 9%, 1% of the land are categorized under woyna dega (intermediate), kola (low land), dega (highland) and wurch (afro alpine) respectively (GARDo, 2018). The topographic variation or elevation of Gozamin wereda extends from 920 m.a.s.l to 3700 m.a.s.l, which forms the Choke Mountain range. The annual rainfall of the Woreda varies from 1000 –1510 mm per year. The Woreda high rainfall season is during Kiremt that starts in June and ends in September and short rain season is in Belg, which encompass March, April, and May. Temperature is the major determinant factor for Ethiopian Climate. The mean minimum temperature for the Woreda is 8.5^0 c to mean maximum temperature of 30^0 c. The upper part of the Woreda is known for its minimum temperature which result in the prevalence of Dega type of climate while the lower part of the Woreda, which has the highest temperature, which is known for its Kolla type of climate (GARDo, 2018).

3.1.4 Socio-economic Activities

The farming system of the area is predominantly subsistence farming based on mixed crop-livestock production. The most important crops grown in the district were cereals like wheat, teff, maize, barley and oats. Pulse crops such as beans and chickpeas were produced. Oil seed crops such as linseed and Niger seed; Vegetables (onion, garlic, potato, tomato, pepper and carrot) and fruits (banana, mango, papaya, orange and lemon) were also produced in the district (GARDo, 2018).

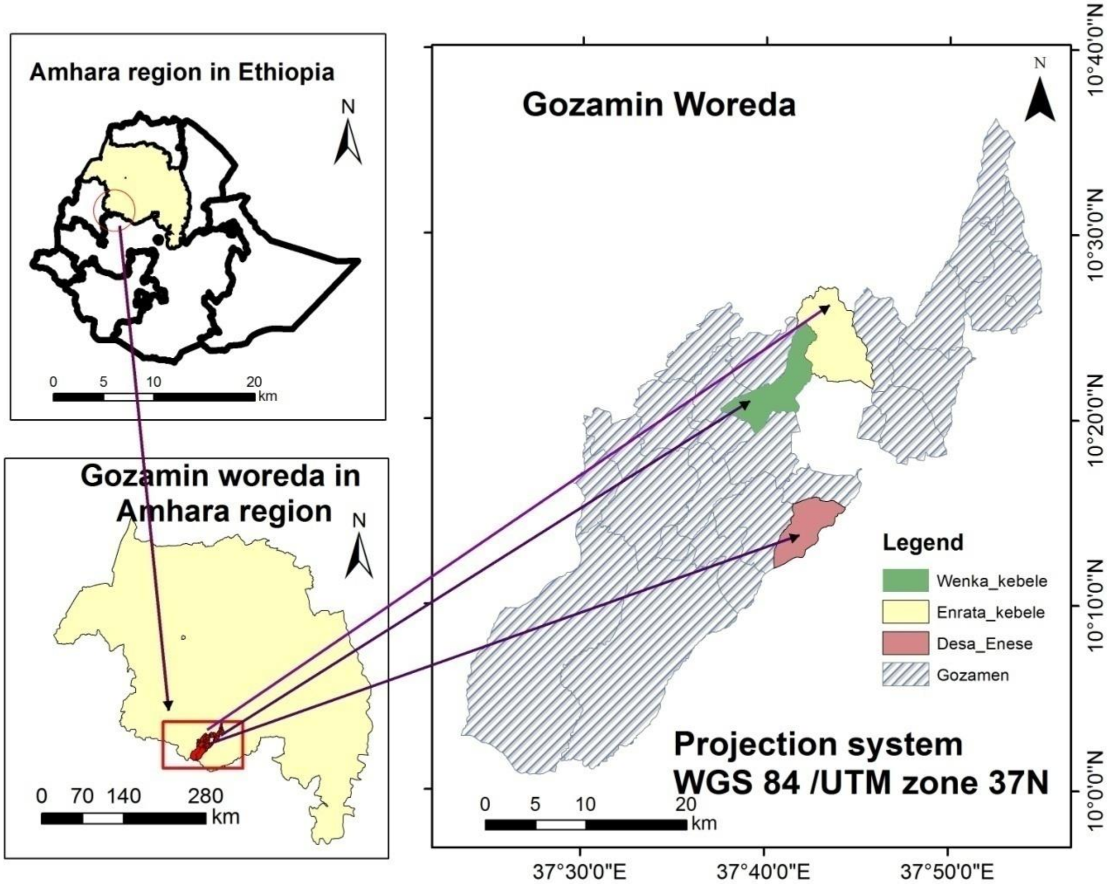

Figure 2: Map of the Study Area (own prepared).

3.2 Research design

Mixed quantitative and qualitative research design was employed. The quantitative method was employed to collect and analyze quantitative data while qualitative method was used to analyze qualitative data which cannot be handled quantitatively. The basic research design type that was used is cross-sectional due to shortage of time-series data on the research issue in Gozamin district.

3.3 Sampling Procedures and sample size determination

3.3.1 Sampling techniques

Gozamin district was selected purposively because of its characteristics of three farming agro-ecology; as highland (dega), midland (woyna dega) and lowland (kola). It has 25 rural kebele administrative. All kebeles of the district were stratified in to three agro-climatic zones i.e. Dega, Woyna dega and kola. The number of kebeles stratified under dega, woyna dega and kola agro-ecologies were 7, 15 and 3 kebeles respectively. Kebele selection from the three stratified agro-ecologies was performed using simple random sampling procedure to evaluate different crop production adaptation strategies. One kebele was selected randomly from each agro-ecologies, totally 3 kebeles were selected. The numbers of kebeles used for the study were purposively decided. The rationale for deciding the numbers of kebeles used for the study were based on factors like the cost of the survey, physical accessibility, shortage of time, to make it manageable, large number of factors to be analyzed and the precision level required/ increase the quality. As a result, those three sample kebeles were considered to be represented three different (dega, woyna dega and kola) agro-ecological zones. Sample kebeles were named Enerata from dega, Wonka from woyna dega and Desa Enesie from kola kebeles with 1168, 1142 and 910 household sizes respectively.

Finally, sample households were selected from each sample kebele by simple random sampling procedure from the sample units. Sample units (list of household heads from which the sample respondents drawn) were available in their respective kebele administrative offices.

3.3.2 Sample Size Determination

The household population size of the study area was 3220. Size of sample households were decided to 132 based on the formula (Cochran, 1977 cited in Teshome, 2014 and Weldlul Ayalew, 2016).

$$n_o = \frac{z^2pq}{D^2} \quad , \quad n = \frac{n_o}{1+\frac{(n_o-1)}{N}}$$

Where, n_o= the desired sample size when the population greater than 10,000.

n= the desired sample size when the population less than 10,000.

z= 95% of confidence i.e. 1.96

p= 0.1(population proportion to be included in the sample i.e. 10 %.)

q=1- 0.1 i.e. 0.9

N= total number of population

D= margin of error or degree of accuracy required (i.e. 0.05)

$$n_o = \frac{z^2pq}{D^2}$$

$$n_o = \frac{(1.96)^2 \times 0.1 \times .9}{0.05^2} = \frac{0.346}{0.0025} = \underline{\underline{\mathbf{138}}}$$

$$n = \frac{n_o}{1+\frac{(n_o-1)}{N}} = \frac{138}{1+\frac{138-1}{3220}} = \underline{\underline{\mathbf{132}}}$$

Efforts were made to ensure representation of the sample depending on the population of the study areas. Proportionate random sampling was designed to select divisions from each kebele. The sample size that was drawn from each sample kebeles such as Wonka, Enerata, and Desa Enesie kebeles were 47, 48, and 37 respectively. Proportionate sampling is the sample size determination from each kebele in proportional way with the others as:

$$n_i = n\ (Ni/N).$$

Where, n_i = sample size of a sample kebele,

n = total sample size

N= total HH population size of all sample kebeles and

Ni=population size of a sample kebele.

Table 1: The sample areas of the study site

No	Name of Sample kebele	HH Population size of kebele	Sample size (no)	Sample Percentage	Remark
1	Enerata	1168	48	37	Dega kebele
2	Wonka	1142	47	35	Woyna dega
3	Desa Enesie	910	37	28	Kola kebele
	Total	N=3220	n=132	100	

Source: Own developed (2019)

3.4 Data Sources and Collection Methods

The data used for this study was derived from both primary and secondary sources.

3.4.1 Primary Data Collection

Primary data is a type of data which is new data that can be gathered by the researchers directly. These data were collected through Survey Questionnaire, Key Informant Interview and Focus group discussion (FGD).

Household survey

A total of 132 sampled households were used for the study. As it is indicated on Table 1, the survey questionnaires were taken from Wonka, Enerata, and Desa Enesie kebeles with 47, 48 and 37 households respectively. The questionnaire was designed to fit into the objectives of the study. This contained structured with open-ended and closed-ended questions that were used to collect the primary data from the sample HHs and covered a wider range of information. This includes household information, social and economical information and crop production improvement adaptation strategies.

The data collection was done in February 2019 with the help of three enumerators for three kebeles who were temporarily employed and trained from the study area. Before starting the survey, the questionnaires were translated in to Amharic language for the ease of communication between sample HHs and the enumerators. The enumerators were briefed about the purpose of the study and made them familiar with the questionnaires. There was also a closely and timely supervision, adjustment and consulting the enumerators from the beginning up to the end of the data gathering work.

Key Informant Interview

Key informant interviews were conducted with different individuals at different levels. Key informants were selected based on their work which was related to this study. Such key informants were conducted from the sample kebeles' agricultural office experts (DAs), local NGOs (Migibare senay), agro-metrology experts and woreda crop production case team. A total of 6 key informant interview data were collected from the study area. Information gathered through this way help to grasp unforeseen data which was analyzed qualitatively and bring this study fruitful.

Focus Group discussion

Three focus group discussions with open- ended questions were conducted in all three sample kebeles. The participants of this discussion were selected among young, olds and both males and females, not involved in household survey. Each group had five to seven participants so that the discussion was manageable. The main purpose of this method was to triangulate the data obtained through sample HH survey and investigate additional facts that were not addressed by the survey method. It is very important to incorporate social and general information or data about the environment and used to build the qualitative data which was not assessed by household survey.

3.4.2 Secondary data sources

Secondary data source included both published and unpublished secondary documents, i.e. previous research works pertaining to this study, relevant and related literatures, research articles, journals, magazines and others, records and reports data related with the issue were gathered from the community, individuals, Development center, Kebele Administrative office and woreda agricultural development office, etc.

3.5 Data Analysis

Both descriptive statistics and econometric model analysis were employed for achieving the objectives of the study.

3.5.1 Descriptive Analysis

Integrated data analysis techniques were used to summarize the qualitative and quantitative data. STATA (a statistical software package) version 12 and Microsoft Excel were used to evaluate the existing adaptation strategies persuaded by smallholder farmers to cope climate change and variability including descriptive statistics such as mean, number, standard deviation, range, and percentage and econometric analysis.

3.5.2 Econometric Analysis

3.5.2.1 Choice of Appropriate Analytical Models

Binary versions were employed when the number of choices available is two (whether to adopt or not) and multivariate models are employed when the number of choices available is more than two. Multivariate models of choice have advantages by allowing the exploration of factors conditioning specific choices or combination of choices for self-selection and interactions between alternatives. For example, (Bedeke *et al.*, 2018) employed the multivariate probit model to analyze factors influencing the choice of climate change adaptation strategies among maize-dependent smallholders. Gebremariam and Tesfaye, (2018) analyzed the effect of idiosyncratic and covariate shocks on adoption of different agricultural innovations, assuming interdependence among the innovations. The studies by Aung Tun Oo, *et al*., (2017) and Ashraf, *et al*., (2018) used multinomial logistic regression to analyze the determinants of farmers' choice of specific adaptation methods.

In contrast to multivariate probit (MVP) model, multinomial logit (MNL) model used single choice of adaptation strategies and ignores the potential correlation among the unobserved disturbances in the adoption equations, as well as the relationships between the adoptions of different adaptation practices. Farmers may consider a combination of adaptation options as complementary and others as competing. The major limitation of a MNL model is the assumption of the practices to be mutually exclusive. This assumption is not true in reality, as a single household can simultaneously adopt more than one adaptation strategies. MNL is still a poor approximation to the true underlying outcome probabilities relative to the MVP model (Piya *et al*., 2019).

MVP model estimates the influence of explanatory factors on dependent variables, whilst allowing the unobserved error terms to be freely correlated. Such correlations of the error terms can be the source for complementarily (positive correlation) and substitutability (negative correlation) between different adaptation strategies (Ndiritu *et al*., 2014; Tongruksawattana & Wainaina, 2019). Multivariate probit model was used to determine the factors influencing farmers' adoption of adaptation Measures (Kassem *et al*., 2019). Therefore, this study utilizes MVP model to identify factors that determine crop production adaptation strategies by smallholder farmers under the changing climatic conditions.

3.5.2.2 Multivariate probit model

Farmers are more likely to adopt a mix of adaptation strategies to deal with a multitude of climate induced risks and constraints than adopting a single strategy. Based on this argument, the study adopted multivariate probit (MVP) econometric model to identify the influence of the set of explanatory variables on choice of each of the different adaptation strategies. The dependent variable in the empirical estimation for this study is the choice of crop production improvement adaptation strategies from the set of adaptation options (crop diversification, using improved seeds, use of irrigation, and use of fertilizer).

The multivariate probit econometric approach for this study is characterized by a set of *n* binary dependent variables $y\ hpj$ such that:

$$\mathbf{y}^{*}\ hp\,j = \boldsymbol{x}'\ hpj\ \boldsymbol{\beta}_{j} + \boldsymbol{U}\ hpj, \quad j = 1,2\ , \ldots.\ \mathrm{m}. \tag{1}$$

$$\boldsymbol{y}\ hpj = \begin{cases} 1, \text{ if } Y^{*}\ hpj > 0 \text{ or (if the farmer adopt)} \\ 0, \text{ otherwise} \end{cases} \tag{2}$$

Where j = 1,2, ...m denote the climate change adaptation strategies available; $x'\ hpj$ is a vector of explanatory variables, β_j denotes the vector of parameter to be estimated, and $U\ hpj$ are random error terms distributed as multivariate normal distribution with zero means and unitary variance. It is assumed that a rational h^{th} farmer has a latent variable, $y^{*}\ hpj$ which captures the unobserved preferences or demand association with the j^{th} choice of adaptation strategy. This latent variable is assumed to be a linear combination of observed households and other characteristics that affect the adoption of adaptation strategies, as well as unobserved characteristics captured by the stochastic error term.

Given the latent nature of the variable, *y** hpj, the estimation is based on the observed variable *y hpj* which indicates whether or not a household adopt a particular climate change adaptation strategy. Since adoption of several adaptation strategies is possible, the error terms in equation (1) are assumed to jointly follow a multivariate normal distribution, with zero conditional mean and variance normalized to unity. The off-diagonal elements in the covariance matrix represent the unobservable correlation between the stochastic component of the j^{th} and m^{th} type of adaptation strategies. This assumption means that equation (2) gives a MVP model that jointly represents decisions to adopt a particular adaptation strategy. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations which represent unobserved characteristics that affect the choice of alternative adaptation strategies.

3.6 Variables Definition and Hypothesis

3.6.1 Dependent Variables for Multivariate Probit Model

The dependent variable in the empirical estimation of this study is the choice of adaptation strategies from the set of adaptation options in the multivariate probit model. The choice of adaptation mechanism is assumed to be done among the most prevalent adaptation mechanisms in the study area.

Some of the adaptation measures used in response to climate change and variability were organic manure, inorganic fertilizer, soil and water conservation techniques, improved crop variety, crops diversification, and irrigation (Menike and Keeragala, 2016; Teklewold *et al*., 2018; Yaméogo *et al*., 2018; Guodaar, L. *et al*., 2019). Similarly, the study of Lalego *et al*., (2019) in Southern Ethiopia used crop diversification, mixed farming, changing crop varieties, irrigation farming, adjusting planting time, soil and water conservation practices as climate change and variability adaptation strategies. The adaptation choices for this study were based on asking sample households, the actions they take to counterbalance the negative impact of climate change and these include use of fertilizer, use of improved seeds, crop diversification and using irrigation.

3.6.2 Independent Variables for Multivariate Probit Model

Several socio-economic, environmental and institutional factors and the economic structure are key drivers influencing farmers to choose specific adaptation methods (Menike and Keeragala, 2016). The explanatory variables for this study are those factors which are expected to affect smallholder farmers' choices of crop production adaptation strategies against climate variability. In Kinuthia *et al*., (2018); Guodaar, L. *et al*., (2019); Nkuba *et al*., (2019) study used independent factors considered for analyses included gender, age, level of education, farming experience, farm size, access to credit, and access to extension services influenced farmers' perceived maladaptive outcomes of adaptation strategies. The study of Menike and Keeragala, (2016); Ashraf *et al*., (2018) and Kassem, *et al*., (2019) explored that age, gender, household size, farm income, education level, access to credit, land size, access to market, farming experience, access to extension services, access to climate change information and membership in community based organization are main factors influencing the decision of farmers adoption to climate change.

Based on the findings of past studies on climate change and variability adaptation strategies, the following variables are described about smallholder farmers' choice of crop production adaptation strategies to climate change andl variability. Independent variables for this study were Agro-ecology, Access to climate information, Education level of household head, Sex of household head, Age of household head, Family size of the household, Farm income, off/ non-farm income, Land holding, Extension service, Credit used and Distance to market.

Table 2: Description of independent variables

Variables	Description
Dega Agro-ecology	Value equals 1 if the Agro-ecology is dega and 0 otherwise
Woyna dega Agro-ecology	Value equals 1 if the Agro-ecology is woyna dega and 0 otherwise
Kola Agro-ecology	Value equals 1 if the Agro-ecology is kola and 0 otherwise
Access to Climate Information	Value equals 1 if a farmer has access and 0 otherwise
Sex	Value equals 1 if a farmer is male and 0 otherwise
Level of Education	Years of schooling
Age	Years of the household head
Family Size	Number of family members living in the household head
Land hold	Farm Size of own land holding in hectare
Farm income	Annual income from farming practices in Birr
Non-Farm income	Annual income from non-farm activities in Birr
Credit used	Value equals 1 if a farmer has credit access and 0 otherwise
Extension	Value equals 1 if a farmer has extension access and 0 otherwise
Distance to market	Distance from local market in Km

Source: Revised from (Ashraf, *et al*., 2018; Dembele *et al*., 2018; Sisay Diriba *et al*., 2019)

4 RESULT AND DISCUSSION

This chapter presents the results and discussion of the study obtained from quantitative and qualitative data from a household survey and desk review. Section one presents sample households' characteristics and their climate change and variability crop production adaptation strategies. Section two presents' climatic variability hazards and major constrains affecting crop production adaptation strategies. Section three presents crop production adaptation strategies and result of the maximum-likelihood estimates for factors that affect the choice of crop production adaptation strategies by smallholder farmers under the changing climatic conditions in the study area.

4.1 Characteristics of Sampled Households

4.1.1 Demographic Characteristics of the Households

For this study, essential information was collected from a total of 132 sampled households. Out of the total sample households surveyed, 91.7% of the respondents were male headed while 8.3% accounts female headed households (Table 3). The studies by Wrigley et al., (2017) recommend that climate change adaptation initiatives at the local level must take gender differences into consideration and support particularly women to strengthen their resilience and consolidate their empowerment.

All the sampled households were followers of Orthodox Christianity, who are accustomed to weekly, monthly and annual religious holidays. Saturdays and Sundays are common weekly religious holidays to Orthodox Christian farmers. Farmers do not carry out farm activities such as ploughing, cultivation, weeding and harvesting on these major religious holidays.

The youngest household head that was interviewed was aged 26 years whilst the oldest was aged 71 years with a mean age of 48.69 years. Age was considered as a proxy to the farming experience of the household, which was likely to have a significant influence on choice of crop production adaptation strategies to climate change and variability (Table 3).

The family size of the sampled households varies from 1 to 12 with an average household size of 6.08. The number of the family in the household was varying which is important for agricultural activities and household income contribution (Table 3)

Table 3: Demographic characteristics of the household

Variable	Obs	Mean	Std. Dev.	Min	Max
age	132	48.69	8.05	26	71
Family size	132	6.08	1.83	1	12
sex	132	1.08	0.28	0	1

Source: Own computed result, (2019)

Educational level of sampled household heads was believed to be an important feature that determines the readiness of the household head to accept new ideas and innovations regarding climate change and variability crop production adaptation strategies and efficient use of resources. The empirical result shows that the educational status of the sample household farmers ranges from 0 to 11 grade. The survey results also show that 43.2 % of the household heads were educated, and 56.8% were uneducated (Figure 3). From this, it can be inferred that there is high level of uneducated HH in the study area.

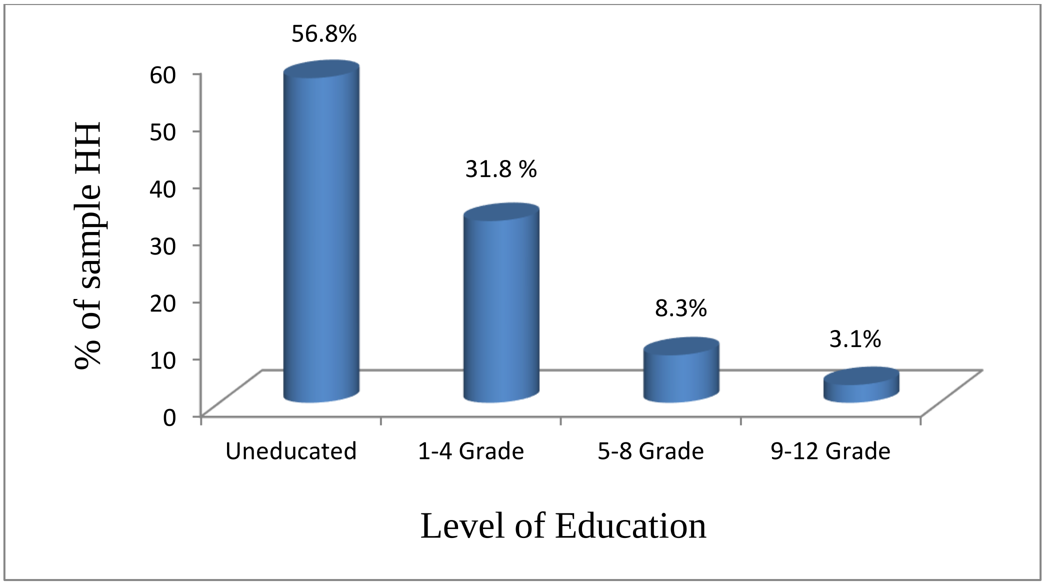

Figure 3: Educational status of sample households. (Own survey result)

4.1.2 Social Characteristics of the Households

The livelihood of many farmers in the study area mainly engaged in agricultural farming activities, including staple food crops production (such as teff, wheat, maize, barley and other cereal crops). Enegedo /Avena sativa/ is such a common crop grown by farmers on degraded lands in the highland areas.

The land holding of sampled households ranges from 0.0625 to 2.75 hectares with an average size of 1.12 ha. To adapt the current climate change and variability to fulfill their food demand majority of the farmers were rented the land an average size of 0.419 ha (Table 4).

Table 4: A sample Household land holding and family size

Variable	Obs	Mean	Std. Dev.	Min	Max
Own Land	132	1.12	0.55	0.0625	2.75
Rented land	132	0.42	0.42	0	2.125

Source: Own computed result, (2019)

4.1.3 Economical Characteristics of the Households

Major sources of income in the study area were on-farm activities mainly from sale of crops and off/non-farm incomes. The source of income distribution varies from farm to off/non-farm income. Farm income from sale of crops and forest of the surveyed households ranged from 1,250 to 159,700 birr with an average of 39,301.17 birr per annum, with standard deviation of 22,425.22 (table 5).

Off/non- farm were also other sources of income for some of the sample households. Petty trade, handicrafts and off/non-farm salary employment, daily labor and renting their assets were some of the off/non-farm income sources in the study area. Engagement in these types of activities may help households to avoid sale of major household assets, renting out agricultural land, and borrowing for coping purposes. As indicated in (table 5), the surveyed farmers' income from off/non-farm activities ranged from 0 to 42,500 birr with an average of 3,341.21 birr per annum. Previous studies found that, to address the negative impacts of climate change and variability, farmers have adopted both off-farm, non-agronomic and on-farm yield enhancing agronomic strategies to address the challenges (Wrigley *et al*., 2017).

Table 5: Farm and Non-farm Income of the household

Variables	Obs	Mean	Std. Dev.	Min	Max
Farm income	132	39,301.17	22,425.22	1,250	159,700
Off/non-Farm income	132	3,341.212	6,239.775	0	42,500

Source: Own computed results, (2019)

4.1.4 Institutional Characteristics of the Household

Provision of better infrastructure such as good roads will improve farmers' adoption of crop production adaptation measures by reducing their transaction costs. In some areas in the district roads are not passable at some times of the year. The main market for the smallholder community in the study area is Debre Markos town. When we see Enerata and Wonka kebeles have road access from Debremarkos town to the kebele center. But Desa Enesie kebele has no transport accesses to Debremarkos town. Accordingly, the average market distance the respondents traveled to reach the nearest market center at the time of survey was about 8.33 kilometers with the minimum and maximum distance of 3 and 17 kilometers, respectively (Table 6).

Extension service is necessary to provide basic information related to agricultural crop production and enhance the knowledge and skills of smallholder farmers. From Focus Group Discussion (FGD), there were no training access directly to climate change and variability to the smallholder farmers but they got training on some adaptation strategies separately like soil and water conservation activities, Irrigation practices, crop diversification, improved seeds and other activities to increase crop production. As indicated in (table 6), out of the surveyed sample households 74.2% had got extension service with a standard deviation of 0.439.

The availability of credit for resource poor farmers is quite important to finance agricultural technologies that could enable them to increase crop production. Access to credit for smallholder farmers is one way of improving economic capacity and ultimately adaptive capacity. In this study, out of the total sample households surveyed, 40.2% reported that they received credit with a standard deviation of 0.492. The received credit was used to buy fertilizer, improved seeds and other technologies. The major source of credit for farmers in the study area was Amhara Credit and saving micro finance (Table 6).

Access to information about seasonal forecast of the weather condition and climate change is necessary to understand the coming weather condition and to take measures. Access to weather information is essential to reduce expected impacts and crop losses. Access to weather forecast and information was 64.4% of the sample households from different sources with a standard deviation of 0.481. The main source of forecast information was development agents they were obtained agro-metrological data from Ministry of agriculture to farmers through agricultural offices. Other sources of forecasted information were from mass media and other farmers (Table 6).

Table 6: Institutional characteristics of the household

Variable	Obs	Percent	Mean	Std. Dev.	Min	Max
Distance to market	132	-	8.33	3.28	3	17
Extension service	132	74.2	0.74	0.44	0	1
Credit used	132	40.2	0.40	0.49	0	1
Climate information	132	64.4	0.64	0.48	0	1

Source: Own survey result, (2019)

4.2 Climatic Variability Hazards for crop production

Temperature in the environment is basic for crop production. The observed change in temperature by sample households in the study area was 87.9% had sensed increase. This shows that majority of them assured there was an increase in temperature could affect crop production. Previous study by Kothari *et al*., (2019) found that heat stress due to rising temperature under climate change could affect wheat yield by shortening grain filling duration and hastening crop maturity. Rainfall is basically important for crop production like temperature. The distribution of rainfall varies from time to time in the study area. From the total sample households 89.4% had observed erratic rainfall distribution in the study area. This erratic nature of rainfall strictly affected smallholder farmers' crop production and can increase susceptibility to climate change and variability (Table 7). The study by Wrigley *et al*., (2017) found that the rainfall pattern has changed in the past we could plant 2 times in the year, nowadays it's only once because the rains are unpredictable. Early flowering has been shown to ameliorate yield loss due to climate change (Kothari *et al*., 2019).

This erratic rainfall and temperature variation created favorable environment for air born crop pest and disease. This climate change and variability seriously affect crop production by different pest and disease outbreak which retards crop growth and reduce the output. This change aggravates vulnerability to climate change and variability. The majority of observed change in pest and diseases by sample households were 90.2% had observed increase in pest and disease infestation (Table 7).

Climate change and variability also seriously affects farm lands productivity in the study area by decreasing soil fertility through time. Farm land productivity was mainly degraded by intensive rainfall in a short period of time. In general, this indicates that repeated flooding on farmland reduces soil fertility and affects the land productivity. The rate of land productivity mentioned by sample households in the studying area was 50% of them said that the land productivity had bad or low productivity (Table 7). The use of chemical fertilizers was a key agronomic adaptation strategy for farmers. This practice is to improve yields and it appeared to be very common as many of the traditional crops have given way to maize production, which requires artificial fertilization to improve yield (Wrigley *et al*., 2017).

Table 7: Observed climate variability by sample households

Climate variability	Obs	Percent								
		Incre ase	Decr ease	No Change	Errat ic	Cons tant	I don't know	Go od	Satisf actory	Bad
Temperature	132	87.9	1.5	10.6	-	-	-	-	-	-
Rainfall distribution	132	-	-	-	89.4	4.5	6.1	-	-	-
Pest and Disease	132	90.2	3	6.8	-	-	-	-	-	-
Farm land productivity	132	-	-	-	-	-	-	9.1	40.9	50

Source: Own survey result, (2019)

4.3 Climate Change and Variability Adaptation Strategies

Tree plantation on farmland contributes for soil fertility improvement by incorporating leaves and roots to the soil. Sustainable forest management requires a clear understanding of the changes in soil quality owing to agricultural activities (Vicente and Gao-Lin, 2019). In addition to this, tree plantation increases water-holding capacity by improving soil organic matter. It can increase farmers' resilience to climate change and variability through carbon sequestration, and reduce risks due to erratic rainfall. Smallholder farmers growing tree plantation as climate change and variability adaptation strategies from the sampled households was 68.9% practiced these technology in different types (Table 8). Some of the common types of tree plantation practices implemented by sample households were boundary plantation, windbreak, parkland agro-forestry, woodlot, and homestead plantation.

Deforestation is the main causal factor of soil erosion. Roots of the trees, shrubs and grasses hold the soils in its place and therefore prevent soil erosion (Sarvade et al., 2019). Land degradation is a global environmental problem that threatens human safety and socioeconomic development. In order to alleviate severe soil erosion implemented unprecedented large-scale afforestation (Jiang *et al.*, 2019). Afforestation has the potential to improve soil quality, although tree species and stand age should be taken into consideration to obtain maximum benefits (Vicente and Gao-Lin, 2019). Tree planting as woodlot was practiced by 31.8% of the sample households used as climate change adaptation strategy. As obtained from the focus group discussion tree planting practices are highly expanding as a cash crop means. Generally, tree planting improves the soil fertility through addition of biomass; reduce soil erosion by holding the soil in place and preventing the loss of top soil by wind and running water.

One of the major challenges that farmers were facing in the study area in striving for crop production development was soil erosion or environmental degradation. The set of tillage practices and management strategies that favor soil and water conservation vary as a function of the main land use, such as cropland, forest, etc. where these practices are used (Vicente and Gao-Lin, 2019). Considering the magnitude of the soil erosion and flooding in the district, soil and water conservation techniques were widely adopted by smallholder farmers. This climate change and variability crop production adaptation strategy was implemented by mass mobilization. Out of the total sampled households, 84.1% used soil and water conservation practice to reduce the adverse effect of running water and to infiltrate in to the soil/plant root zone (Table 8). The most common soil and water conservation techniques adopted by the sample households were soil/stone bunds, water ways, terracing, cut off drains, check dams, and biological conservation practices. Among different land degradation categories, soil erosion through runoff is the major threat for degradation of soil and water resources (Sarvade et al., 2019). The study of Vicente and Gao-Lin, (2019), recommended that proper use of soil and water resources is necessary to ensure and advance the future well-being of humans and of the environment. In general, Jiang *et al*., (2019) result showed that SWC practice significantly reduced runoff and sediment yield in the watershed. SWC measures reduced soil erosion, improved soil structure, fertility, and anti-drought ability.

Table 8: Tree plantation and Soil and water conservation Practices

Variable	Obs	Percent	Mean	Std. Dev.	Min	Max
Tree plantation	132	68.9	0. 69	0. 46	0	1
Soil and water conservation	132	84.1	0. 84	0.37	0	1

Source: Own survey result, (2019)

4.4 Crop production adaptation strategies

Different crop production adaptation strategies were undertaken by the smallholder farmers in the study area to alleviate the current climate change and variability related hazards. To respond climate change and variability and reduce its negative effects, use of fertilizer, using improved seeds, crop diversification and use of irrigation practices were used by farmers in the study area as major adaptation strategies to climate change. These strategies, however, are mostly used in combination with other adaptation mechanisms to safeguard against losses that could result from changes in temperature and precipitation.

Most of the smallholder farmers use more than one improved seeds/crop types at a time to reduce the adverse effects of climate change and variability. The adoption of new crop varieties might be introduced simply as a way to increase crop production and household income. Improved seeds used by sample households in the study area were Teff, Maize and Wheat were 16%, 62.8% and 46.5% respectively (Figure 4). Out of the total sample households 72.8% used improved seeds as climate change and variability adaptation mechanism (Table 9). Use of new varieties of existing crop types are important adaptation strategies (Wrigley *et al*., 2017).

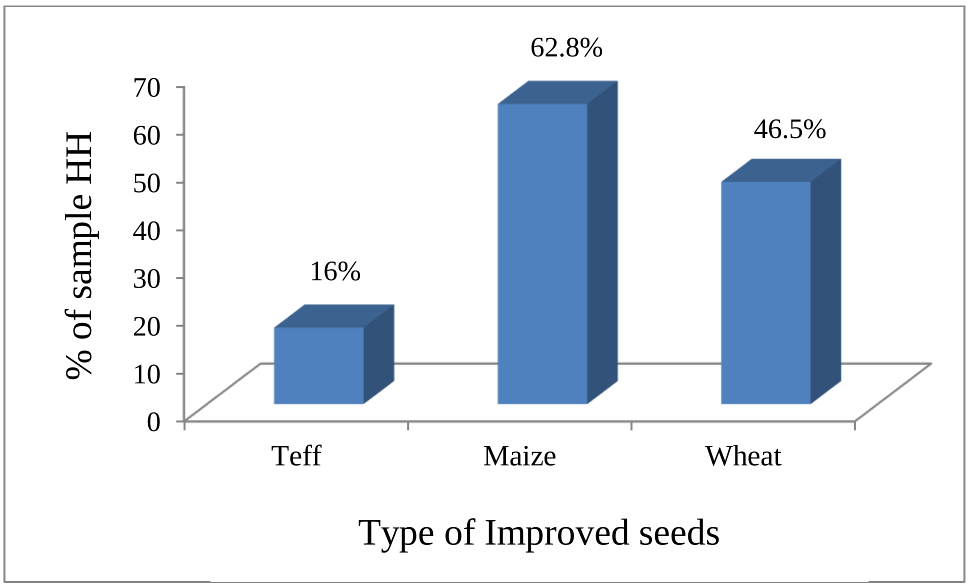

Figure 4: Type of Improved seeds used by sample households.

Crop diversification practice is the number of crops cultivated on the household's farm land. This is an agricultural production system that departs from a simple cereal based farming system to an ecologically diversified cropping system. This includes (mixed cropping, intercropping, crop rotation and dividing farm lands into varying crops) is a common practice in the study area. Crop diversification system is commonly practiced in the district where cereals (maize, barely, teff, and wheat), legumes (beans and peas) and vegetable (potato, onion, pepper and tomato) are grown together. According to the focus group discussions made with farmers, it was noted that they have wide field knowledge on the advantages of mixing crops with varying attributes in terms of maturity period, maintaining soil fertility, drought tolerance, input requirements and end users of the product. From the total sampled households, 53% use crop diversification as adaptation strategy to reduce the adverse effect of climate change and variability on farm productivity (Table 9). Intercropping different crops are sown at different times in alternate rows to shelter the topsoil from rain wash. The system involves growing of two or more crops on the same field, simultaneously (Sarvade et al., 2019). Fallow crop rotation is a common practice that affects soil water recharge and nitrate leaching in fields with annual crops (Vicente and Gao-Lin, 2019).

One of the most effective crop production adaptation options used to cope adverse effect of climate variability is irrigation. Irrigation agriculture has become a substitute for inadequate or unreliable precipitation in the district since recent years. However, unavailability of irrigable land and water for irrigation were among the main problems as reported by farmers during the survey. In the study area, about 39.4% of sample respondents have experience in using irrigation as adaptation strategy to reduce the adverse effect of climate variability and increase their crop productivity (Table 9). Most of them, however, grow vegetables and cereal crops in their irrigated land. The study by Sarvade et al., (2019) found that use of groundwater (by drilling tube wells) in high rates also depletes the groundwater level. The result of Jiang *et al.*, 2019) found that water saving agriculture (e.g., drip irrigation, micro irrigation, and mulching techniques) can improve the water use efficiency and save water resources. When we discuss with focus group discussion there is high ground water potential in different parts of the study area and has favorable land for irrigation with farmers having high interest to practice irrigation. However, it was not implemented as expected in the study area because it needs high technology to pump ground water and use widely. The groundwater plays an important role in hydrological system, because it responds slower to climate variations than other components of terrestrial water cycle (Jiang *et al.,* 2019).

To reduce soil erosion effects and increase crop production, smallholder farmers have used different types of soil fertility management practices. They bought inorganic fertilizers and local soil fertility management practices by applying organic fertilizers like manure or compost. Mostly organic fertilizer was applied in the homestead farming practices. Inorganic fertilizer was used in all farmlands by smallholder farmers. Fertilizer was applied by 75.8% of the sample households on their farm lands to increase or improve crop production (Table 9). Plant macronutrients such as nitrogen (N), phosphorus, potassium, calcium, etc. were carried out along with runoff water which revealed negative effects on agricultural productivity. In addition to this intensive agricultural practices accelerate the rate of soil erosion (Sarvade et al., 2019).

Table 9: Crop production adaptation strategies

Variable	Obs	Percent	Mean	Std. Dev.	Min	Max
Fertilizer application	132	75.8	0. 76	0. 43	0	1
Crop diversification	132	53	0. 53	0. 50	0	1
Irrigation	132	39.4	0. 39	0. 49	0	1
Improved seeds	132	72.8	0. 73	0. 45	0	1

Source: Own survey result, (2019)

Many farmers adopt and use more than one adaptation strategy at a time. Fig. 5 shows the distribution of the number of crop production adaptation strategies adopted by the households.

From the sample households 13.6% of them did not adopt any of the crop production adaptation strategies. On the other hand, around 8.3% of the households have adopted at least one of the crop production adaptation strategies. About 25.8% of the households adopted two of the crop production adaptation strategies. Similarly, around 28.8% of the households have adopted three of the crop production adaptation strategies, in combination. Finally 23.5% of the households have adopted four of the crop production adaptation strategies all together.

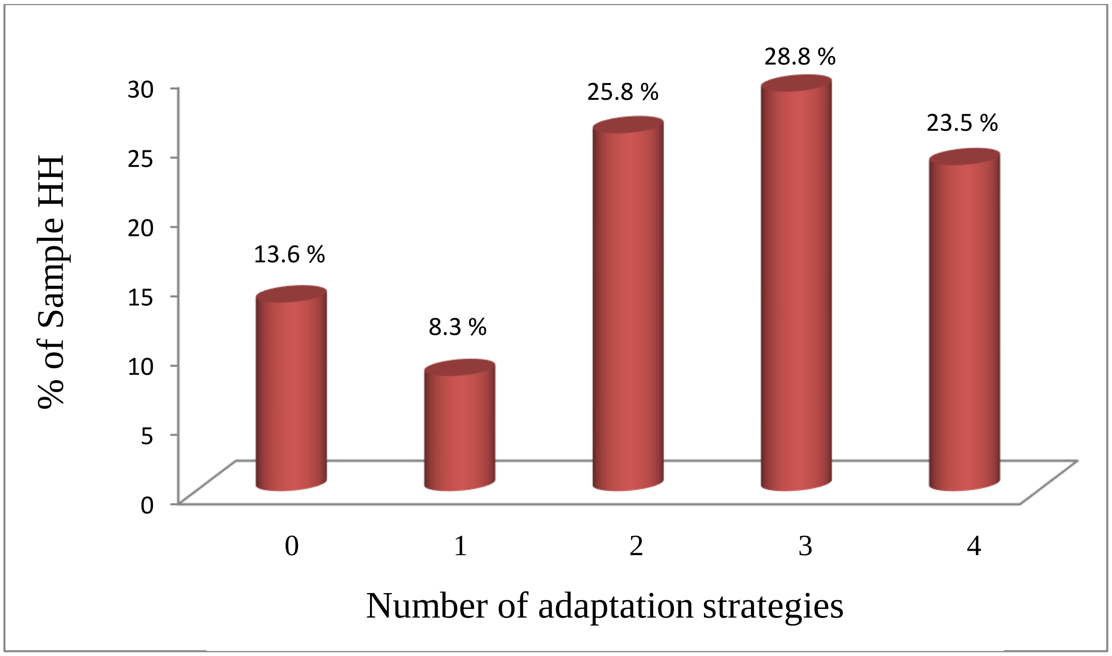

Figure 5: Number of adaptation strategies used by sample households

4.5 Constraints to Crop Production Adaptation Strategies

The farmers in the district faced with various constraints that can make the adaptation mechanisms ineffective at the farm level. The sampled households reported that they had various interrelated constraints that can make their life very difficult in the presence of climate change and variability hazards. Farmers also sort out their major challenge for their failures to adapt which includes lack of technical knowledge about adaptation strategies, lack of irrigation water, lack of money to finance their adaptation strategies, lack of weather information, lack of improved seeds that adapts the environment, shortage of labor, and shortage of land. Households surveyed had encountered more than one constraint for a given adaptation option that they favor. Accordingly, from the total sampled households, 29.5% faced lack of money to finance, 37.12% lack of access to irrigation water, 63.6% lack of technical knowledge, 23.5% lack of forecasted weather information, 12% lack of improved seeds, 32.6% shortage of land and 1.5% shortage of labor (Figure 9). Previous studies found by Masud et al., (2017) that climate change adaptation can be challenging when farmers encounter barriers such as high cost of farm input, unpredictable weather change, insufficient water resources, poor information on weather condition and field officers, inadequate credit facilities and absence of agricultural subsidies.

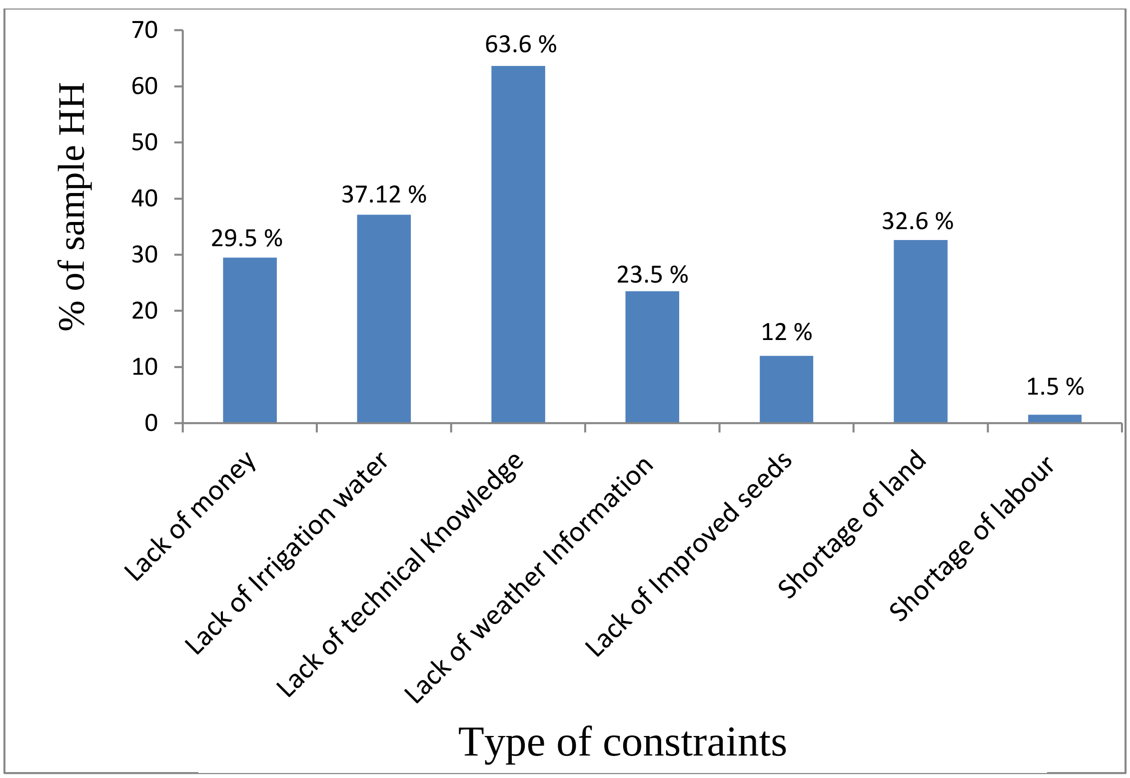

Figure 6: Constraints of crop production adaptation strategies (own prepared).

4.6 Econometric Results

Multivariate probit model was used to identify the determinant factors that affect the choice of crop production adaptation strategies towards climate change. Before running the model, the whole explanatory variables fitted to MVP model were tested for the existence of outliers and collinearities. All explanatory variables were checked for multicollinearity using Variance Inflation Factors (VIF) by Stata software. The variance inflation factors for all variables were less than 10, indicating absence of multicollinearity (Appendix 4: Table 1). In addition to this Breusch-Pagan test was checked for the possible existence of heteroscedasticity and showed that there was no problem. Therefore, all the model outputs were estimated using robust standard errors to correct for heteroscedasticity problem.

4.7 Factors affecting choice of Adaptation Strategies

Multivariate probit model was used to identify factors that determine adoption of crop production adaptation strategies of 132 sampled smallholder farmers in response to climate change and variability. These sample households were taken from three different agro-ecologies in the study area.

The model results revealed that the Wald Chi2 is statically significant. Furthermore, the Likelihood ratio test is also significant, implying that all the Rhoy values are jointly equal to zero. Regarding the determinants of climate change and variability crop production adaptation strategies, the results suggest that different household, socioeconomic, and agro-ecology characteristics were significant in determining the households' decisions to adopt crop production adaptation strategy.

Table 10: Multivariate Probit Model estimation of Crop production adaptation strategies

Explanatory Variables	Use of Fertilizer		Crop Diversification		Use of Irrigation		Use of Improved seeds	
	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
Dega Agro-ecology	0.317	0.808	1.812***	0.455	-1.200***	0.354	-0.288	0.391
Kola Agro-ecology	-4.378***	1.334	2.726***	0.909	-0.301	0.670	-0.651	0.799
Access to Climate Information	1.183*	0.659	0.463	0.376	0.992***	0.354	0.974**	0.395
Sex	0.085	0.962	1.300**	0.570	5.764***	0.542	-1.103*	0.643
Level of Education	5.233***	0.781	1.654***	0.447	0.565***	0.214	0.447	0.392
Age	0.099**	0.043	0.029	0.025	-0.046**	0.021	0.024	0.023
Family Size	-0.108	0.184	0.151	0.135	0.053	0.094	0.093	0.123
Land hold	-0.037	0.804	0.381	0.362	0.340	0.308	-0.517	0.398
Farm income	0.237	0.637	0.127	0.485	0.064	0.459	2.407***	0.646
Non Farm income	-0.057	0.055	-0.012	0.039	-0.001	0.033	0.122***	0.042
Credit used	1.371*	0.724	1.814***	0.384	-0.105	0.293	0.513	0.338
Extension	1.970**	0.791	-0.866	0.578	0.441	0.540	-0.823	0.566
Distance to market	-0.466***	0.180	-0.200*	0.113	0.083	0.083	-0.018	0.106
Constant	-15.818***	5.791	-5.130	4.628	4.272	4.637	-27.164***	6.246

Table 10 (Continue)

Variables	Use of Fertilizer		Crop Diversification		Use of Irrigation		Use of Improved seeds	
	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
rho2	-0.392	0.606						
rho3	-0.040	0.324	-0.341*	0.197				
rho4	-0.054	0.396	-0.006	0.187	-0.167	0.200		

Number of Observation = 132

Log pseudo likelihood = -156.82471

Wald chi2 (52) = 1102.32

Likelihood ratio test of Rhoij = 0: Chi2(6) = 4.74346

Note: * p < 0.10 (10 %), ** p < 0.05 (5 %), *** p < 0.01 (1 %); Coef. = coefficient and Std.Err = standard error

The MVP model results presented on Table 10 showed that level of education, age of the household head, credit used and extension service have significant positive impact on use of fertilizer as an adaptation strategy to increase crop production, whereas, kola (low land) agro-ecology and distance to market caused negatively significant impact. Crop diversification had also positively affected by dega (high land) agro-ecology, kola (low land) agro-ecology, sex of the household head, level of education and credit used. On the other hand distance to market was negatively affecting use of crop diversification. Having access to climate information, sex of the household head and level of education had a significant positive impact on use of irrigation as crop production adaptation strategy, while dega agro-ecology and age of the household head had a significant negative influence. Furthermore, using improved seeds was positively and significantly affected by having access to climate information, farm income and non-farm income, whereas, sex of the household head had negatively affecting adoption of improved seeds.

Some of the explanatory variables are highly significant to affect the decision made by farmers about a particular adaptation strategies and it may be insignificant for the other adaptation groups. Thus, the multivariate probit analysis result revealed that the decision of each class of climate change and variability crop production adaptation strategy was influenced by different factors and at different levels of significance by the same factor. Results of MVP analysis also showed that most of the estimated parameters conform to the expectations except the variables like, family size and land holding of the household, which were not found to be significant in influencing crop production adaptation strategies of smallholder farmers in the study area.

1. Agro-ecology: The result of the study showed that, as compared with farming in woyna dega, farming in dega agro-ecology significantly increases the probability of using crop diversification and significantly decreases the probability of using irrigation practices as adaptation strategies. When we compare with kola the probability significantly increases for using crop diversification and decreases the probability of using fertilizer as adaptation strategies. This result told us dega agro-ecology had less probability of using irrigation because of roughed or mountains topography than woyna dega agro-ecology. When we see kola agro-ecology had less probability of using fertilizer than woyna dega because of lack of transport access and far from market center. The adoption of crop diversification increased in dega and kola agro-ecology than woyna dega because of harsh environment for crop production.

Previous studies found that different farmers living in different agro-ecological settings employ different adaptation methods because of differences in climatic conditions, soil and other factors (Wondimagegn and Lemma, 2016; Alemayehu & Bewket, 2017; Yaméogo *et al*., 2018; Esayas *et al*., 2019; and Jairo and Korir, 2019). FAO, (2016) found that the higher the variability of rainfall causes the lower the probability of organic and inorganic fertilizer adoption. The result of Wondimagegn and Lemma, (2016) found that farmers in the highlands and mid-highlands are more likely to choose cultivation of different crops, planting different crop varieties compared to those in the lowlands. Menike and Keeragala, (2016) also found that farmers located in the alluvial plains and hilly agro-ecological zones tend to do high adaptation as compared to those located in windy and river side agro-ecological zones. The result by Gebremariam and Tesfaye, (2018) reported that the geographic and location variables are also important determinants of adoption of most of the agricultural innovations. Similar result to this study found by Yaméogo *et al*., (2018) that compared to the drier area, farming in wetter areas significantly decreases the probability of using organic fertilizer and irrigation. But, farming in wetter areas significantly increases the chance of using crop diversification as adaptation strategy. Similarly Weldlul Ayalew, (2016) concluded that choice of farmers' adaptation strategy to climate change varies across agro-ecology. In general, different agro-ecological locations call for different strategies due to climatic and weather variations. This implies that different households living in different agro-ecological settings affect the adoption of crop production adaptation strategies.

2. Access to climate/weather information: the result of this study shows access to weather forecasting information has positive and significant impact on the use of fertilizer, irrigation and improved seeds as adaptation strategy to cope up the negative effects of climate change and variability in the study area. Seasonal climate forecasts provide information on early warning for impending floods and droughts (Nkuba *et al*., 2019). Increasing rainfall variability significantly decreases the likelihood of adoption of fertilizer and modern seeds, because of adoption of risk-increasing inputs. But reliable information on temperature and rainfall has a significant and positive impact on the likelihood of using different adaptation options (Teklewold *et al*., 2018). Farmers who are aware of changes in climatic conditions have higher chances of taking adaptive measures to combat the impact from risks related to climate change and variability (Belay *et al*., 2017; Getachew Teferi *et al*., 2018; Dang, H. *et al*., 2019; Piya *et al*., 2019; Korir and Ngenoh, 2019). This study is in line with the result of Frehiwot Assefa, (2016) that having access to climate information increases the tendency of farmers to adopt new crop varieties, crop diversification and fertilizer greater than non accessible farmers. Similar finding with Abid M. *et al.,* (2018) they argued that farmers may enable to adjust their short-term and day-today crop management decisions, such as watering crops, harvesting, and fertilization according to daily or weekly weather forecasts. This is similar to the finding of Kinuthia *et al*., (2018), who also reported that farmers who received weather information were more likely to adjust planting dates and do some irrigation as adaptation strategies. Similar result with this study found by Frehiwot Assefa, (2016) and Soglo and Nonvide, (2019) that farmers who have more access to climate information are more motivated to accept improved crop varieties instead of local variety. In general, to conclude this result, farmers with easy access to weather forecasting information have significant impact to adopt and use crop production adaptation strategies to reduce the negative effects of climate change and variability in the study area.

3. Sex of household head: Sex of the household head is an important variable affecting adaptation decision at the farm level. The result of this study suggests that, male headed households increases the probability of using crop diversification and irrigation as adaptation strategies whereas, female headed households increases the probability of using improved seeds as climate change and variability crop production adaptation strategy. The negative coefficients for sex variable shows that female headed households are more likely to take up adaptation strategy than males, whereas, the positive coefficients for sex variables shows that male headed households are more likely using adaptation strategies than females. Male headed households had better opportunities to practice adaptation measures than the female headed households (Belay *et al*., 2017). Whereas, the result of Wondimagegn and Lemma, (2016) study shows that targeting women groups and associations can have significant positive impacts for increasing the uptake of adaptation measures by smallholder farmers. The result of Korir and Ngenoh, (2019) they found that gender of the household head was statistically significant with positive effects on the adoption of the community-based adaptation strategies to impacts of climate change among the pastoral community in Kenya. This is in line with previous studies Ubisi *et al*., (2017) reported that male smallholder farmers adapted by employing crop diversification better than female farmers. This result is also in line with Korir and Ngenoh, (2019); Sisay Diriba *et al*., (2019) found that gender of the household head showed a significant positive effect on farmers' irrigation usage. Similar results found by Gebremariam and Tesfaye, (2018) that male headed households are more likely to adopt crop rotation than their female-headed counterparts. Contrary result found by Wondimagegn and Lemma, (2016) that female headed households are more likely to take up crop diversification as an adaptation option. Frehiwot Assefa, (2016); Ubisi, *et al*., (2017) and Soglo and Nonvide, (2019) also found contrary results that male headed households are more adopt improved crop verities compared to female headed households. Similarly, Kinuthia *et al*., (2018) in east Kenya found that gender was not to be a significant factor for crop production adaptation strategies. The community is traditionally nomadic pastoralists who did little or nothing in crop farming. To conclude this result, sex of the household heads has significant influence on the adoption and use of crop production adaptation strategies in the study area.

4. Education level of the household head: The result of this study showed that education level of the household head has positive and significant effect on the adoption of fertilizer, crop diversification and irrigation as crop production adaptation strategies to climate change than that of less educated farmers. This suggests that being educated smallholder farmers would improve access to information, easily understand and analyze the situation better than less educated farmers (Abid M. *et al.*, 2018; Yaméogo *et al*., 2018; Dang H. *et al*., 2019; Kassem *et al*., 2019; Korir and Ngenoh, 2019). This shows us formal education increases knowledge level and broadens their perspectives of understanding of the environment, particularly regarding environmental changes (Guodaar, L. *et al*., 2019). The study in western Uganda was hypothesized that farmers with higher levels of education should more likely adapt better the climate change and variability (Nkuba *et al*., 2019). The result of this study indicated that educational status increase the awareness of farmer about the consequence of climate change and variability on crop production and benefit of fertilizer, crop diversification and irrigation to reduce the impact of climate change and variability. This finding is similar with Sisay Diriba *et al*., (2019) farmers with a higher educational attainment are more likely to use intercropping to combat adverse climate change effects. Similar results found by Seid Sani *et al*., (2016) and Dembele *et al*., (2018) that literacy status of the household head significantly and positively affected use of crop diversification as adaptation strategies. The result of this study is similar with Belay *et al*., (2017); Kinuthia *et al*., (2018); Tarfa *et al*., (2019) they found that increase in number of years of education could increase use of crop diversification and irrigation as adaptation measures. Similar result by Guodaar, L. *et al*., (2019) found that farmers' access to formal education was significant and positive for perceiving application of agrochemicals and irrigation as adaptation strategies. On the reverse of this study Piya *et al*., (2019) report that educated household heads are less likely to adopt adaptation strategies related to farming. In general, more educated household heads were more likely to adopt crop production adaptation strategies compared to non educated ones. This means one more years of schooling of the household head increases the rate of adoption of crop production adaptation strategies under the changing climatic conditions.

5. Age of household head: Age of the households has positive and significant impact on use of fertilizer as an adaptation strategy. But, it has negative and significant impact on use of irrigation as crop production adaptation strategy for climate change and variability. This shows us increased age of the household head have high experience in the livelihood on adaptation to climate change and variability. Various literatures provide mixed influence of age on the decision of choosing adaptation strategies to climate change and variability. On the one hand, older farmers have considerable experience in farming practices. More experienced farmers may have better information to evaluate the impacts of climate change and variability on crop production as well as implement the adaptation strategies (Lalego *et al*., 2019). On the other hand, older farmers were more conservative to adopt technological innovations in their farming practices (Belay *et al*., 2017; Dang, H. *et al*., 2019). The result of Piya *et al*., (2019) found that higher age and education of the household head are less likely to depend on traditional coping strategies and more likely to adopt improved adaptation practices. This result is in line with Gebremariam and Tesfaye, (2018); Kinuthia *et al*., (2018); Al-Amin *et al*., (2019) that age of the household head is negatively correlated with irrigation use. Similarly Yamba *et al*., (2019) also hypothesized that farms were manually irrigated with the undulating nature of the terrain made it difficult for aged farmers to adopt irrigation. On the other hand, Belay *et al*., (2017) found age is positively related with the decision to intensify agricultural inputs like fertilizer. Contrary to this study found by Yaméogo *et al*., (2018) that older and educated farmers have a higher probability of adopting agro-forestry and irrigation techniques than younger and non-educated ones. Another opposed result by Gebremariam and Tesfaye, (2018) found that age of the household head is negatively correlated with chemical fertilizer adoption. To conclude this result, increased age of the household head have high experience in the livelihood to choose appropriate crop production improvement adaptation strategy like fertilizer to climate change and variability but have less labor to implement hard works like irrigation practices.

6. Farm income: The result of this study shows farm income of the households has a positive and significant impact on use of improved seeds. This could be apparent because use of improved seeds requires financial resources to purchase and hence increased income will encourage the investment capacity on this adaptation strategy. The implication of the result was that availability of farm income improves farmers' financial position, which in turn, enables them to purchase farm inputs such as improved seeds. Cash income for the smallholder farmers was obtained from selling farm produce (Ubisi *et al*., 2017). Higher incomes allow farmers to have access to critical productive resources such as farm assets, inputs and land which increases crop production (Dembele *et al*., 2018). Similar findings of Ashraf, *et al*., (2018); Dang, H. *et al*., (2019) farmers who have more income are more likely to adopt strategies to climate change. The likelihood of adoption strategies increases with increasing in income. The result of this study is consistent with Seid Sani *et al*., (2016) and Tarfa *et al*., (2019) that farm income has a positive and significant impact on use of improved crop varieties as an adaptation strategy. The reverse of this result found by Ubisi *et al*., (2017) reported that farming as a source of income for smallholder farmers has a negative impact on improved crop varieties and crop diversification for farmers. In general, when the main source of income in farming would increase, farmers tend to invest on purchase of improved seeds to increase crop productivity. The result confirms the hypothesis which states that farm income of the households has a positive and significant influence on the adoption of crop production adaptation strategies under the changing climatic conditions.

7. Non-farm income: The non-farm income of the households like farm income has a positive and significant impact on use of improved seeds. Smallholder farmers' practice other activities, in addition to farming, such as wage labor, making handcrafts (Ubisi *et al*., 2017) guard in the nearby organization (include cooperative association and school), being laborer force in the nearby community, petty trading (such as local drink, Areqe, Tela as well as firewood and charcoal selling) for income generation (Frehiwot Assefa, 2016). Off-farm activities play vital role in reducing vulnerability of farm households from climatic change it is only very limited number of farmers engaged in such activities (Frehiwot Assefa, 2016; Weldlul Ayalew, 2016). This means availability of off /non-farm income improves farmers' financial position, which, in turn, enables them to purchase farm inputs such as improved seeds and other materials needed for crop production. The result of Bedeke *et al*., (2018) and Korir and Ngenoh, (2019) also showed that household non-farm income can be positively correlated with adoption of climate change adaptation strategies. The result of this study are similar to Sisay Diriba *et al*., (2019) reported that access to non-farm income influences a household's decision to adopt improved seed varieties positively and significantly. The result of Seid Sani *et al*., (2016) stated that off/non-farm income increases uptake of irrigation and improved crop varieties as adaptation strategies to climate change. Contradict result to this study found by Jairo and Korir, (2019) that monthly income reduces the probability of planting drought tolerant crops with no effect on planting new crops or practicing soil and water conservation measures. This shows that one can easily buy the product from the market instead of laboring with planting. In general, this result told us off /non-farm income generating activities increase the household economic strength to use the appropriate adaptation strategies like improved seeds as crop production adaptation strategies under the changing climatic conditions.

8. Credit used: The result of this study indicates that credit used have a positive and significant impact on likelihood of using fertilizer and crop diversification as adaptation strategies to climate change and variability on crop production. Availability of credit is important in the process of adaptation to climate change (Soglo and Nonvide, 2019). Access to credit increased financial resources of farmers and their ability to meet affordable transaction costs associated with the various adaptation options they might want to take (Menike and Keeragala, 2016; Tessema *et al*., 2018; Korir and Ngenoh, 2019; Piya *et al*., 2019). The result of this study is consistent with the finding of Gebremariam and Tesfaye, (2018) access to credit was found to have a positive and significant association with chemical fertilizer and crop rotation adoption. Similarly, the result of Bedeke *et al*., (2018) found that access to microcredit services may ease farmers' cash constraints and thus positively associated with use of chemical fertilizers, high-yielding crop varieties and use of irrigation. Similar study by Hailu Elias, (2016); Tarfa *et al*., (2019) found that access to credit is one of the critical factors in the crop diversification decisions of farm households. Planting different types of crops, especially cash crops, is risky and requires substantial cash outlays to purchase inputs like seeds and fertilizers. Similarly, Wondimagegn and Lemma, (2016) who found that better access to credit services is found to have a strong positive influence on the probability of adopting cultivating different crops as an adaptation measure and abandoning the relatively risky mono cropping systems in eastern Ethiopia. On the contrary to this study, Getachew Teferi *et al*., (2018) found that households with better access to credit were less likely to choose crop management related adaptation strategies (which include using different crop varieties, adopting drought-resistant crops, increased use of fertilizer). This tendency could be because households may prefer to fill food gap which resulted from frequent drought with the money they borrowed. Similarly Frehiwot Assefa, (2016) found that if farmers get credit they are not motivated to adopt adaptation strategies and could more intended to other adaptation strategy. Fagariba *et al*., (2018) also obtained reverse result with this study that access to credit facilities had a negative correlation with climate change adaptation options. Farmers suggested that difficulties in accessing credit coupled with high interest rates make credit facilities unattractive. To conclude this result, use of credit services have strong positive influence on the probability of adopting crop production adaptation strategies by increasing financial resources of smallholder farmers to use fertilizer and crop diversification as an adaptation measure to increase crop production in the study area.

9. Extension service: The result indicates that access to extension service has significant positive impact on use of fertilizer, which helps to increase crop production under the changing climatic conditions. This could be due to the fact that extension services create access to information about climate change and variability and their adaptation mechanisms. Access to extension services showed a positive impact on the implementation of climate change adaptation strategies (Abid M. *et al.,* 2018; Nkuba *et al*., 2019). Awareness creation and knowledge generation on the suitable climate change adaptation option is a timely requirement so as to minimize the effect of climate change and optimize crop yield (Lalego *et al*., 2019). To put in another way, farmers with more access to information and technical assistance on agricultural activities have more awareness about the consequence of climate change (Belay *et al*., 2017; Abid M. *et al.,* 2018). The results of Gebremariam and Tesfaye, (2018) and Piya *et al*., (2019) found that extension service is positively correlated with adoption of different agricultural innovations. It is the common source of information for smallholder farmers to learn about agricultural innovations. This result is consistent with Ndiritu *et al*., (2014) that the probability of adopting maize-legume intercropping, minimum tillage, chemical fertilizer, and manure increased with access to agricultural extension services. This result is similar with Tessema *et al*., (2018) that access to agricultural extension services increases the adoption of fertilizer use in the Semien Shewa Zone of Ethiopia. Similarly the result by Guodaar, L. *et al*., (2019) found that access to extension services was significant and positive for perceiving application of fertilizers, mixed cropping and irrigation as adaptive strategies. Concluding this result shows that extension services often involve education on adoption and application of fertilizer that can increase crop production on less fertile areas. This means extension service increases use of fertilizer to increase crop production as adaptation strategies under the changing climatic conditions.

10. Distance from the market center: The result of this study showed that distance to the nearest market has a negative and significant impact on use of fertilizer and crop diversification as adaptation strategy. Proximity to market is an important determinant factor to use adaptation strategy, because the market serves as a means of exchanging information with other farmers (Menike and Keeragala, 2016; Yaméogo *et al*., 2018). When farmers are far from the market, the transaction cost for acquiring input and output will be high and this will, in turn, reduce the relative advantage of adopting new technologies. The result of Gebremariam and Tesfaye, (2018) found that, distance related variables were expected to have a negative relationship with the agricultural innovation adoption especially for the high input innovations, due to the increasing travel time and transaction costs involved. Similarly, the result of Piya *et al*., (2019) reported that households in remote areas were constrained by the lack of information, lack of access to market to dispose their products, have less off-farm employment opportunities, and are less served by development agencies leading to lesser dissemination of information regarding the improved agricultural practices.

Contrary to the results of this study Getachew Teferi *et al.*, (2018) found that an increase in distance to input/output markets increased the probability of adoption of using different crop varieties and fertilizer as adaptation strategies. This could be because as the distance increases from the marketplaces, adaptation through the options available becomes a must as households do not have other options to fall back on. Similarly, Wondimagegn and Lemma, (2016) found that positive effect of market distance on the adoption of crop diversification indicates that remoteness from markets tends to favor multiple cropping over specialized crop cultivation. Concluding this result shows us distance from market centers negatively affects the adoption of crop production adaptation strategies like fertilizer and crop diversification; because, it makes discourage/difficult for farmers to access new technologies and information necessary to increase crop production.

4.8 Crop production adaptation strategies complementarities and tradeoff

The results of MVP model above in Table 10 presented the pair wise correlation coefficients between crop production adaptation practices. This shows that the correlation coefficients are statistically different from zero. This suggests that crop production adoption are not mutually exclusive, showing that, the probability of adopting of one adaptation strategy does not mean other adaptation strategy could not be adopted. A positive correlation among adaptation strategy showed that households perceived the adaptation strategy as complements to increase crop production while a negative relationship showed households perceive tradeoff among crop production adaptation strategies. The result of this study indicated that there existed a negative correlation between adoption of using irrigation and crop diversification. The negative correlation between using irrigation and crop diversification suggested that households view the two as tradeoffs. The negative correlation may sometimes simply show the difference in suitability based on plots and household conditions (Wainaina *et al*., 2016). The cross-correlation among the adaptation practices may have important policy implications. These interactions can help define appropriate packages of adaptation practices tailored to specific areas (Teklewold *et al*., 2018). This finding is similar with Wainaina *et al*., (2016) and Gebremariam and Tesfaye, (2018) that adoption of irrigation with crop rotation and adoption of improved seeds with organic fertilizers are found to be negatively correlated showing possible tradeoffs associated with combined adoption of the innovations such as competition for scarce resources. Contrary to this study, the result of Seid Sani *et al*., (2016) found that there was positive and significant interdependence between household decisions to adapt use of irrigation and crop diversification practices.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Most smallholder farmers in the study area were aware that the area is getting warmer and rainfall patterns have changed. The most pronounced effects of climate change and variability were decline in soil fertility, erratic rainfall, crop diseases and pests, reduce crop yield and change in livelihood patterns of the households. These adverse effects are found to be more severe in Gozamin districts. Important crop production adaptation options being used by farmers in response to adverse effects of climate change include crop diversification, use of soil fertilizer, use of irrigation and use of improved seeds. Tree plantation and soil and water conservation practices by smallholder farmers were also used as a climate change and variability adaptation practice. The major sources of income in the study area were on-farm activities mainly from sale of crops. Off-farm and non-farm activities were also other sources of income for some of the sample households in the district.

The farmers in the district have faced various interrelated crop production constraints that can make their life very difficult in the presence of climate change and variability hazards. Smallholder farmers sorted out their major challenge for their failures to adapt which include lack of technical knowledge about adaptation strategies, lack of irrigation water, lack of money to finance their adaptation strategies, lack of climate and weather information, lack of improved seeds that adapts the environment, shortage of labor and shortage of land.

The results from the MVP analysis indicated that agro-ecology, access to climate information, sex, educational level, age, farm income, non-farm income, credit used, extension service and distance to market have significant impact on adaptation to climate change. The result also shows that use of all crop production adaptation strategies was 23.5% and failure to adopt any one of the crop production adaptation strategies was 13.6%. From all crop production adaptation practices, irrigation had low adoption efficiency and use of fertilizer had high adoption efficiency compared to others.

Thus, the results of the study are believed to give information to policy makers and extension workers on how to improve farm level crop production adaptation options and identify the determinants of crop production adaptation strategies. This could contribute to reduce the adverse effects of climate change and variability and generally help agricultural as well as economic development.

5.2 Recommendations

Smallholder farmers those live in the study area were highly dependent on rain feed agriculture. Some change on climate variability seriously affects their livelihood because of low adaptive capacity. So, to resist such effect they need urgent action on the environment to increase crop production in a sustainable way by reducing the impact of climate change and variability. Some of the recommendations based on the finding of this study are listed below:

- ✓ Smallholder farmers' technical knowledge and skill gaps should be filled by giving scheduled technical and practical training on crop production adaptation strategies. In terms of policy implications, it appears that an effort on education would be done to improve education level of the household through adult education system established by the government in each kebele.
- ✓ Timely addressing reliable weather forecast for smallholder farmers is important to take crop production adaptation measures from the coming impacts of weather variability.
- ✓ Crop diversification with high value crops and high productivity crops is necessary to increase crop production and reduces vulnerability to climate change and variability.
- ✓ Enhancing research on use of improved seeds; produce and distribute enough improved seeds to smallholder farmers based on the demand created and suitable agro-ecology for crop production. The types of improved seeds were small as much as possible try to increase different crop varieties in a short period of time is basic for increase crop production.

- ✓ Road Infrastructures should be constructed by the district and the regional government to increase crop production by accessing different inputs like fertilizer, improved seeds and other technologies to the smallholder farmers and sell their products.
- ✓ Extension services have to be updated in line with the current existing climate condition needs.
- ✓ Support smallholder farmers for intensive irrigation practice by using ground water and flowing water like rivers and streams integrated with improved seeds to cope up the current unreliable and inadequate rainfall.
- ✓ Policy makers give considerations on agro-ecology, age and sex of the household head, because they have significant impact on the adoption of crop production adaptation strategies.

Generally, future policies shall focus on the smallholder farmers' technical capacity through adult education system and on updated extension services in line with the prevailing climatic condition, improving irrigation facilities, credit facilities, road accessibilities, farm and off-farm income earning opportunities, and use of new crop varieties that are more suited to the local environment.

Further study on the use of telecommunication facility on crop production adaptation strategies and the contribution of tree plantation as woodlot of Eucalyptus for climate change adaptation shall be assessed in another study.

REFERENCES

Abid M., Scheffran J., Schneider U. and Elahi E. 2018. Farmer Perceptions of Climate Change, Observed Trends and Adaptation of Agriculture in Pakistan. Environmental Management. https://doi.org/10.1007/s00267-018-1113-7

Akinnagbe and Irohibe. 2014. Agricultural Adaptation Strategies to Climate Change Impacts In Africa: A Review, Bangladesh J. Agril. Res. 39(3): 407-418

Alam G.M. M., Alam K. and Mushtaq S. 2017. Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management*. http://dx.doi.org/10.1016/j.crm.2017.06.006

Al-Amin, Akhter, T., Islam, A., Jahan, H., Hossain, M. J., Prodhan, M. M. H., Kirby, M. 2019. An intra-household analysis of farmers' perceptions of and adaptation to climate change impacts: empirical evidence from drought prone zones of Bangladesh. *Climatic Change*.doi:10.1007/s10584-019-02511-9

Alemayehu A., & Bewket W. 2017. Determinants of smallholder farmers' choice of coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia. Environmental Development, 24, 77–85.doi:10.1016/j.envdev.2017.06.006

Alemu T. and Mengistu A. 2019. Impacts of Climate Change on Food Security in Ethiopia: Adaptation and Mitigation Options: A Review. Climate Change Management. Pp 397-412. https://doi.org/10.1007/978-3-319-75004-0_23

Arega Shumetie, Molla Alemayehu Yismaw. 2018. "Effect of climate variability on crop income and indigenous adaptation strategies of households". *International Journal of Climate Change Strategies and Management.* Vol. 10 Issue: 4, pp.580-595, https://doi.org/10.1108/IJCCSM-04-2016-0039

Arun Khatri, P.K. Aggarwal, P.K. Joshi, S. Vyas. 2017. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems.* 151 pp 184–191

Ashraf, M. Q., Khan, S. A., Muhammad R. K., and Iqbal W. 2018. Determinants of Adaptation Strategies to Climate Change by Farmers in District Sargodha, Pakistan. *Journal.* Int. J. Econ. Environ. Geol. Vol. 9(1)16-20.

Aung Tun Oo, Guido Van Huylenbroeck and Stijn Speelman. 2017. Determining factors for the application of climate change adaptation strategies among farmers in Magwe

District, dry zone region of Myanmar. *International Journal of Climate Change Strategies and Management.* DOI: 10.1108/IJCCSM-09-2015-0134

Bagamba, F., Bashaasha, Claessens And J. Antle. 2012. Assessing Climate Change Impacts and Adaptation Strategies For Smallholder Agricultural Systems In Uganda, *African Crop Science Journal*, Vol. 20, Issue Supplement s2, pp. 303 – 316. ISSN 1021-9730/2012

Balama, C., Augustino, S., Eriksen, S., Makonda, F.S.B. And Amanzi, N. 2013. Climate Change Adaptation Strategies By Local Farmers In Kilombero District, Tanzania. *Ethiopian Journal of Environmental Studies and Management Vol. 6,* http://dx.doi.org/10.4314/ejesm.v6i6.3S

Bedeke, S., Vanhove, W., Gezahegn, M., Natarajan, K., & Van Damme, P. 2018. Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. NJAS - *Wageningen Journal of Life Sciences*. doi:10.1016/j.njas.2018.09.001

Belay A., Recha, J. W., Woldeamanuel T., and Morton. 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agriculture & Food Security. DOI 10.1186/s40066-017-0100-1

Central Statistics Authority (CSA). 2010. Federal Democratic Republic of Ethiopia Population Census Commission. The 2007 Population Housing census of Ethiopia: Results for Country Level Statistical Report, Addis Ababa Ethiopia

Climate Resilient Green Economy (CRGE). 2011. Ethiopia's Climate-Resilient Green Economy, Green Economy Strategy. Federal Democratic Republic of Ethiopia

Dang, H. L., Li, E., Nuberg, I., & Bruwer, J. 2019. Factors influencing the adaptation of farmers in response to climate change: a review. *Climate and Development*, 1–10.doi:10.1080/17565529.2018.1562866

Deines J. M., Anthony D Kendall, James J Butler and David W Hyndman. 2019. Quantifying irrigation adaptation strategies in response to stakeholder-driven groundwater management in the US High Plains Aquifer. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/aafe39

Dembele, B., Bett, H. K., Maina Kariuki, I., Le Bars, M., & Ouko, K. O. 2018. Factors influencing crop diversification strategies among smallholder farmers in cotton production zone in Mali. *Advances in Agricultural Science*, *6*(3), 01-16.

Dinse, K. 2010. Understanding climate variability and climate change. *Michigan Sea Grant Report*, 1–25. Retrieved from http://www.miseagrant.umich.edu /downloads/ climate /11-703. *Climate Variability and Climate Change*.pdf

Echnoserve. 2014. Guideline for Conducting Vulnerability Assessment. Federal Democratic Republic of Ethiopia. Ministry of Agriculture, Addis Ababa, Ethiopia

Esayas B., Simane B., Teferi E., Ongoma V., & Tefera N. 2019. Climate Variability and Farmers' Perception in Southern Ethiopia. Advances in Meteorology, 1–19. doi:10.1155/2019/7341465

Ethiopian Institute of Agricultural Research (EIAR). 2015. Natural Resources Research Strategy 2016-2030. Addis Ababa. Website: http://www.eiar.gov.et

Fadina R., and Barjolle D. 2018. Farmers' Adaptation Strategies to Climate Change and Their Implications in the Zou Department of South Benin. Environments,Vol. 5, No. 15; doi:10.3390/environments5010015.

Fagariba, C. J., Shaoxian Song, and Serge Kevin Gildas Soule Baoro. 2018. Climate Change Adaptation Strategies and Constraints in Northern Ghana: Evidence of Farmers in Sissala West District. *Sustainability*. 10, 1484; doi:10.3390/su10051484.

FAO. 2016. Smallholder productivity under climatic variability: Adoption and impact of widely promoted agricultural practices in Tanzania, by Aslihan Arslan, Federico Belotti and Leslie Lipper. ESA Working Paper No. 16-03. Rome, FAO.

FAO. 2017. FAO Strategy on Climate Change. Rome

Frehiwot Assefa. 2016. Determenants of Farmers' Adaptation Strategies to Climate Change and Variability: The Case of Mareka District of Dawuro Zone, South Ethiopia. *American Journal of Human Ecology*. Vol. 5, No. 1, Pp. 20-35. DOI: 10.11634/216796221605784.

Gebremariam, G., and Tesfaye W. 2018. The heterogeneous effect of shocks on agricultural innovations adoption: Microeconometric evidence from rural Ethiopia. *Food Policy*. doi.org/10.1016/j.foodpol.2017.12.010

Georgis K. 2015. Planning Responses to Climate Change. CCAFS Outcome Study no.1. CGIAR Research Program on Climate Change. Agriculture and Food Security (CCAFS). Copenhagen, Denmark.

Getachew Teferi, Degefa Tolossa and Negussie Semie. 2018. Perception and Adaptation Strategies of Rural People against the Adverse Effects of Climate Variability: A Case Study of Boset District, East Shewa, Ethiopia. *Environmental Development.* https://doi.org/10.1016/j.envdev.2018.07.005

Gozamin agricultural and rural development office (GARDo). 2018. Gozamin District Agricultural and Rural Development Office Annual Report. Debre Markos, Ethiopia.

Guodaar, L., Asante, F., Eshun, G., Abass, K., Afriyie, K., Appiah, D. O., … Kpenekuu, F. 2019. How do climate change adaptation strategies result in unintended maladaptive outcomes? Perspectives of tomato farmers. International Journal of Vegetable Science, 1–17.doi:10.1080/19315260.2019.1573393

Hailu Elias. 2016. Welfare Implications of Credit Constraints and Climate Change Adaptation Strategies on Ethiopian Farm Households. Phd Dissertation. Addis Ababa University. Addis Ababa, Ethiopia.

Iglesias A., and Garrote L. 2015. Adaptation strategies for agricultural water management under climate change in Europe. *Agricultural Water Management*. 155. Pp. 113–124. http://dx.doi.org/10.1016/j.agwat.2015.03.014

Jairo MN and Korir E. 2019. Climate Knowledge, Adaptation and Intensity of Adaptation Strategies among Farmers in the Slopes of Mount Kenya. *Climatol Weather Forecasting*. Vol.7 Iss.1 No: 246.

Jiang, C., Zhang, H., Wang, X., Feng, Y., & Labzovskii, L. 2019. *Challenging the land degradation in China's Loess Plateau: Benefits, limitations, sustainability, and adaptive strategies of soil and water conservation. Ecological Engineering, 127, 135–150.*doi:10.1016/j.ecoleng.2018.11.018

John K. M. Kuwornu1, Ramatu M. Al-Hassan, Prince Maxwell Etwire and Yaw Osei-Owusu. 2013. Adaptation Strategies of Smallholder Farmers to Climate Change and Variability: Evidence from Northern Ghana. *Information Management and Business Review.* Vol. 5, No. 5, pp. 233-239, (ISSN 2220-3796)

Kassam, A., Friedrich T., & Derpsch R. 2018. Global spread of Conservation Agriculture. *International Journal of Environmental Studies*, DOI: 10.1080/00207233.2018.1494927.

Kassem H., Suleiman A., Alotaibi B., Aldosri F., and Straquadine G. 2019. Climate Change Adaptation in the Delta Nile Region of Egypt: Implications for Agricultural Extension. *Sustainability*. 11, 685; doi:10.3390/su11030685

Kinuthia K. J., Shadrack K. Inoti and Lenah Nakhone. 2018. Factors Influencing Farmer's Choice of Crop Production Response Strategies to Climate Change and Variability in Narok East Sub-county, Kenya. *Journal of Natural Resources and Development 2018; 08: 69- 77*. DOI number: 10.5027/jnrd.v8i0.07

Korir, J.C. and Ngenoh, E. 2019. Factors Influencing the Adaptation Decisions to Impacts of Climate Change among the Maasai Pastoral Community in Narok County, Kenya. *Agricultural Sciences*, 10, 689-705. https://doi.org/10.4236/as.2019.105054

Kothari, K., Ale, S., Attia, A., Rajan, N., Xue, Q., & Munster, C. L. 2019. Potential climate change adaptation strategies for winter wheat production in the Texas High Plains. *Agricultural Water Management*, 225, 105764.doi:10.1016/j.agwat.2019.105764

Lalego B., Ayalew T. and Kaske D. 2019. Impact of climate variability and change on crop production and farmers' adaptation strategies in Lokka Abaya District, Southern Ethiopia. African Journal of Environmental Science and Technology. Vol. 13(3). http://www.academicjournals.org/AJEST

Maharjan S. K. 2019. Household-Level Factors Affecting the Climate Change Adaptation in Agriculture in Central and Western Nepal. *Ecology, Pollution and Environmental science*. Volume 2(1): 199-203

Mari Gjengedal. 2016. Conservation agriculture in Gimbi, Ethiopia. Benefits and barriers to adoption. Master thesis in Human Geography. Department of Sociology and Human Geography faculty of social sciences, University of Oslo. Pp. 1-105

Mary Nyasimi, Philip Kimeli, George Sayula, Maren Radeny, James Kinyangi and Catherine Mungai. 2017. Adoption and Dissemination Pathways for Climate-Smart Agriculture Technologies and Practices for Climate-Resilient Livelihoods in Lushoto, Northeast Tanzania. *Climate*, 5, 63; doi:10.3390/cli5030063

Masud MM, Azam MN, Mohiuddin M, Banna H, Akhtar R, Alam ASAF, Begum H. 2017. Adaptation barriers and strategies towards climate change: Challenges in the agricultural sector. *Journal of Cleaner Production*. doi: 10.1016/j.jclepro.2017.04.060.

Mazvimavi, Kizito; Ndlovu, Patrick V.; Nyathi, Putso; and Minde, Isaac J. 2014. Conservation Agriculture Practices and Adoption by Smallholder Farmers in Zimbabwe

Menike L.M.C.S., and Keeragala Arachchi. 2016. Adaptation to climate change by smallholder farmers in rural communities: Evidence from Sri Lanka, International Conference of Sabaragamuwa University of Sri Lanka. *Procedia Food Science* 6 PP. 288 – 292. Available online at www.sciencedirect.com

Michler J. D., Kathy Baylis, Mary Arends-Kuenning and Kizito Mazvimavi. 2019. Conservation agriculture and climate resilience. *Journal of Environmental Economics and Management*. pp *148–169.* Agricultural and Resource Economics, University of Arizona, Tucson, USA.

Muhammad Abid. 2016. Climate change Impacts and Adaptation in the Agricultural Sector of Pakistan- Socioeconomic and Geographical Dimensions. *Thesis*. Hamburg University. Hamburg.

Mussa Said Bakari. 2015. A Climate Change Impacts and Adaptation Strategies of Small Scale Agriculture Production in Micheweni District Pemba, Tanzania. MSC thesis. Sokoine University of Agriculture, Morogoro, Tanzania.

Ndiritu, S.W., Kassie, M., Shiferaw, B. 2014. Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy*, 49 (1), 117–127. https://doi.org/10.1016/j.foodpol.2014.06. 010.

Nkuba, M., Chanda, R., Mmopelwa, G., Kato, E., Mangheni, M. and Lesolle, D. 2019. "The effect of climate information in pastoralists' adaptation to climate change: A case study of Rwenzori region, Western Uganda". *International Journal of Climate Change Strategies and Management*. https://doi.org/10.1108/IJCCSM-10-2018-0073

Parvin, M., Hossain, S., and Rahman A. 2019. Unsustainable groundwater depletion of Madhupur tract aquifer underneath Dhaka city and its relation to climate change. Conference Paper. Bangladesh Inland Water Transport Authority, Dhaka, Bangladesh.

Patrick Madulu Ndaki. 2014. Climate Change Adaptation for Smallholder Farmers in Rural Communities: the Case of Mkomazi Sub-Catchment, Tanzania. Dissertation. Carl von Ossietzky University of Oldenburg. P. 277

Piya, L., Maharjan, K. L., & Joshi, N. P. 2019. Adaptation Strategies and Factors Influencing the Adaptation Choices. *Socio-Economic Issues of Climate Change*, 161–190. doi:10.1007/978-981-13-5784-8_12

Reyes-Paecke S., Gironás J., Melo O., Vicuña S., & Herrera J. 2019. Irrigation of green spaces and residential gardens in a Mediterranean metropolis: Gaps and opportunities for climate change adaptation. *Landscape and Urban Planning*, 182, 34–43.doi:10.1016/j.landurbplan.2018.10.006

Sarvade, S., Upadhyay, V. B., Kumar, M., & Imran Khan, M. 2019. Soil and Water Conservation Techniques for Sustainable Agriculture. *Sustainable Agriculture, Forest and Environmental Management, 133–188.* doi:10.1007/978-981-13-6830-1_5

Seid Sani, Jema Haji and Degye Goshu. 2016. Climate Change Adaptation Strategies of Smallholder Farmers: The Case of Assosa District, Western Ethiopia. *Journal of Environment and Earth Science.* Vol.6, No.7, Pp 9-15.

Sisay Diriba, Mulugeta Damie and Molla Alemayheu. 2019. Climate change adaptation strategies in response to food insecurity: The paradox of improved potato varieties adoption in eastern Ethiopia. *Cogent Food & Agriculture.* DOI: http://dx.doi.org/10.1080/23311932.2019.1640835

Soglo, Y. Y., & Nonvide, G. M. A. 2019. Climate change perceptions and responsive strategies in Benin: the case of maize farmers. *Climatic Change*. 155 pp: 245–256 doi:10.1007/s10584-019-02452-3

Sujata Manandhar, Dietrich Schmidt Vogt, Sylvain R. Perret and Futaba Kazama. 2011. Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. *Original Article.* DOI 10.1007/s10113-010-0137-1. Reg Environ Change 11 pp: 335–348

Tadesse Woldemariam. 2015. Aboveground Biomass Field Guide for Baseline Survey: GHG Emission Assessment Guideline Volume II. Ministry of Agriculture, Addis Ababa, Ethiopia.

Tarfa, P. Y., Ayuba, H. K., Onyeneke, R. U., Idris, N., Nwajiuba, C. A., Igberi, C. O. 2019. Climate change perception and adaptation in Nigeria's guinea savanna: empirical evidence from farmers in Nasarawa State, Nigeria. *Applied Ecology and Environmental Research*. 17(3): 7085-7112.

Teklewold H., Mekonnen A., & Kohlin G. 2018. Climate change adaptation: a study of multiple climate-smart practices in the Nile Basin of Ethiopia, Climate and Development, DOI: 10.1080/17565529.2018.1442801

Teklewold, H., Gebrehiwot, T., & Bezabih, M. 2019. Climate smart agricultural practices and gender differentiated nutrition outcome: An empirical evidence from Ethiopia. *World Development*, 122, 38–53. doi:10.1016/j.worlddev.2019.05.010

Tesfaye Samuel Saguye. 2016. Determinants of Smallholder Farmers' Adoption of Climate Change and Variability Adaptation Strategies: Evidence from Geze Gofa District, Gamo Gofa Zone, Southern Ethiopia. *Journal of Environment and Earth Science.* Vol.6, No.9, ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online), available on: www.iiste.org.

Teshome Tamiru. 2014. Adoption of Physical Soil and Water Conservation Structures in Debre Elias woreda, Amhara region, Ethiopia. MA Thesis (unpublished). Bahir dar university, Bahir dar ,Ethiopia.

Tessema, Y. A., Joerin, J., & Patt, A. 2018. Factors affecting smallholder farmers' adaptation to climate change through non-technological adjustments. *Environmental Development*, 25, 33–42. doi:10.1016/j.envdev.2017.11.001

Tongruksawattana S., & Wainaina P. 2019. Climate shock adaptation for Kenyan maize-legume farmers: choice, complementarities and substitutions between strategies. *Climate and Development*. DOI: 10.1080/17565529.2018.1562862

Ubisi N.R., Paramu L Mafongoya, Unathi Kolanisi and Obert Jiri. 2017. Smallholder farmer's perceived effects of climate change on crop production and household livelihoods in rural Limpopo province, South Africa. Change Adaptation Socioecol. Syst. 3: 27–38. DOI 10.1515/cass-2017-0003

Vicente M. L. and Gao-Lin Wu. 2019. Soil and Water Conservation in Agricultural and Forestry Systems. *Water*, 11, 1937; doi:10.3390/w11091937

Wainaina, P., Tongruksawattana, S., & Qaim, M. (2016). Tradeoffs and complementarities in the adoption of improved seeds, fertilizer, and natural resource management technologies in Kenya. *Agricultural Economics*, 47(3), pp. 351–362. doi:10.1111/agec.12235

Weldlul Ayalew. 2016. Analysis of Smallholder Farmers' Perceptions of Climate Change and Adaptation Strategies to Climate Change: The Case of Western Amhara Region, Ethiopia. Doctor of Philosophy in Environmental Management. Univeristy of South Africa.

Wondimagegn Tesfaye and Lemma Seifu. 2016. "Climate change perception and choice of adaptation strategies: Empirical evidence from smallholder farmers in east Ethiopia". International Journal of Climate Change Strategies and Management. Vol. 8 Issue: 2, pp.253-270, doi: 10.1108/ IJCCSM-01-2014-0017

Wrigley-Asante, C., Owusu, K., Egyir, I. S., & Owiyo, T. M. 2017. Gender dimensions of climate change adaptation practices: the experiences of smallholder crop farmers in the transition zone of Ghana. *African Geographical Review, 1–14*.doi:10.1080/19376812.2017.1340168

Yamba, S., Divine Odame Appiah1 and Lawrencia Pokuah Siaw. 2019. Smallholder farmers' perceptions and adaptive response to climate variability and climate change in southern rural Ghana. *Cogent Social Sciences*, 5: 1646626. doi.org/10.1080/23311886.2019.1646626

Yaméogo, T.B., William M. Fonta, and Tobias Wünscher. 2018. Can Social Capital influence Smallholder Farmers' Climate-Change Adaptation Decisions? Evidence from Three Semi-Arid Communities in Burkina Faso, West Africa. *social sciences.* 7, 33; doi:10.3390/socsci7030033

Appendix 1: Household Survey Questionnaire

Introduction

This questionnaire is designed to study smallholder farmers' Adaptation Strategies to increase crop production under the changing climatic conditions in the case of Gozamin district. The information you provide honestly is invaluable to understand the actual situation in the kebele. It will be a useful policy tool to address farmers' problems and needs. We kindly ask your collaboration to spare your valuable time. My name is Alemayehu Tadele. I am studying Climate Smart Agricultural Land Escape Assessment at Hawassa University Wondogenet College of Forestry and Natural Resource. I am doing my Master's Thesis on adaptation strategies by Smallholder farmers' to increase crop production under the changing climate. Thus I appreciate your cooperation to give me your time for the success of the paper.

Name of the Enumerator: ______________________________________

Date of interview: _______ /______ / 2011 E.C,

Time: From: _________to __________

A. HOUSEHOLD INFORMATION

1. Region ________________Zone__________________ District_______________________
2. Peasant Association_______________________ Village/got______________________
3. Agro-ecological zone of the village 1.Woyna dega 2. Dega 3. Kola
4. Name of respondent: ___________________________ Phone number: ____________
5. Sex of the respondent: 1. Male 2. Female
6. Level of education of the respondent___ years of formal schooling completed (0 illiterate)
7. Religion of the household head

   1. Orthodox 2.Muslim 3.Protestant 4.Catholic 5. Other (specify) ______________
8. Marital status of household head?

1. Married 2. Single 3. Divorced

9. Age of the household head __________ years.

10. Farming experience ____________ years.

11. How many family members do you have in your household? _________

Please indicate the number, age and sex of your household members

S/n	Age categories (years)	M	F	Number of family members working on the farm full time		Number of family Members working on off/nonfarm activities		Total	Number disabled
				M	F	M	F		
1	Children < 7								
2	Between 7 & 14								
3	Between 15 & 64								
4	Elder >65								
	Total								

B. CROP PRODUCTION INFORMATION

1. Land holding pattern (2017/2018)

Land ownership	Last season (2017/18) cultivation						
	Total Land *(ha)*	Irrigated land *(ha)*	Cultivated Land *(ha)*	Grazing Land(ha)	Shared out *(ha)*	Rented Out *(ha)*	Fallow Land *(ha)*
Owned							
Rented in							
Shared in							
Total							

2. How do you rate the productivity of your land? 1. Good 2. Satisfactory 3. Bad
3. Do you think that your land productivity is decreasing? 1. Yes 2. No
4. Do you feel your land holding is adequate to satisfy your family needs? 1. Yes 2. No

5. If not, what strategy you follow to maximize your land holding?

   1. Renting the land 2.Shared in the Land 3.Reclaiming the soil 4.Other___________

6. What is your relative wealth position as compared to other farmers in your locality?

   1. Very rich 2. Rich 3.Medium 4.Poor 5.Very poor

7. If your main sources of income include off-farm and non-farm income, what was the estimated annual income of the household in 2017/18 __________ birr.

No	**Income source**	**Annual income**	**Remark**
1	Casual work/sale labor		
2	Hand craft		
3	Sale fuel wood and charcoal		
4	Petty trading		
5	Brewing		
6	Renting Asset		
7	Salary/Pension payments		
8	Remittance		
9	Other		
	Total		

8. The estimated amount of annual farm income of the house hold in 2017/18 ________ birr

Crops grown	Area (ha)		Seed Used (1 improved 0 local)	Fertilizer (Kg)	Amount produced (kg)	Amount Consumed (kg)	Amount sold (kg)	Average Selling price	Income (Birr)	Currently available in Irrigated rain fed store (kg)
	Irrigated	rain fed								
Teff										
Maize										
Wheat										
Potato										
Pepper										
Finger millet										
Barely										
Onion										
Coffee										
Forest & Its										
Others										

9. The estimated amount of annual total income of the household in 2017/18 was _____ birr

C. INSTITUTIONAL / GOVERNMENT SUPPORT

1. Did you receive any credit in your surrounding? 1. Yes 2. No
2. If yes to Q 1, fill the following table

No	Source of credit (Codes A)	Type of collateral (Codes B)	Purpose of credit (Code C)	Amount borrowed
1				
2				

3. If yes in Q 1, for what adaptation mechanism?
    1. To buy food for the family and the livestock
    2. To buy resistant crop varieties and livestock species
    3. To conserve soil and water
    4. To buy irrigation equipment's
    5. To be engaged in alternative income activities
    6. Other, specify ____
4. Have you ever got extension service? 1. Yes 2. No
5. Have you ever been advised by any development agent about the impact of climate change and means of crop production adaptation strategies? 1. Yes 2. No
6. Have you received training on adaptation mechanisms to climate change? 1. Yes 2. No
7. If yes in Q6, on which adaptation mechanism? _________________________
8. If yes in Q6, do you think the training was helpful for your practical problem? 1.Yes 2.No
9. How far you should travel to get the nearest market center to sell your products and buy the necessary items? ____________________ km.
10. Have you got transport access in your locality? 1. Yes 2. No

D. ISSUES RELATED TO CLIMATE CHANGE AND VARIABILITY

1. Have you observed any climatic variability in your locality in the last 15 year? 1. Yes 2. No.
2. If yes in Q 1, how do you characterize the weather of your area in the last 15 years?
    a. In terms of temperatures 1. Increased 2. Decreased 3. No change
    b. In terms of Rainfall amount 1. Increased 2. Decreased 3. No change

c. In terms of rainfall distribution 1. Erratic 2. Constant 3. I don't know

d. In terms of crop disease/insect infestation 1. Increased 2. Decreased 3. No change

e. In terms of other (specify___) 1. Increased 2. Decreased 3.No change 4.1 don't know

3. Is the amount of rainfall enough to support your crop production? 1. Yes 2. No
4. What is the most common manifestation of rainfall in your area? Rank it______________

   1. Early onset 4. Low at ploughing 7.Low or absent at pod/seed/flower setting

   2. Late onset 5.Heavy at planting 8.Heavy at harvest

   3. Heavy at ploughing 6. Low at planting 9.Early cessation 10.Others, _______
5. Do you think that climate related shocks are creating a problem in your locality? l. Yes 2. No
6. If yes in Q 5, to what extent did climate change and variability affect your livelihood?

   1. No impact 2.Low 3.Medium 4. High
7. What are the main climatic shocks (hazards) affecting livelihood in your locality? Rank based on their severity (1 highest to 6 least)

E. CROP PRODUCTION ADAPTATION STRATEGIES

1. Do you have reliable access to seasonal forecasts and climate information? 1. Yes 2. No

2. If yes to Q1, what is your main source of information regarding the climate?

   1. Listen from radio/mass media 2. Owen experience 3. Listen from other farmers

   4. Training & Workshop 5. Extension workers 6. NGOs 7. Others specify ________
3. How would you rate the weather information that you receive?

   1. Poor 2. Average 3.Good
4. Identify any precautionary measures you have taken to overcome the side effect of climate change?

   1. Sell of food grain 2. Sale Livestock and its product 3. Mobility/Migrate

   4. Saving money 5. Others (specify) _________________________________
5. Have you used adjusting planting date as a strategy to adapt climate change? 1 .Yes 2.No
6. Have you observed any change on soil fertility based on climate variability? l. Yes 2.No
7. If yes in Q 6, what do you observe on soil fertility? 1. Increase 2. Decrease 3. No change
8. Do you use fertilizer in your farm? a. Yes b. No

9. If yes in Q 8, which type of fertilizer do you used?

   a. Inorganic b. Organic / Manure

10. Have you used tree planting as a strategy to adapt climate change? 1 .Yes 2.No
11. If yes to Q 10, what do you used? 1. Boundary Plantation 2. Windbreak 3. Parkland 4. Woodlot 5. Alley Cropping 6. Others ____________________________
12. Have you used any crop diversification system to adapt climate change? 1. Yes 2.No
13. If yes to Q 12, when and which option have you used? Type and reason for used the options.

Options	Type X	Reason
Mixed cropping		
Intercropping		
Dividing farm lands in to varying crops		

14. Have you ever engaged in another occupation other than crop production to get more income? 1. Yes 2. No
15. If yes to Q 15, in what occupation? 1. Non-farm income 2. Off farm income 3. All
16. Have you used any soil and water conservation practices in your farm as adaptation strategy? 1. Yes 2. No
17. If the answer is yes, which Practices? (Rank according to its importance) _________

    1. Terrace/bund 2. Cut-off drains 3. Chuck dam 4. Waterway

    5. Biological conservation 6. Others____________________

18. Have you used irrigation practices to adapt climate change and variability? 1. Yes 2. No
19. If your response is yes, your source of water

    1. River 2. Harvesting Water 3. Hand dig wall 4. Pond 5. Other_______________

20. What are the major constraints that hinder your adaptation mechanisms? (Rank it 3)_____

    1. Lack of irrigation 2. Lack of technical knowledge on appropriate adaptation strategies 3. Lack of money to finance 4. Lack of weather information 5. Lack of improved seed variety 6. Shortage of land 7. Shortage of labor 8. Others specify________

Appendix 2: Questionnaire for focus group discussion (FGD)

1. Do you think that governmental and non-governmental agencies gave you enough considerations about climate change and variability problems? 1. Yes 2. No
2. If your response yes to Q3, How does they support you?
3. What is your observation on the climatic (temperature and rainfall) condition in your area? Over the past 15 years by each type
4. What is the capacity of farmers' production in your village?
5. What are the main climatic shocks (hazards) affecting livelihood in your locality?
6. Do you get any early warning/agro metrological information, credit access, extension service, training, etc on climate change and variability in your district?
7. What are the major crop production coping mechanisms /adaptation strategies used to reduce the adverse impacts in your kebele? (Improved seeds, Fertilizer, Irrigation, Crop diversification, Soil and water conservation, etc.) Determine their effectiveness
8. What are the common options implemented to cop climate change and variability other than crop production? (tree plantation, income generating activities, etc)
9. What do you recommend to be done so as to reduce the adverse effects of climate change and variability?
10. What are the main barriers for use of adaptation strategies of combating climate change and how do you think they can be improved?

Appendix 3: Checklist for Key Informants

1. How long have you been in this village/district? ____________________ years
2. What are the general conditions of crop production in the district for the past 15 years?
3. How can you comment on climate change and variability situation in the district for the past 15 years?
4. What is the extent of rainfall intensity and patterns for crop production in the district/kebele for the last 15 years?
5. What is the temperature trend for crop production in the district/kebele for the last 15 years?
6. Have you encountered any climate change and variability impacts to crop production in the district?   Yes / No
7. What crop production adaptation measures do you under take to overcome climate change and variability impacts? ((Improved seeds, Fertilizer, Irrigation, Crop diversification, Soil and water conservation, etc.) Determine their effectiveness
8. What improved adaptation measures do you take to cop up climate change and variability impacts?
9. Do you have credit access, extension service, training, transport access; weather forecast information etc for climate change adaptation practice?
10. What do you recommend to be done so as to reduce the adverse effects of climate change and variability on crop production?
11. What is the institutional effort made to reduce future climate change and variability impacts?
12. What are the main barriers for use of adaptation strategies for combating climate change and variability and how do you think they can be improved?

Appendix 4: Additional Result datas

Table 11: Variance Inflation Factors (VIF) Test

Variables	VIF	1/VIF
Kola Agro-ecology	5.76	0.173659
Distance to market	5.22	0.191445
Farm income	3.69	0.270762
Extension service	2.55	0.392109
Family size	2.09	0.479352
Climate information	1.73	0.578700
Land holding	1.68	0.596434
age	1.65	0.605668
sex	1.60	0.625478
Credit used	1.48	0.676731
Level of education	1.47	0.679843
Non-farm income	1.16	0.862140
Mean VIF	**2.51**	

Source: own Survey result (2019).