

**Impacts of Climate Change, Variability and Adaptation
Strategies on Household Food Security in Southern Ethiopia**

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This is to certify that the thesis prepared by Tsegaye Ginbo, entitled: Climate Change, Variability and Adaptation Strategies: Implications for Household Food Security in Southern Ethiopia, and submitted in partial fulfillment of the requirements for the degree of Master of Science in Economics (Resource and Environmental Economics) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Graduate Programs Coordinator, Department of Economics

To

My beloved mother, Soreeti Kajawa

&

The memory of my father, Ginbo Gatiso

Dad, you are ideally not dead as your vision and plans are all alive in me!

Abstract

Climate Change, Variability and Adaptation Strategies: Implications for Household Food Security in Southern Ethiopia

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This study presents an empirical investigation of climate change, variability and adaptation strategies' impacts on households' multidimensional food security in rural villages of southern Ethiopia. For this purpose, Two-stage Least Square estimation framework is employed based on cross-sectional data collected from 148 households. Food security index constructed from various indicators representing four dimensions of food security indicates substantial food insecurity problem among sample households. Empirical results reveal that climate change and variability affect households' food security. Higher temperature and unfavorable rainfall conditions have significant negative impact on household food security. Results also show that education, access to agricultural extension, credit, climate information and market significantly enhance adaptation decisions. Moreover, results confirm that climate adaptation strategies namely soil and water conservation, modern varieties and crop diversification are effective in mitigating climatic risks and ensuring household food security. Consequently, programs enhancing households' skills, awareness, adaptations decision and farm yield would be helpful.

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List of Acronyms

CGE = Computable General Equilibrium

CSA = Central Statistics Agency, of Ethiopia

CC = Contingency Coefficient

CCC = Canadian Climatic Center

FAO = Food and Agriculture Organization of United Nations

GCMs = General Circulation Models

GIEWS = Global Information and Early Warning System on Food and Agriculture

GDP = Gross Domestic Product

OLS = Ordinal Least Squares

2SLS = Two-Stage Least Squares

PCA = Principal Component Analysis

PCM = Parallel Climate Model

PSNP = Productive Safety Nets Programme

IPCC = Intergovernmental Panel on Climate Change

MDFSI = Multidimensional Food Security Index

MoFED = Ministry of Finance and Economic Development, of Ethiopia

MoARD = Ministry of Agriculture and Rural Development, of Ethiopia

NMA = National Meteorology Agency, of Ethiopia

PPS = Probability Proportional to Sample Size

UN/ECA = United Nations Economic Commission for Africa

VIF = Variance Inflation Factor

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Chapter One: Introduction

1.1. Background of the Study

Climate change has become one of the great challenges to the development of countries. It is now affecting agriculture and food production worldwide. There is evidence of declining crop yield due to climate change in many countries (Muamba and Kraybill, 2010; Orindi *et al.*, 2006 and Stige *et al.*, 2006). This challenge appears to be more devastating in the case of low-income countries. This is partly because high vulnerability of poor countries to climatic shocks due to their limited capacity to adapt and that agriculture accounts for a larger fraction of their economy. And agriculture in these countries is climate sensitive partly because of generally already high temperature and that it is largely rain-fed. As a result, significant proportions of people living in poor countries are facing the risks of food insecurity.

In Ethiopia, agriculture contributes about 45% of GDP, 60% of foreign exchange earnings and 80% of total employment (MoFED, 2010). The livelihood of overwhelming majority of people depends on agriculture, directly or indirectly. Despite its lion's share in the economy, however, Ethiopian agriculture has remained rain-fed with traditional methods of farming and livestock rearing since time immemorial.

According to IMF (2012), agricultural sector remains a key source of growth in Ethiopia but it continues to face major challenges. Rural livelihoods remain extremely vulnerable to climatic shocks as food production is mainly dependent of natural rainfall and irrigation supports only negligible portion of the country's total cultivated land. Irrigation agriculture accounts for only 1% of the countries total cultivated land

(Yesuf *et al.*, 2008). Thus, the amount and temporal variation of rainfall and other climatic factors during the growing season are critical to crop yield and can induce food shortage and famine. This shows that climate change and variability can have greater negative impacts on poor farm households due to high vulnerability leading to food insecurity. In turn, food insecurity has become a very important development challenge in Ethiopia.

Similarly, vulnerability and poverty mapping in Africa, as it is noted in Orindi *et al.* (2006) and Stige *et al.* (2006), ranked Ethiopia as one of the countries most vulnerable to climate change with the least capacity to adapt. Undiversified means of livelihood and excessive reliance on rain-fed agriculture are one of the key factors responsible for vulnerability. These make agricultural production and income highly sensitive to fluctuations in rainfall and other key climatic variables.

Consequently, it is argued that rainfall variability and associated droughts have been major causes of food shortage and famine in Ethiopia. Climatic vulnerability is more severe in the case of drylands where there is already scanty rainfall and high temperature resulting in frequent climatic shocks. This situation is observed in southern mid-altitude drylands of Ethiopia including Boricha, particular case study area for this study, where temperature is getting higher and rainfall lower than used to before (Hameso, 2012).

According to Hameso (2012), rainfall variability and change and other meteorological shocks greatly affect agricultural production in dryland district of Boricha more than

any other area in Sidama Zone of southern Ethiopia. It is the most severely affected area in the zone due to its semi-arid and dry climatic conditions. It experiences higher temperature and receives less rainfall (Hameso, 2012). The same area has been subjected to several intervention programs including the Productive Safety Net Program (PSNP). This is due to more food insecurity and vulnerability of people to climate change in the area. A report by the Disaster Risk Management department of Ethiopian Ministry of Agriculture indicates that Boricha district is a major recipient of PSNP fund in Sidama zone (MoARD, 2013). Rural livelihoods in the district remain extremely vulnerable to severe food insecurity.

Furthermore, food security is a multidimensional concept. According to FAO (1996), food security condition exists when all people at all times have physical or economic access to sufficient, safe and nutritious food. The food requirement is not only to meet peoples' dietary needs but also their food preferences for an active and healthy life. FAO's definition implies that food security have four dimensions: Availability, access, utilization and stability. To achieve food security, all four of the components must be adequate. Besides, FAO (2008) stressed that the impacts of climate change on food security should be examined under the larger and multidimensional framework encompassing socio-economic and environmental variables.

In view of that, any analysis dealing with food security or insecurity should include all these factors and approach food security from its multidimensional perspective measured by different indicators. Addressing multiple dimensions through multiple indicators may help provide important information on implications of climate change to households' food insecurity problem. Therefore, this study uses four indicators to

construct multidimensional food security index and determine household's food security status. It investigates the empirical impact of socioeconomic, climate and adaptations on household's multidimensional food security.

1.2. Statement of the Problem

The issue of climate change vulnerability and adaptation strategies have drawn a great attention from policy makers and academicians for last decades. In view of that, a number of studies have been done at regional and country levels to estimate economic impacts of climate change on agriculture and factors affecting adaptation strategies. For instance, Molua (2002) for Cameroon, Muamba and Kraybill (2010) for Tanzania, Deressa *et al.* (2005) for South Africa, Krishna (2011) for Nepal and Mendelsohn *et al.* (2004) for Sri Lanka are some of the studies that deal with the impact of climate change on agriculture focusing on crop production and net farm revenue. From this, at best, one may infer that most of the studies on climate change and food security so far have focused on only one dimension of food security: food availability measured by crop production and farm revenue.

Similarly, most of the existing literatures on climate change in Ethiopia are focused on the estimation of impacts on crop production and net farm revenue. Moreover, vast majority of research works have targeted the perceptions of stakeholders and determinants of adaptation at country or regional scale. Studies like Deressa (2007); Yesuf *et al.* (2008), Deressa, Hassen, and Ringler (2008), Deressa *et al.* (2008); Deressa and Hassan (2009), Di Falco *et al.* (2011a) and Di Falco *et al.* (2011b) have assessed the impacts of climate change on agriculture and determinants of adaptation in case of Nile Basin region. At country level, Gebreegziabher *et al.* (2011) have

modeled the impacts of climate change on overall Ethiopian economy using a countrywide Computable General Equilibrium (CGE) model.

Besides, literatures examining the determinants of food security or insecurity have overlooked the role of changing climatic factors. However, a framework document by FAO in 2008 pointed out that any analysis aiming to examine the potential impacts of climate change on food security must be viewed within the larger and multidimensional framework encompassing all of the indicators under observable changes in multiple socio-economic and environmental variables. In global perspective, however, studies examining climate change – food security nexus within multidimensional framework are lacking.

Despite persistent food insecurity problem in many parts of Ethiopia, the research works examining direct impact of climate change and variability on households' food security are very scanty. Not only climate change but also short-term weather variations can affect food security in rain-fed agriculture based livelihood setups. As variations of weather variables may have significant impacts on household food security, one may not obtain full impacts of climate change if short-term climatic variations are omitted. Furthermore, micro evidence on the impact of key climatic variables such as rainfall and temperature on food security measured in multidimensional perspective is, to our knowledge, non-existent. For instance, Di Falco *et al.* (2011a, 2011b and 2011c) focused only on availability dimension of food security that is crop production and net revenue. But, addressing food security through only one indicator may not provide clear insight into the problem which may lead to misinformed policy interventions.

In this regard, a study by Abera *et al.* (2011) can be taken as good advancement in the literature on food security and climate nexus. It tried to address food security from multidimensional perspectives using indicators representing availability, access and stability. However, their study fails to account for the utilization aspect of food security due to the limitation of data they used. Their study also focused on only one climatic variable i.e. rainfall and did not consider the impact of temperature.

To our knowledge, there is also little, though growing evidence on the effectiveness of climate change adaptation strategies to ensure household food security. This is particularly important to inform policy makers in identifying most effective adaptation measure that could help reduce smallholders' vulnerability to climate induced food insecurity. In this regard, Di Falco *et al.* (2011b) deserve credit. They have partly dealt with the effectiveness of adaptation options, a step forward from climate change impacts and determinants of adaptation strategies. But, their study treats different climate adaptation strategies as a package. For this reason, the authors have acknowledged the need for further study focusing on distinction of different adaptation strategies and the identification of the most effective ones in reducing risks pertaining to climatic shocks. In view of that, Di Falco *et al.* (2011c) distinguish common adaptations and assess the effectiveness of each of the strategies. However, their analyses focus only on the food production and hence did not consider multiple dimensions of food security.

Motivated by the above gaps, this study focuses on the identification of common farm-level adaptation options and evaluates the effectiveness of each of the strategies

in ensuring household food security. In addition, it aims to contribute to existing debate on food security measures through constructing multidimensional food security index using four indicators representing all four dimensions of food security, i.e. availability, access, utilization and stability.

The study takes Boricha district from southern Ethiopia as a case and aims at tackling the following three basic questions:

1. What are the household levels factors affecting adaptation decisions to climate change and variability?
2. What are the impacts and relative significance of climate change and variability on multidimensional food security of farm households?
3. Are adaptation strategies to climate change and variability effective in helping households ensure food security?

1.3. Objectives of the Study

The general objective of the study is to examine impacts of climate change, variability and adaptation strategies on household food security in rural villages of southern Ethiopia.

Specifically, the study seeks to achieve the following objectives:

- ✚ To investigate household level determinants of decisions for each of the adaptation strategies to climate change and variability
- ✚ To examine impacts of climate change and variability on multidimensional food security of smallholder farm households

- ✚ To assess the relative significance of climate change and variability in affecting households' multidimensional food security
- ✚ To evaluate the effectiveness of each of the adaptation strategies in helping ensure multidimensional food security of households

1.4. Significance of the Study

In response to climate change, adaptation and mitigation initiatives are being pursued. Hence, it is important to examine the household welfare impacts of climate change, variability and adaptation strategies.

Particularly, this study may serve two basic purposes. First, it would contribute to existing body of scientific knowledge through examining the empirical link among climate change, adaptation strategies and food security. More importantly, it may give an insight into the identification of most effective climate change adaptation options which could help reduce vulnerability and ensure food security among households in rural and drought-prone areas.

Second, the study contributes toward the construction of multidimensional food security measures taking multiple indicators into account. Though there is theoretical consensus about multidimensional nature of household food security, empirical works so far have not, to our knowledge, developed a measure that encompasses all dimensions. In view of that, the contribution of is worth noting because such a multidimensional measure has not been used in the study which links food security to climate change and adaptation.

1.5. Scope and Limitations of the Study

This study is confined to the impact of key climatic variables such as rainfall and temperature, and most common adaptation strategies on household food security. Besides, it utilizes cross-sectional data generated from 148 households selected from four rural villages of Boricha district in Sidama zone of southern Ethiopia.

In addition, the study uses village level rainfall data obtained from Ethiopian National Meteorological Agency. Hence, one of the limitations of this study is lack of significant spatial variation in household level rainfall data. This is because only few rain gauge stations were set to cover wide geographic areas in the study area. To partially solve this problem of household level data on rainfall, qualitative information on plot specific observed rainfall condition experience of the farmers is collected to develop subjective rainfall satisfaction index as a measure of rainfall variability.

Another inadequacy of the study is that due to time and financial constraints it focused on relatively similar agro-ecological zones and generates data on small sample drawn from single lowland district of Boricha. Hence, the findings of the study are limited to comparable agro-ecological setups. As this study is based on small sample and single district the findings and policy implications should be considered cautiously.

1.6. Organization of the Paper

The study is organized into five chapters. The first chapter deals with the introductory parts including background, statement of the problem, objectives, significance, scope and limitations of the study. The second chapter presents review of related theoretical and empirical literatures.

In the third chapter, methodology of the study comprising the data, model specification and methods of data analysis is presented. The empirical findings of the study are discussed in the fourth chapter. Finally, chapter five is devoted for the conclusion and policy implications based on the findings.

Chapter Two: Literature Review

2.1. Theoretical Literature Review

2.1.1. Food Security: Concepts and Measurements

It is believed that definitions of food security ascertain its outcomes and are useful for formulating policies and deciding on actions. But, there is no single definition of food security applicable worldwide though it has become a growing concern throughout the world. The most commonly used working definition is the one developed by the United Nations Food and Agricultural Organization (FAO) in 1996. According to FAO (1996), food security exists when all people at all times have physical or economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Based on this definition, food security is influenced by four key dimensions. These are availability of sufficient food, economic and physical access to the resources needed to acquire food, stability of this availability and access and utilization including nutrition, food safety and quality.

FAO (2008) pointed out that food availability is determined by the physical quantities of food that are produced, stored, processed, distributed and exchanged. Thus, food availability depends on domestic production and imports of food implying any factors that affect production and import will also impact food availability. This implies that availability of food is a broad concept which is determined by not only domestic production but also imports from abroad. From this perspective, we can consider it as the existence of food stocks for consumption.

Food access refers to a measure of the ability to secure entitlements, which are defined as the set of resources required in obtaining food access (Sen, 1981). This definition for food access implies that food availability alone is not sufficient to secure food. Though aggregate production may be high in a country, food security might be challenged with access problems at household level to secure entitlement to food because of lack of the ability to acquire food. Hence, household food access is the ability to acquire sufficient quality and quantity of food to meet all household members' nutritional requirements.

Stability refers to a situation where individuals may be at risk of temporarily or permanently losing their access to the resources needed to consume adequate food (Felix and Romuald, 2009). It is determined by the temporal availability of and access to food. Thus, all the factors that affect food availability and access will also impinge on food stability. Stability, therefore, can be approached through shortfall of food supply from the household.

Food use or utilization is justified based on the nutritional value of the food supplied to individuals. Utilization of food depends on how food is used, whether food has sufficient nutrients, and whether a balanced diet can be maintained (FAO, 2000). It is related to the actual processing and absorption capacity of the body of the supplied nutrients. Hence, we can associate food utilization with having balanced nutritious food, access to pure drinking water, sanitation and health.

FAO stressed that food security depends more on socio-economic conditions than simple agro-climatic ones, and on access to food rather than the production or

physical availability of food. It stated that, to evaluate the potential impacts of climate change on food security, “it is not enough to assess the impacts on domestic production in food-insecure countries. One also needs to (i) assess climate change impacts on foreign exchange earnings; (ii) determine the ability of food surplus countries to increase their commercial exports or food aid; and (iii) analyse how the incomes of the poor will be affected by climate change” (FAO, 2003b: 365-366). In this regard, studies focusing only on the food production impact of climate change fail to measure full multidimensional aspect of the possible impacts.

This discussion of the concept of food security suggests that the overall impact of climate change on food security has to be framed within a multidimensional context. Hence, this study tries to measure food security from its multidimensional perspective at household level.

2.1.2. Climate Change, Agriculture and Food Security: Theoretical Aspects

Agriculture is inherently sensitive to climatic conditions. It is a sector vulnerable to current and anticipated global climate change. Consequently, livelihood of the people leading agriculture dependent life is highly vulnerable to climatic shocks which result in food insecurity. This is evidenced by the United Nations Food and Agriculture Organization report on World Agriculture toward 2015/2030. This report estimated that about 776 million people were food insecure during 1997/99 (FAO, 2003). These people live in 98 countries mostly concentrated in South Asia and Sub-Saharan Africa. They also argued that the greenhouse gas induced climate change would

further worsen the food security situation, especially in the tropics by reducing agricultural productivity.

This situation is pervasive in case of Africa. Despite a good performance with high economic growth rates over the last decade, Africa has not made significant progress on some of its major challenges, especially food security and employment for the growing youth population (UNECA, 2012). Climate change has affected agriculture negatively and triggered food security problem in various regions of Africa. Higher temperatures, reduced rainfall and increased rainfall variability reduce crop productivity in many tropical areas. This affects food security in low income and agriculture-based poor economies. Thus, the impact of climate change is detrimental to countries in which people depend on agriculture as their main means of livelihood (Jones et al. 2009). Many African countries which have economies largely based on weather-sensitive agricultural production systems are particularly vulnerable to climate change.

From the African region, countries in the Horn are among the most vulnerable but least prepared for adverse global environmental change in the world (Aklilu and Alebachew, 2008). In the Horn of Africa, food insecurity has increased in drought-affected pastoral areas of Somalia, Kenya, Djibouti and Ethiopia. The recent drought of 2011-2012 has been qualified as the worst drought in 60 years, caused by a prolonged lack of rain and resulting dry conditions. South-eastern Ethiopia, northern and eastern Kenya, and southern Somalia, are the worst affected areas. The severity and scale of the drought has raised concerns because 80 per cent of the population in this sub-region depend on crops and livestock for their livelihoods and food security,

while only about 1 per cent of arable land is irrigated (GIEWS, 2012). Among the horn countries, Ethiopia is one of the most poverty stricken, ecologically vulnerable country whose growing population and economy are heavily impacted by climatic change and variability.

In Ethiopia, agriculture is important for food security in three ways. Firstly, it produces the food people eat and contributes about 45 percent of Gross Domestic Product (GDP). Secondly, it provides the primary source of livelihood for about 80 percent of the country's total workforce. Thirdly, it can provide income through generating about 60% of export earnings from the exports (MoFED, 2010). This implies that climate change can affect food security mostly through affecting agriculture. As Ethiopian agriculture is predominantly rain-fed and its economy is dependent on primary commodities, any irregularities in weather and climate conditions have adverse welfare implications.

Studies show that rainfall in Ethiopia is expected to be irregular and affects food production negatively. Von Braun (1991) has confirmed that a 10% decline in the amount of rainfall below the long run average leads to a 4.4% reduction in the country's national food production. According to Funk *et al.* (2005), rainfall is expected to decline in the future and also become more irregular. Drought has been an increasing occurrence in Ethiopia over the last decades affecting a significant proportion of the population. Food shortage and famine associated with rainfall variability cause a situation of high dependency on international food aid. Consequently, Ethiopia has become one of the biggest food aid recipient countries in

Africa that accounts for 20-30% of all food aid to Sub-Saharan Africa (Bezu and Holden, 2008).

According to African Development Bank report in September 2010, there is a strong correlation between weather conditions and Ethiopia's economic growth performance. A change of 1 percent in average annual rainfall is associated with a change of 0.3 percent in real GDP in the following year. This has a clear implication for the impact of climatic conditions on smallholders' food security in the country. Above all, climate change has the potential to undermine sustainable development, increase poverty, and delay or prevent the realization of the Millennium Development Goals (IPCC, 2007). An effective way to address the impacts of climate change is by integrating adaptation measures into sustainable development strategies so as to reduce the pressure on natural resources, improve environmental risk management, and increase the social well-being of the poor.

Furthermore, climate change will have impact on all four dimensions of food security such as food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns (FAO, 2008).

Therefore, the potential impacts of climate change on food security must be viewed within the larger and multidimensional framework encompassing all of the indicators

under changing earth system dynamics and observable changes in multiple socio-economic and environmental variables.

2.1.3. Notion of Adaptations to Climate Change

The vulnerability of agricultural sector to long-term changes in climatic variables such as temperature and precipitation is greatly influenced by its adaptive capacity. Adaptation is generally described as those responses by individuals, groups and governments to climatic change or other stimuli that are used to reduce their vulnerability or susceptibility to adverse impacts or damage potential. It has the potential to significantly contribute to reductions in negative impacts from changes in climatic conditions (Kandlinkar and Risbey, 2000).

According to IPCC (2001), adaptations are adjustments or interventions which take place in order to manage the losses or take advantage of the opportunities presented by a changing climate. It is the process of improving society's ability to cope with changes in climatic conditions across time scales, from short term (e.g. seasonal to annual) to the long term (e.g. decades to centuries). The IPCC (2001) also defines adaptive capacity as the ability of a system to adjust to climate change including climate variability and extremes to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The goal of an adaptation measure should be to increase the capacity of a system to survive external shocks or change.

Adaptation to climate change can occur at two main scales. First, it can be at farm-level that focuses on micro-analysis of farmer decision making. Second, adaptation can take place at the national level or macro-level that is concerned about agricultural

production at the national and regional scales and its relationships with domestic and international policy (Kandlinkar and Risbey 2000). Micro-level analysis of adaptation focuses on tactical decisions farmers make in response to seasonal variations in climatic, economic, and other factors. Farm-level decision making occurs over a very short time period usually influenced by seasonal climatic variations, local agricultural cycle, and other socio-economic factors. According to Kandlinkar and Risbey (2000), macro-level analysis on the other hand focuses on strategic national decisions and policies on local to regional scales taking into account long term changes in climatic, market and other conditions over longtime periods.

Adaptation to climate change is critical in developing countries particularly in Africa where vulnerability is high partly due to low ability to adapt. In this circumstance, adaptation helps farmers achieve their food, income and livelihood security objectives in the face of changing climatic and socioeconomic conditions including climate variability, extreme weather conditions such as droughts and floods, and volatile short-term changes in local and international markets (Kandlinkar & Risbey, 2000). Farmers can reduce the potential damage pertaining to climate change and variability by making tactical responses to these changes. Therefore, analyzing climate change adaptation and its effectiveness is of great importance for identifying ways to help poor farmers in agriculture dominant economies like Ethiopia.

2.2. Empirical Literature Review

The impact of climate change on agriculture and adaptation strategies has been widely studied in different parts of world. Most commonly applied empirical approaches in climate change impact analysis literatures include partial equilibrium approaches such

as Agronomic or Production Function approach and Ricardian approach, and Computable General Equilibrium approach. Before stepping into empirical literature on climate change, adaptation and food security arena, brief discussion of commonly used model is presented in succeeding paragraphs.

Some of the existing quantitative evidences on the estimation of the magnitude of climate change impacts in low-income countries are based on production function also known as agronomic models. According to Mendelsohn *et al.* (2004), production function models use carefully controlled crop simulation experiments that measure damages on crop growth due to variation in temperature, precipitation and Carbon dioxide. The advantage of these models is that it predicts the way climate affects yield more dependably because the impact of climate change on crop yields is determined through controlled experiments.

However, it is argued that agronomic studies tend to overestimate negative impacts and underestimate positive impacts. This is because they fail to account for adaptations that farmers undertake in order to cope with climate pressures and their behavioral responses (Mendelsohn *et al.*, 1994).

Another line of alternative empirical approach in climate change literature is Ricardian approach developed by Mendelsohn *et al.* (1994). This approach is named the Ricardian method because it is based on the observation made by David Ricardo (1817) that land values would reflect land productivity at a site under perfect competition. It uses cross-sectional data to capture the impact of climatic, economic and other factors on land values measured by net farm income. The value of land

reflects the sum of all discounted future profits that can be obtained from its use. The key assumption here is that any factor that influences the productivity of land will be reflected in land values or net revenue. This implies that information about the value of climate as one attribute of land productivity is contained in the value of land or net revenue (Deressa and Hassan, 2009).

Ricardian approach is more flexible than agronomic models and it also captures the role of farmers' adaptation mechanisms (Mendelsohn *et al.*, 1994; Deressa and Hassan, 2009). Consequently, this model has been commonly applied in many countries across the world. However, the limitation of Ricardian approach is that it fails to include price effects and role of carbon fertilization (Cline, 1996).

In addition to partial equilibrium analysis, there are some studies undertaken at economy-wide level. These studies used Computable General Equilibrium (CGE) model. Computable General Equilibrium models are analytical models, which look at the economy as a complete system of interdependent components. Despite the fact that CGE models can analyse the economy-wide impacts of climate change and incorporate the complex interactions among different sectors, they are not free from problems. There are difficulties with model selection, parameter specification and functional forms. Data consistency or calibration problems, the absence of statistical tests for the model specification, the complexity and high skills needed are also additional problems in CGE models (Gillig and McCarl, 2002).

2.2.1. Empirical Literature on Climate Change, Agriculture and Food Security

A large body of empirical literature on impacts of climate change on agriculture and food security exists in various countries using different approaches. Both economy-wide and micro level studies generally report negative impact of climate change on agricultural production and productivity.

Some studies estimate economy-wide impacts of climate change. For instance, Thurlow *et al.* (2009) has examined the impacts of climate variability and change on economic growth and poverty in case of Zambia under different scenarios. The result of their study indicated that climate variability has imposed significant cost to Zambian economy. Specifically, the estimated cost to the economy was USD 4.3 billion over a 10-year period and USD 7.1 billion under worst-case rainfall scenario.

Another study by Zhai *et al.* (2009) modeled the potential long-term impacts of global climate change on agricultural production and trade in the case of China. They employed an economy-wide, global CGE model, and simulation scenarios of how global agricultural productivity may be affected by climate change up to 2080. The interesting finding of their study is that as the share of agriculture in GDP decline, the impact of climate change on the overall economy become less intense.

Similarly, Gebreegziabher *et al.* (2011) have modeled the impacts of climate change on overall economy using countrywide dynamic Computable General Equilibrium (CGE) model in Ethiopia. They simulated the impacts of climate change-induced variations in land productivity in the Ethiopian economy for 2010–2060 periods.

The results of simulation indicated that the projected reduction in agricultural productivity may lead to 30 percent less average income, compared with the possible

outcome in the absence of climate change in Ethiopia. They also confirmed that climate change does have a dramatic impact on agriculture dominated Ethiopia's economy even in the high-growth scenarios.

As indicated, the above two studies estimate overall impact of climate change on economy in general and agriculture in particular using Computable General Equilibrium models. However, a large majority of existing studies on climate change impact are based on partial equilibrium methods namely Ricardian approach and production function models.

Molua (2002) employed Ricardian model to analyze the relationship between farm revenue and climate variables in southwestern Cameroon using a sample size of about 110 farmers. Molua (2002) used village level precipitation volume and controlled for indigenous soil and water conservation practices to capture the marginal effects of precipitation on farm income. The results indicate that marginal impact of precipitation on farm income is 38%. But, this study fails to incorporate the effect of soil characteristics on farm productivity and the role of household characteristics on farm revenue which could have significant impact on farm yield. It also ignored the role of temperature as climatic factor in affecting farm yield and takes net farm revenue as measure of food security. Besides, it did not consider the multidimensional nature of food security.

In case of Tanzania, Muamba and Kraybill (2010) examined climate change impact on yields of maize, banana, and coffee in Mt. Kilimanjaro area using Ricardian framework. The study estimates yield reaction to a 1%, 2%, and 3% annual

precipitation decrease. For a 1% precipitation decrease, their simulation predicts that maize, coffee, and banana yield will decrease by 74.8%, 76%, and 8.4% respectively. For 2% precipitation decrease, the simulation predicts that maize, coffee, and banana yield will decrease by 94%, 95%, and 11% respectively. For a 3% decrease in rainfall, the model predicts that maize, coffee, and banana yield will decrease by 98.7%, 99%, and 23.3% respectively. These results indicate strong evidence of a negative impact of climate change on all three crops.

Another study by Kurukulasuriya and Ajurad (2007) examined the relationship between climate variables such as precipitation and temperature and farm profitability in Sri Lanka. Using farm level data of more than 1500 farmers, Kurukulasuriya and Ajurad (2007) found that climate variables explain about 30% of net revenue variation when controlling for other variables. However, this study considered irrigation as an only strategy to adapt climatic shocks and ignored other options such as changing planting date, crop diversification, use of modern varieties and diversifying from farm to non-farm income activities.

In Ethiopia, Deressa and Hassan (2009) assessed the vulnerability of Ethiopian farmers to climate change in broad region of Nile Basin by using Ricardian approach. They conducted regression of net farm revenue on climate, household and soil variables. The results indicate that vulnerability to climate shocks is not uniform across agro-ecological zones. Also, marginal increase in precipitation during spring would increase revenue, while marginal increase in temperature during summer and winter would reduce net revenue. After forecasting future climate using three climate scenario models, Deressa and Hassan (2009) predict that there would be a reduction

of net farm revenue in 2050 and 2100. However, this study did not examine the effectiveness of adaptation strategies adopted by farmers to cope with climate change so that they can maximize their net revenue.

All of the above studies do not address the direct impact of climate change and variability on household food security. Rather, they estimate the impact on farm revenue, crop yields, and farm profitability. However, only production cannot reflect real climate impact on household food security.

There are some studies that dealt with climate change impacts on food security. Lemma *et al.* (2012) examine household food security implications of climate in pastoral areas of Jigjiga district in Eastern Ethiopia. They use rainfall and temperature data from the period 1952 to 2010 and primary data collected from 140 sample households. Mann-Kendall trend test results reveal existence of statistically significant declining trend in rainfall in the rainy season and increasing trend in temperature at annual and seasonal time scale. Their Rash model estimation based on the Food Security Core Module show high prevalence of food insecurity in the district with 81 percent of food insecure households consisting of 27 percent food insecure without hunger, 29 percent food insecure with moderate hunger, and 25 percent food insecure with severe hunger. Moreover, their econometric result indicates the significance of climate perception in affecting household's food security. The limitation of their analysis is that they did not take multidimensional aspects of food security.

Another study by Claudia *et al.* (2010) uses a comprehensive climate change scenario (CCC) that integrates climate projections from 17 GCMs and considers the GCMs' relative performance regarding their prediction of temperature and precipitation for the Sub-Saharan Africa region. The result from process-based crop growth simulation model and a global hydrological model indicate that climate change will lead to changes in yield and area growth, higher food prices and therefore lower affordability of food, reduced calorie availability, and growing childhood malnutrition in Sub-Saharan Africa. Though aggregated, their study presented empirical work on food security and climate change arena.

Similarly, previous studies by Ziervogel *et al.* (2006), Mary and Majule (2009) in case of Tanzania, have focused on the theoretical aspects and are at the aggregate level. But, micro level empirical research can give better insights in the impacts of climate change on smallholder households' food security as many investigators have acknowledged the perspective.

Moreover, the existing studies fail to address multidimensional aspects of household food security except Abera *et al.* (2011). Abera *et al.* (2011), used panel data to investigate the effect of rainfall shocks on Ethiopian rural households' food security and vulnerability over time while controlling for a range of other factors. They generate a time-variant multidimensional household food security index which is developed from various indicators by using principal component analysis. Taking food security index as the dependent variable, Abera *et al.* (2011) use fixed effects instrumental variable regression model to identify determinants of households' food

security over time. Their results reveal that both the level and variability of rainfall are important determinants of persistent household food insecurity and vulnerability.

Though Abera *et al.* (2011) try to address multidimensional nature of food security, the set of food security indicators they considered is limited. They do not address the utilization dimension of food security due to inconsistency in the data available for constructing the food security index. Hence, the authors recommend further studies to address food utilization indicators and consideration of other parts of the country with different agro-ecological setting.

2.2.2. Empirical Literature on Adaptations to Climate Change

Large numbers of empirical studies are undertaken in the areas of farmers' perception and determinants of adaptation strategies to climate change in different countries across the world.

Hassan and Nhemachena (2008) analyze determinants of farm-level climate adaptation measures in 11 African countries using a multinomial choice model. They use the data obtained from a cross-sectional survey of over 8000 farms. Their results reveal that specialized crop cultivation or mono-cropping is the agricultural practice most vulnerable to climate change and warming poses the highest risk especially during the summer season. Results also confirm that better access to markets, extension and credit services, technology and farm assets particularly labor, land and capital are critical for helping African farmers adapt to climate change in Africa.

Another study by Seo (2010) also reported the superiority of mixed farming over specialized farming in hotter climate areas. Seo (2010) modeled climate change adaptation portfolio using microeconomic selection in case of Latin America. Selection model was used to explain both changes in choices and net revenues simultaneously. He utilized approximately 2,000 farm surveys collected from seven South American countries during the 2003–2004 in order to examine whether an integrated farming system which manages both crops and livestock would be more resilient than specialized farms when faced with climate change. The results showed that farmers in a hotter climate prefer a mixed system over specialized systems either in crops or livestock. Under a hot and dry scenario, the land values of all three systems would fall, but the damage would be much smaller in the mixed system than for the farms specializing in crops. Farmers are predicted to lose 8% of their land's value under the Canadian Climatic Center (CCC) scenario, but only 2% under the Parallel Climate Model (PCM). These losses would increase to 18% if farmers do not use climate adaptation measures.

In Ethiopia, Deressa *et al.* (2008) assess determinants of farmers' choice of adaptation strategies and perceptions of climate change in the Blue Nile Basin. They indicate that the common adaptation measure employed by farmers in the area are use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation. Using multinomial logit model, their study finds that the level of education, gender, age, and wealth of the head of household, access to extension and credit, information on climate, social capital, agro-ecological settings, and temperature all influence farmers' choice of adaptations. Their analysis also reveals that age of the household head, wealth, information on climate change, social capital, and agro-ecological settings have significant effects on farmers' perceptions of climate change. Moreover,

the study also reports lack of information on adaptation methods and financial constraints as key constraints to climate change adaptation.

Similarly, Di Falco *et al.* (2011a) has examine drivers of climate change adaptation and differences in food productivity between farm households that adapted and those that did not adapt in the blue Nile Basin. Their result indicate that the main drivers of farm households' decision to adopt some strategies in response to long term changes in mean temperature and rainfall are represented by the provision of climate information both from formal and informal institutions, and access to credit.

The unique contribution of Di Falco *et al.* (2011a)'s analysis is building of counterfactual analysis in which they compare the expected food productivity under the actual and counterfactual cases. Results confirm that there are significant differences in food productivity between the farm households that adapted and those that did not adapt to climate change. They also find that adaptation to climate change increases food productivity. Furthermore, their analyses show the impact of adaptation on productivity is smaller for the farm households that actually did adapt than for the farm households that did not adapt in the counterfactual case that they adapted.

Moreover, Di Falco *et al.* (2011b) examined the climate change impacts and adaptation strategies in the same region (i.e. the Blue Nile Basin) using production function and Ricardian approach. The results of this study indicated that access to information, extension services, household size, age and education of household head

have positive impact on adoption of climate change adaptation options. The study also found that those farmers who adopted climate adaptation strategies such as changing crops, tree planting and soil conservation do have higher food productivity than those who do not.

From the brief review of previous theoretical and empirical literatures, this study identifies important research gaps. First, empirical works addressing the direct impact of climate change and variability on food security is limited. Second, a majority of existing studies do not take multidimensional aspects of household food security into consideration. Third, empirical studies separately investigating the effectiveness of each micro-level adaptation strategies to climate change and variability is almost non-existent. The current study attempts to fill each of these gaps.

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Appendix 1

Household-Level Survey Questionnaire for the Research on *Climate Change, Variability and Adaptation Strategies: Implications for Household Food Security in Southern Ethiopia*

Esteemed Enumerators,

Please read the following to each respondent at the beginning of every interview:

Dear respondent, this is special purpose survey aiming at investigating Climate Change, Variability, Adaptation Strategies and food Security to know the link among these issues and propose policy recommendations to the concerned stakeholders. The survey mainly covers some relevant aspects of your situation including: food security status, farm-level climatic conditions, adaptation mechanisms you adopt and your socioeconomic characteristics. Please, answer the questions honestly and in accordance with the actual situation of your household, assisting the enumerator earnestly to complete the questionnaire.

I would like to assure you that the information that you reveal in this interview will be used solely for research purpose, and we will keep any personal information that you provide confidential. I thank you in advance for your cooperation!

4. Members of your household (people living in your household)
1. Between 0 – 15 years of age: _____
 2. Between 15 – 65 years of age: _____
 3. Above 65 years of age: _____
5. Educational level of household head (in number of schooling years): _____
6. What is the size of the farm land you have (owned)? Measured in:
1. Local units ('Timad'): _____
 2. In hectare: _____
7. How many kilograms of chemical fertilizer you use on your total farm land (Both DAP and Urea)? _____
8. How many people work on farming in your land?
1. Male: _____
 2. Female: _____
- And for how many hours they work per day? _____
9. Do you own (have) livestock (like cattle, sheep, goat, etc.)? 1. Yes 2. No

10. Total annual income household's earned (in Birr)

1. Income earned from farm activity

	Amount produced	Price of one unit (quintal)	Total cost incurred
Maize production (quintal)			
Coffee (quintal)			
Chat			
Enset			
Livestock			
Others (specify)			

2. Income from the non- farm activity: _____

3. Remittances: _____

4. Money obtained from government and non-government transfers such as the Safety Net Program and others within a year (Other, if any specify):

17. If your answer is yes for the question number 17 is yes, what type of extension is most commonly available for you (please encircle your choice)?

1. Farmer-to-farmer extension
2. Government extension service
3. Both farmer-to-farmer and government extension service

Section 3: Food Security Status of a Household

Instruction: Dear enumerator, kindly circle the number representing respondent's answer for the following questions

18. Does your household have food stock available all the time for consumption?

1. Yes
2. No

19. Do you think that food prices prevailing in the market is affordable (able to pay) for your family given the income you earn?

1. Yes
2. No

20. Do you have all time access to drinking water for both people as well as livestock nearby your household?

1. Yes
2. No

21. Have ever your household faced periodic shortfalls (shortages) in food items from household especially during non-harvest period?

1. Yes
2. No

Section 4: Observed Rainfall Variability

Instruction: Dear enumerator, kindly circle number representing respondent's answer for the questions given below

22. Does the rainfall coming on time?

1. On time 2. Too early 3. Too late

23. Is there enough rain on your fields at the beginning of the rainy seasons?

1. Enough 2. Too little 3. Too much

24. Is there enough rain on your fields during the growing seasons?

1. Enough 2. Too little 3. Too much

25. Does the rains stopping on time on your fields?

1. On time 2. Too early 3. Too late

26. Is it raining during the harvest time?

1. Yes 2. No

Section 5: Adaptation Strategies to Climate Change and Variability

Instruction: Dear enumerator, I kindly request you to choose number representing respondent's answer to following questions

27. Do you adopt crop diversification (changing crop varieties) strategy as a coping measure of climatic variations?

1. Yes 2. No

28. Do you vary your crop planting and harvesting dates to cope changing climate?

1. Yes 2. No

29. Do you diversify your means of earning income from farm to non-farm activities?

1. Yes

2. No

30. If your answer for the question number 30 is yes, in what are the main non-farm revenue generating activities do you get involved?

31. Do you use soil and water conservation measures in your farm lands?

1. Yes

2. No

32. If your answer is 'yes' for the question number 32, what water and soil conservation measures do you use?

33. Do you have a practice of reserving water from rain to be used for minor irrigation during dry seasons?

1. Yes

2. No

34. Do you practice reforestation or afforestation at your own farm level?

1. Yes

2. No

35. Do you use of modern varieties and fertilizer inputs?

1. Yes

2. No

36. Do you have an access to irrigation facility in your area?

1. Yes

2. No

37. Do you irrigate your farm during the season where there is no rainfall?

1. Yes

2. No

Section 6: Barriers to Climate Adaptation

Instruction: Dear respondent, kindly answer the following questions by choosing main barriers that hinder you from using various adaptation strategies to climate change and variability

38. If you do not use any of the above strategies, what are the main reasons that hinder you from employing the options at your farm?

Please choose your main reasons for not using any of the above strategies from the given alternatives below

- A. Lack of skills required to implement the strategies
- B. Lack of sufficient manpower to implement the strategies
- C. Lack of climate related information and awareness creation from the concerned bodies
- D. Lack of sufficient financial resource required to implement the strategies
- E. Shortage of land to implement the given strategies
- F. First, I want to see the impact of these strategies from other farmers using the strategies and then I will follow the suit
- G. For the reason I don't know
- H. Others (specify):

Thank you so much for the time you spent answering the questions!

Appendix 2

Variance Inflation Factor (VIF) for testing Multicollinearity among Variables Included in Regression Models

Variables	<i>VIF</i>	$1/VIF$
Long-term average village rainfall	9.02	0.110864
Age of household head	8.39	0.119189
Access to market	8.19	0.122100
Sex of household head	7.53	0.132820
Access to agricultural extension service	7.30	0.136987
Educational level attended by household head	6.90	0.144930
Fertilizer use	6.74	0.148367
Climate information	6.43	0.155521
Access to credit	6.33	0.157977
Altitude	5.75	0.173913
Crop diversification (predicted value)	4.60	0.217392
Household size	4.07	0.245701
Varying planting and harvesting dates (predicted value)	3.91	0.255754
Soil and water conservation (predicted value)	3.58	0.279329
Modern varieties (predicted value)	3.31	0.302115
Subjective rainfall satisfaction index	3.17	0.315457
Cultivated land size	2.64	0.378788
Daily total labor hours spent on farming	2.19	0.456622

Declaration

I declare that this thesis is my original work and has not been presented for a degree award in any other university, and that all sources of materials used for the thesis have been duly acknowledged.

Declared by: **Tsegaye Ginbo**

Signature: _____

As thesis advisor, I hereby confirm that this thesis is the output of research undertaken by Tsegaye Ginbo under my supervision and that it be submitted for the MSc degree award.

Confirmed by Advisor: **Alemu Mekonnen (PhD)**

Signature: _____

Addis Ababa University, June 2014

Addis Ababa, Ethiopia