ADDIS ABABA UNIVERSITY

COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR FOOD SECURITY STUDIES

AGRICULTURAL TECHNOLOGY ADOPTION, COMMERCIALIZATION AND FOOD SECURITYLINKAGE: MICRO EVIDENCE FROM BORICHA WEREDA, SIDAMA ZONESNNPR ETHIOPIA

BY

TAGEL ALEMU TAFESE

JUNE 2018

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A THSIS SUBMITTED TO COLLEGE OF DEVELOPMENT STUDIES, CENTER FOR FOOD SECURITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OFMASTER OF SCIENCE IN FOOD SECURITY AND DEVELOPMENT STUDIES

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As members of the examining board of the final MSc open defence, we certify that we have read and evaluated the thesis prepared by TagelAlemu, titled "Agricultural Technology Adoption, Commercialization and Food Security Linkage: Micro Evidence from BorichaWereda, Sidama Zone Ethiopia" and recommend that it to be acceptedas fulfilling the thesis requirement for the degree of Masters of Science in Food Security and Development Studies.

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DEDICATION

I dedicate this thesis to my beloved wife, Salem Abera. It's after I met her that good things began to happen in my life. She deserves my appreciations for her encouragement.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of therequirements for an advanced MSc degree at the Addis Ababa University, and is deposited at theUniversity Library to be made available to borrowers under rules of the Library. I solemnlydeclare that this thesis is not submitted to any other institution anywhere for the award of anyacademic degree, diploma, or certificate.

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God bless you all.

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Abbreviations and Acronyms

ADOCOM	Adoption and Commercialization
ADOPT	Adoption Only
ATA	Agricultural Transformation Agency
BANRD	Bureau of Agriculture and Natural Resource Development
CSA	Central Statistics Agency
DAs	Development Agents
FAO	Food And Agriculture Organization
FIES	Food Insecurity Experience Scale
GDP	Gross Domestic Product
GHI	Global Hunger Index
HCI	Household Commercialization Index
HDDS	Household Dietary Diversity Score
HH	Household Head
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
MoADR	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
NGO	Non-governmental Organization
SNNPR	Southern Nation Nationality People Region
UNICEF	United Nations Children's Emergency Fund
USAID	United States Agency for International Development
WFP	World Food Program
WFS	World Food Summit
WHO	World Health Organization

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Agricultural Technology Adoption, Commercialization and Food Security Linkage: Micro Evidence from Boricha*Wereda*, Sidama Zone SNNPR Ethiopia

Abstract

This study was aimed at examining the impact of .agricultural technology adoption on agricultural productivity, level of commercialization and household food security, and also to identify determinants of technology adoption, commercialization, household dietary diversity and level of food insecurity of households in BorichaWereda, Sidama Zone southern Ethiopia. A total of 334 household heads from the wereda were selected by random sampling method from three kebeles.Descriptive and inferential statistics as well as econometric models were used. In this regard, Propensity Score Matching (PSM) was put in place to examine impact of adoption on productivity, commercialization, and food security status. Logit and Tobit models were used to identify determinants of adoption and commercialization, respectively. Multinomial logistic regression was used to sort out factors that gear households solely to engage in commercialization or solely to adopt agricultural technology and to engage both in commercialization and technology adoption. Eventually, ordered logistic regression was deployed to examine the effects of technology adoption on the food insecurity status of households. The result indicated that adoption showed positive impact on productivity, commercialization and dietary diversity, and negative impact on food insecurity. Farmer's union memberships, farm size, livestock holding, off farm income were positively urge households to adopt while education status and age negatively related with adoption. Livestock holding, farm size and off farm income were positively related to adoption-commercialization. Adoption, livestock holding, farm size and vehicular road showed positive relation while market distance, market information and productive labor showed negative relation with commercialization. Adoption, livestock holding and marital status were positively related with high dietary diversity. Finally, adoption, productive labor, family size, marital status and maximum education, all except age, were negatively related to food insecurity.It is therefore important to note that the technology adoption should be promoted to combat food insecurity and to enhance commercialization in the study area.

Key words: Adoption, commercialization, dietary diversity, food security

1. INTRODUCTION

1.1. Background

Based on FAO and its associate report number of people in the World affected by severe food insecurity in the year 2016 is reported to be 688.5 (±27.6) million. The majority of people who are suffering from severe food insecurity live in Africa put to be 333.2 (±8.6) million. Among others, the number of food insecure and hungry people living in sub-Saharan Africa is reported to be 306.7 (±8.3) million (FAO, IFAD, UNICEF, WFP and WHO, 2017).

Based on the above figure around half of severely food insecure people live in Sub-Saharan Africa. Sub-Saharan Africa region in general is known for its abject poverty, low level of agricultural productivity, low level of social and economic development, and lack of adequate infrastructure that promote overall change in development. The majority of the region`s population, 62.6%, live in rural areas. Of these, more than 70% of the poor depend on agriculture as their sole means of livelihood (IFAD, 2012). This discloses the incapacitate condition of agriculture sector in resolving long pertained poverty as a whole and the chronic challenge of severe food insecurity in particular within the respected region.

And more specifically, being in Sub-Saharan African region, Ethiopian economy is also dominated by agricultural sector accounting 45% of the national GDP. The economic growth is often guided by the performance of the agricultural sector, which continues to be the most dominant aspect of the country's economy, accounting for 85% of employment and nearly 90% of foreign exports (MoADR, 2010).

According to Agricultural Transformation Agency (ATA) (2014) and Ministry of Agriculture and Rural Development's report (MoARD) (2010).the majority of the agriculture sector is made up of smallholder farmers who own less than two hectares of land productivity and production are strongly influenced by climatic variability, land degradation, limited household assets, low levels of farm technologies, lack of employment opportunities, and population pressure.

As a result of the above challenges, the agriculture sector has been short-handed to radically avoided long stayed country's problem of poverty. This is disclosed by many empirical studies and reports of the concerned institutes. According to Food and Agriculture Organization's report

(2015) about 52% of the rural population and 36% of the urban population consume under the minimum recommended daily intake of 2100 calorie per person per day. According to global hunger index (GHI) report of 2016 reported by International Food Policy Research Institute (IFPRI) (2017), Ethiopia was ranked 107th, its hunger index being 33.4%.

Furthermore, empirical studies done in different part of the country associate the current food insecurity situation with attribute like technology adoption, education status of the household head, family size, land size, livestock holding, off farm income, and so on (Ramakrishna and Demeke, 2002; Felke*et al*, 2003 and Kidane*et al*, 2005). And also, a study by Solomon *et al* (2011)and Marte*yet al* (2012) strengthen the fact that agricultural technology bring about surplus production as a result it initiate household market participation, and improves household's welfare, particularly food security status.

As to the interest of this research and reports in this regard, in addition to technology adoption that enhance farm land productivity, the depth and intensity of food insecurity in Ethiopia is high, as a result of being influenced by poor functioning of marketing systems and other household and socioeconomic factors (Justus *et al*, 2015; Ahmed, 2017; Ismael *et al*, 2017). Based on the above empirical reports, adopting yield enhancing farm inputs is likely to increase productivity, as a result it tend to decrease the probability of being food insecure.

This paper focuses on the contribution of agricultural technology adoption and commercializing of agricultural products as alternative way of improving rural household's food security status.

1.2. Statement of the Problem

The Ethiopian economy is heavily depending on small holder farm agriculture. The contribution of the agricultural sector to gross domestic product (GDP) is the largest(41%); comprises 85% of the employment opportunity, generate 90% of the export earnings, and provides 70% of the country's raw material demand of the large and medium scale industries (MoFED, 2012). Poverty and food insecurity are quite pervasive in Ethiopia particularly in the rural areas. For instance, according to joint publication report of Ethiopia Central Statistical Agency (CSA) and the World Food Program (WFP) on Comprehensive Food Security and Vulnerability Analysis (2014), nationally, 40% of households are food energy deficient, using the threshold of 2,550

kilocalories per adult equivalent per day. Furthermore, according to FAO (2015), about 52% of the rural population and 36% of the urban population consume under the minimum recommended daily intake of 2100 calorie per person per day. To combat such problems of the nation, prime attention has been given to the agricultural sector. This ultimately necessitates adopting technology that ameliorates agricultural productivity.

The role of agriculture is very important in southern regional states where 27% of the total households is food energy deficient in terms of calorie consumption and has a very low dietary diversity.This is evidenced by the fact that 47% of SNNPR rural households consume less than three food groups within 7 days. In this regard, Zeleke*et al* (2016) revealed in Borichawereda that the 72.2% of respondents found to be food insecure in terms of food energy consumption. The research has further enunciated that lack of integrated farming system and low level of agricultural inputs usage have been considered as the reason for such high precedence of food insecurity.

Cognizant to the importance of the agricultural sector, different agriculture yield enhancing measures have been adopted. The main intention of such initiations is to increase the productivity of farmers thereby increasing their level of commercialization that eventually improves the nutritional status of households. There are studies that have been conducted so far on the issues of agricultural technology adoption in rural Ethiopia (Assefa and Gezahegn, 201; Degnet and Mekibib, 2013; Hailu, 2008; Nega and Senders, 2006 and Solomon *et al*,2011).

Moreover, impact of technology adoption in enhancing productivity and commercialization has been reported by many empirical studies. The finding of Solomon *et al* (2011) also shows that the average treatment of improved chickpea adoption contributed to farmers' chickpea sold ranges from 16 to 20 percent. Similarly, Marte*yet al* (2012) in Ghana reported the extent of maize and Cassava sold by smallholders are 53 and 72 percent, respectively, whereas the total agricultural commercialization with respect to these two crops is 66 percent. A study by Tigist (2017) shows the use of high-yielding varieties increases marketable surplus production by 7.4 percent per year, whereas inorganic fertilizer use increases it by 2.3 percent. The multiple adoption of the two technologies jointly increase the surplus by 6 percent.

But no research has been carried out that linked the technology adoption, commercialization and food security in Ethiopia in general and in Burchaworeda in particular. Therefore, this researcher will investigate food security situation of the woreda using HDDS to assess their dietary habit as food security measurement tool rather than calorie consumption. Therefore, the study will try to find out the inter-relationship between agricultural technology adoption, commercialization and household dietary habit.

1.3. Objectives of the Study

1.3.1. General objective

The overall objective of the study is to analyze agricultural technology adoption, commercialization and food security linkage in Boricha*Wereda*, Sidama Zone.

1.3.2. Specific objectives

The study pursued the following specific objectives:

- To identify impact of agricultural technology adoption on agricultural productivity, level of commercialization and household food security status;
- To examine determinants of technology adoption, commercialization and both adoption with commercialization at the same time, household dietary diversity and level of food insecurity

1.4. Research Questions

The following pertinent research questions are addressed in this study.

- Does agricultural technology adoption positively influences agricultural productivity, commercialization and food security situation of farming households?
- What are those demographic and socioeconomic factors that play determining role in adoption of agricultural technology, commercialization and food security statusamong farming households?

1.5. Significance of the Study

The formulation of this paper can, primarily, be used for academic exercise. The study will give insight and serve as a document for researchers and students interested in the topic to stimulate further study in the area. Analysis of inter-linkage among technology adoption, commercialization and food security can help public policy makers, service providers like extension workers, and local and international NGOs, and community groups to assess the need for assistance, judge the effectiveness of existing programs designed to help such households. Accordingly, the result of the study carried out on households of Boricha*wereda* will support development practitioners, policy makers and the authorities of the region with a view to comprehend the problem and design plausible intervention course of action to bring about food security in the region.

1.6. Scope and Limitation of the Study

The study was conducted to examine inter-linkage among agricultural technology adoption, commercialization and food security in Boricha*wereda*, Sidama Zone. The study covered only Boricha*wereda* andthree *kebeles* among 39 rural *kebeles*. Moreover, the study dealt with a limited number of households; appliedhousehold dietary diversity score (HDDS) and Food insecurity experience scale (FIES) to evaluate food security status of farmers, and dealt with the kind of technology adopted in the *wereda*which are improved seeds and fertilizer. The scope of this study was limited by time, budget and other resource limitations. Even if the study is restricted in terms of its coverage, its findings can be used as a springboard for more detailed and area specific studies.

1.7. Organization of the Study

This report is organized into five chapters. Chapter one introduces and sets out the background information, statement of the problem, research objectives, research questions, significance, scope and limitation and organizationof the study; chapter two talks about review of related literature. Chapter three tries to introduce description of the study area and research methods which discusses location, demographic and socio-economic profile of the study area; research design and approach; types and sources of data; sampling techniques and data collection tools; and techniques of data collection. Chapter four deals with result reporting and the related discussions.Chapter fivesummarize the finding and suggest few recommendation.

2. REVIEW OF RELATED LITERATURES

2.1. Review on Agricultural Technology Adoption

2.1.1. Basic concepts of technology adoption

The concept of technology adoption could be better conceptualized through understanding the difference between technology adoption and diffusion, which are highly interrelated but distinct concepts. Technology adoption is measured at one point in time while technology diffusion is the spread of a new technology across population over time. While explaining the distinction between these concepts, Rogers (1962) argued that, technology (synonymously used with the term innovation) is often accompanied by two processes, namely the processes of adoption and diffusion. Technology is described as an idea, practice, or object that is perceived as new by an individual or groups of a society. Technology adoption is the use or non-use of a new or improved technology by an individual or farmer at a given period of time. On the other hand, technology diffusion is defined as "the process by which a technology is communicated through certain channels over time among the members of social systems". It signifies a group of phenomena, which suggests how technology spreads among users. It takes place at the individual level and is the mental process that starts when an individual first hears about the technology and ends to its final adoption or rejection.

2.1.1.1.Components of technology adoption

Rogers (1962) summarized the above definition of technology diffusion using the following four core elements: The technology that represents the new idea, practice, or object being defused, Communication channels which represent the way information about the new technology flows from change agents‟ suppliers (extension, technology suppliers) to final users or farmer, The time period over which a social system adopts a technology and the social system. Overall, the technology diffusion process essentially encompasses the adoption process of several individuals or farmers over time.

Further, another study by Rogers (1995), defined the rate of adoption (speed of adoption) of a given technology. It is the relative speed with which farmers adopt technology; in this definition consideration is given to the element of „time‟ in adoption of a given technology to the farmers.

2.1.1.2.*Stages of technology adoption*

Rogers (1962) developed a technology adoption model, generalized the use of it in his book entitled as “Diffusion of Innovations”. The process of adoption over time is typically illustrated as a classical normal distribution or bell-curve and use the mean and standard deviation to divide the normal adopter distribution categories. The model indicates that the first group of people to use a new product or technology is called innovators, followed by early adopters. Next come the early and late majority, and the last group to eventually adopt a product are called laggards.

While explaining each of the categories the study by Rogers (1962) defined as:

- Innovators: These are the first individuals to adopt a given technology and hence they are willing to take risks, youngest in age, have the highest social class, have great financial liquidity, are very social and have closest contact with scientific sources and interacting with other innovators.
- Early adopters: These are those groups of individuals who are typically younger in age, have a higher social status, have more financial liquidity, advanced education, and are more socially forward than late adopters, which means more discrete in adoption choices than innovators.
- Early majority: Individuals in this category adopt technology after a varying degree of time. This time of adoption is significantly longer than the innovators and early adopters. Early majority tend to be slower in the adoption process, have above average social status, contact with early adopters, and seldom hold positions of opinion leadership in a system.
- Late majority: Individuals in this category will adopt technology after the average member of the society. These individuals approach technology with a high degree of skepticism, and after the majority of society has adopted the technology. Late majority is typically skeptical about technology, have below average social status, very little financial lucidity, in contact with others in late majority and the early majority, very little opinion leadership.
- Laggards: Individuals in this category are the last to adopt a technology. Unlike some of the previous categories, individuals in this category show little to no opinion

leadership. These individuals typically have an aversion to change-agents and tend to be advanced in age. Laggards typically tend to be focused on "traditions", likely to have lower social status, lowest financial fluidity, older of all other adopters, in contact with only family and close friends.

2.1.2. Factors affecting technology adoption

From the extensive review of the literature on technology adoption in developing countries, by Feder*et al* (1985), the various factors that influence technology adoption can be grouped into the following three broad categories: factors related to the characteristics of producers; factors related to the characteristics and relative performance of the technology and institutional factors.

The factors related to the characteristics of producers include: education level, experience in the activity, age, sex, household size, level of wealth, farm size, labor availability, risk aversion and capacity to bear risk, etc. The factors related to the characteristics and performance of the technology include food and economic functions of the product, the perception by individuals of the characteristics, complexity and performance of the innovation or technology, its availability and that of complementary inputs, the relative profitability of its adoption compared to substitute technologies, the period of recovery of investment, the susceptibility of the technology to environmental hazards, etc.

Similarly, a study by Meinzen-Dick *et al* (2004) identified assets, vulnerability, and institutions as the main factors affecting technology adoption. Assets deal with whether farmers have the requisite physical (material) and abstract possessions (e.g. education) essential for technology adoption. Lack of assets will limit technology adoption and it is recommended that developing countries should promote technologies with low asset requirements as they are likely to have higher adoption rates among poor farmers. Vulnerability factors deal with the impact of technologies on the level of exposure of farmers to economic, biophysical and social risks. Institutional factors deal with the extent or degree to which institutions impact on technology adoption. Institutions include all the services to agricultural development, such as finance, insurance and information dissemination. They also include facilities and mechanisms that enhance farmers‟ access to productive inputs and product markets. Institutions also include the embedded norms, behaviors and practices in society.

The institutional factors include availability of credit, the availability and quality of information on the technologies, accessibility of markets for products and inputs factors, the land tenure system, and the availability of adequate infrastructure (Danded et al., 2012). These explanatory indicators vary from study to study based on their contextual applicability and specific local condition.

The determinants of agricultural technology from the traditional, social, physical, and economicperspectives are discussed below. The factors are: institutional factor, technological,economics, financial, physical, human, cultural and householdspecific factors.The degree to which a potential adopter can try something out on a small scale before adopting it completely is a major determinant of technology adoption. Farmers who perceive the technology as being consistent with their needs andcompatible to their environment are likely to adopt such since they find it as a positive investment. Farmers' perception about the performance of the technologies significantly influences their decision to adopt them (Doss, 2003).

Off-farm income is reported to act as a substitute for borrowed capital in rural economies where credit markets are either missing or dysfunctional (Yaron*et al,* 2000).The study done by *Makokha et al* (2001) on determinants of fertilizer and manure in maize production Kiambucounty, Kenya reported high cost of labor and other inputs, unavailability of demanded packages and untimely delivery as the main constraints to fertilizer adoption. Off farm income has been shown to have a positive impact on technology adoption. This is because off-farm income acts as an important strategy for overcoming credit constraints faced by the rural households in many developing countries (Ahmed, 2004). A key determinant of the adoption of a new technology is the net gain to the farmer from adoption, inclusive of all costs of using the new technology (Foster, 2010). High cost of agricultural technology has been reported hindrance to adoption agricultural technology.

Physical factors such as the farm size play a critical role in adoption process of a new technology (Mwangi and Kariuki, 2015). Many studies have reported a positive relation between farm size and adoption of agricultural technology. Farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new technology unlike those with less farm size.

Farmers are consumers of the products of agricultural research and their subjective preferences for characteristics ofnew agricultural technologies affect their adoption decisions (Adesina and Baidu, 1995).Farmers are also important as sources of technology informationand agents of technology transfer. The risk preferences of farmersare also important in influencing the technology adoption decision,especially if capital-intensive technology costs are irreversible.

Farmers need to know the existence of technology, its beneficial, and its usage for them to adopt it. Acquisition of information about a new technology is another factor that determines adoption of technology (Karki and Siegfried, 2004). Access to extension services helps to spread information about new agricultural technology leading to adoption. Farmers are usually informed about the existence as well as the effective use and benefit of new technology through extension agents. In fact, the influence of extension agents can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies (Kuuma, 2005). Belonging to a social group enhances social capital allowing trust, idea and information exchange. Farmers within a social group learn the benefits and usage of a new technology from one another. Uaiene et al. (2011) suggests that social network effects are important for individual decisions, and that, in the particular context of agricultural innovations, farmers share information and learn from each other.

Access to credit is found to be very important factor influencing the adoption of agricultural technology by the smallholders (Lavison, 2013). Credit can facilitate farm households to purchase the needed agricultural inputs and enhance their capacity to effect long-term. Human capital of the farmer is assumed to have a significantinfluence on farmers' decision to adopt new technologies (Mwangi and Kariuki, 2015). Most adoption studies have attempted to measure human capitalinvestment in their farms through the farmer's education, age, gender, and household size. Education of the farmer has been assumed to have apositive influence on farmers' decision to adopt new technology.Education level of a farmer increases his ability to obtain; processand use information relevant to adoption of a new technology.

Other parts of the social science literature emphasize the role of distance and geography in the adoption of agricultural technologies. In this case, any significant travel costs involved in the initial learning about a technology and subsequentlyestablishing it might reduce the likelihood of that technology'sadoption.

2.2. Adoption of Technologies to Ensure Food Security

A number of technologies can play a role in addressing concerns related to the four dimensions of food security. New and existing technologies to combat biotic and abiotic stresses, raise crop and livestock productivity, improve soil fertility and make water available can potentially increase the amount of food produced. Storage, refrigeration, transport and agro-processing innovations can address the dimension of food accessibility. Science to produce high-nutrient staple crops can combat malnutrition, improving food utilization and use. Finally, STI for climate change mitigation and adaptation – including precision agriculture, index-based insurance and early warning systems – can address food instability (Mohamoud, undated).

Food availability: Science and technology can play a critical role in producing more food by creating plant varieties with improved traits, as well as optimizing the inputs needed to make agriculture more productive.

Cross-breeding for improved plant varieties: Genetic modification of plant varieties can be used for nutrient fortification, tolerance to drought, herbicides, diseases or pests, and for higher yields. Earlier forms of genetic modification in agriculture have involved conventional cross-breeding approaches. Although plant improvements are limited to the best traits available within the same family of crops, such technology continues to be useful, especially for smallholder farmers across a number of geographies.

Soil management: Genetically improved varieties might not increase yields if constraints such as low soil fertility are not overcome. Synthetic fertilizers have been used to increase agricultural yields for decades but their capital intensity, dependence on natural gas –particularly in the case of nitrogen – and a large ecological footprint make them unsustainable. Fertilizer and water overuse can cause environmental damage and represent an economic waste for smallholder farmers.

Irrigation technologies: Like soil fertility, the availability of water is a critical input for ensuring and improving crop productivity. Approximately 70 per cent of global freshwater supply is devoted to agriculture. Unfortunately, many farmers do not have access to water for agriculture because of physical water scarcity (not enough water to meet demands) or economic water scarcity (lack of investments in water infrastructure or insufficient human capacity to satisfy

water demand), among other factors. In response to such challenges, low-cost and affordable drills, renewable energy-powered pumps and technologies for desalination and improved water efficiency can potentially make water more available for food production.

Food access: A key aspect of accessing food is minimizing food losses during production, storage and transport, and waste of food by retailers and consumers. Such agricultural losses are attributable to a number of factors, including lack of access to ready markets, adequate storage facilities, affordable refrigeration and local crop-processing facilities.

Food utilization and use: Science for nutrition. Biofortification – or the breeding of critical micronutrients and vitamins into staple crops – has emerged as an effective approach to combat malnutrition, especially in developing countries. To date, the most successful example of vitamin and micronutrient biofortification is the orange-fleshed sweet potato, developed at the International Potato Centre.

Food stability: New ways to combat acute and chronic food insecurity. Locally adapted breeding for drought or heat-tolerant crop varieties, with 40. a focus on underutilized crops, has great potential to support climate change adaptation in agriculture. In particular, climate change mitigation and adaptation should focus on information provision and knowledge transfer and should include social, as well as technical innovations. Many practices, however, deliver both, and many of the effective adaptation, resilience and mitigation approaches to a changing climate offer important ecological, agronomic, economic and social co-benefits.

2.2.1. Adoption status of agricultural technologies in Ethiopia

Food insecurity in Ethiopia derives directly from dependence on undiversified livelihoods based on low-input, low-output rain fed agriculture. Ethiopian farmers do not produce enough food even in good rainfall years to meet consumption requirements. There is, off course, a trend of technology adoption, even though, varies factors affect its implementation. A number of studies examined factors affecting adoption of improved agricultural technologies in crop production. Most of these studies, however, have tended to have a bias towards measuring the status and intensity of improved agricultural technologies adoption.

The food security and adoption status of agricultural technologies in Ethiopia was generally hypothesized to be determined by family size, gender of the household head, literacy status, farming experience, total cultivated land and its allocation to production of staples and cash crops, irrigation water use, quantity of fertilizer used for crop production, livestock holding in tropical livestock unite, gross income earned, access to credit, participation in off-farm activities, distance to major town, nearest road and development station as a proxy for market information on food and agricultural technologies, transaction cost, and access to government extension services (Ruel 2002, 2003).

Hailu (2008) demonstrated the impact of improved technology on productivity and found that low adoption of improved agricultural technologies was attributed to unavailability of technologies, high cost of required inputs, lack of access to and high interest on credit, and policies that discourage improved technology adoption such as promotion of state farm.

Assefa and Gezahegn(2010) and Solomon *et al* (2011) found that age of household head, educational status, livestock holding, non-farm income, sex, and information access plays important factors in affecting the decision of farmers to adopt improved technology.

Nega and Senders (2006) showed the positive effect of credit on fertilizer adoption and improved maize varieties, respectively. Degnet and Mekibib (2013) found that membership to farmer cooperatives has a strong positive effect on adoption of chemical fertilizer. Yu and Nin-Pratt (2014) pointed out that extension service, farmer knowledge, farming skills; risk aversion behavior, household wealth and land fragmentation are important factors in affecting fertilizer adoption in Ethiopia.

2.3. Review on Agricultural Commercialization

2.3.1. The concept of agricultural commercialization

The welfare gains from market-oriented production arise from specialization that builds on and creates comparative advantages, potential for large-scale production, and from dynamic technological, organizational and institutional change effects that arise through the flow of ideas due to exchange based interactions (Romer 1993, 1994). Commercializing smallholder agriculture is an indispensable pathway towards economic growth and development for most

developing countries relying on the agricultural sector (von Braun 1995; Pingali and Rosegrant 1995; Timmer 1997). In the long-run, subsistence agriculture may not be a viable activity to ensure sustainable household food security and welfare (Pingali 1997).

Smallholder commercialization also typically leads to an increased diversity of marketed commodities at a national level and increased specialization at regional and farm levels (Pingali and Rosegrant 1995; Timmer 1997; Kurosaki 2003). Moreover, commercialization has a linking power between input and output sides of a market. Demand for modern technologies promotes the input side of production and facilitates the development and advancement of technological innovations. In turn, the use of modern technologies can result in higher productivity and production entering markets.

The concept of agricultural commercialization can be complex, and has contributed to varying definitions and emphases given in the literature. According to Pingali (1997), agricultural commercialization is more than marketing agricultural outputs. Pingali argued that agricultural commercialization is attained when household product choice and input use decisions are made based on the principles of profit maximization. Moreover, according to von Braun et al. (1994), commercialization implies increased market transactions to capture the benefits from specialization. Increased market transactions are more easily attained when there are favorable policies and institutional arrangements that promote open domestic and international trade environment and the development of market infrastructure and support services that facilitate access to existing markets and the opening up of new market opportunities under a secured legal system.

There is largely a consensus that commercialization has differential impacts on different socioeconomic groups (wealthy and poor, land owners and landless farm households, women, and children) under different socio-economic, institutional and policy environments, although the net impacts are not necessarily or universally positive. However, there are only a few, if any, who contend the need for commercialization to promote social development and economic growth. With all the merits and demerits of agricultural commercialization to different clusters of the society and under different socio-economic and policy situations, this paper tries to investigate major findings and advancements in literature on this issue. Moreover, it tries to look

for potential gaps that warrant further research both in conceptual and methodological aspects related to agricultural commercialization (Moti et al, 2009).

2.3.2. Determinants of agricultural commercialization

Findings of Martey et al (2012) confirmed assertions in the literature that off-farm income contributes more to marketed output if off-farm income is reinvested in farm technology. Consequently, farm outputs falls if non-farm income triggers off-farm diversification. Output price is an incentive for farm households to supply more output in the market. Assertion in literature that distance confines rural farmers to perpetual production of low-value and less perishable commodities, particularly cereals was established. Household heads with higher level of education are more likely to increase the sales of maize. Education is believed to increase a household's understanding of market dynamics and therefore improve decisions about the amount of maize sold. Age of the household head is used as a proxy for experience in farming. It is believed that older household heads have more contacts which allow trading partners to be discovered at lower cost relative to younger household heads. On the other hand, younger household heads are more dynamic with regards to adoption of innovations both in terms of those that enhances productivity and marketing at reduced costs.

According to Kirimi et al (2013) enabling access to affordable production inputs, suitable to small scale farmers, thus ensures that farmers are not trapped in low productivity–low return farming activities that lead to food insecurity. The use of productivity enhancing inputs will improve the ability of smallholder farmers to produce sufficient marketable surplus. Also, it will be important to strengthen efforts geared toward creating market linkages for the various agricultural enterprises. Moreover, innovations that enhance households' access to land, education, savings and employment can be instrumental in raising their ability to produce food and access it from the market, ensuring food security.

Kirui and Njiraini (2013) highlighted determinants of agricultural commercialization (market participation) by the farm households in Kenya. The study showed that farmer-specific characteristics (age and gender) farm specific (distance to bank and the number of crop enterprises grown by the farmer) and capital endowment variables (education level, non-farm as well as total farm income) influence the commercialization process. Collective action (farmer

groups) as well as use of ICT tools (mobile phones) significantly and positively determines commercialization. The interaction of these two variables with gender show that participation in collective action as well as use of ICT tools (mobile phones) significantly increases commercialization of female farmers.

Programs that promote commercialization of smallholder agriculture coupled with improved infrastructure in terms of roads and market information systems are continuously needed to facilitate commercialization of farm produce (Justus et al, 2015).

2.3.3. Impacts of agricultural commercialization on food security

Commercialization is often viewed as an avenue to improve household food security due to its comparative advantages over subsistence production. However, there are arguments for and against smallholder commercialization as a pathway for ensuring household food security. Kirimi et al (2013) sought to identify factors that influence household food security for Kenyan rural smallholder households, and in particular, determine if household commercialization as defined by household participation in input (fertilizer and seed) and crop output markets affects food security position. Results showed that household commercialization was associated with a reduced risk of being in the chronically food poor. Hence, market participation can play a significant role in reducing food poverty, thus ensuring food security. This suggests that facilitating the expansion of market participation by smallholder farmers can be critical in helping households transition out of food poverty.

Malumfashi and Kwara (2013) examined the impact of agricultural commercialization on food security in Nigeria. The result showed that commercialization enhances food security in the country.

A study done by Justus et al (2015) showed that commercial oriented farmers have more diverse diets than non-commercial oriented ones because they can easily purchase other foods to supplement own production. Commercialization has a robust and positive effect on household food security. It significantly increases household dietary diversity and reduces the number of coping strategies adopted during food shortage.

Ahmed (2017) investigated the potential impacts of commercialization on smallholder farmers' welfare in Bangladesh. The results of the analysis revealed a significant positive relationship between commercialization and household welfare, with key variables like market access and internal farming activities positively and significantly contributing to improved household income and farm outputs. The result further predicted a 16.9% improvement in household welfare if farmers actively work on commercialized farms with better market access and internal farm activities.

Ismael et al (2017) investigate the impact of commercialization on rural households' food security in majorcoffee growing districts of south west Ethiopia, Jimma zone. Commercialization has positive effect on food security level of smallholder farmers. The survey result on the impact of agricultural commercialization on rural household food security found out that agricultural commercialization (Crop output market participation) affect the rural households food security in the study area due to the significance of the crop Commercialization index at 1% probability level in the Logit model used and it has a positive coefficient of showing a positive relationship to food security or likelihood of being food secure which is in line with a previous expectation. This means that the higher the smallholder farmer's commercialization, the higher the probability of being food secure. These specify that those farmers with higher commercialization index are associated with higher agricultural income suggesting the likely positive effects of market participation on farmers' food purchasing power. Other things being constant, the odds ratio in favor of being food secure increase by a factor of 1.114 as commercialization increase by one unit. This result is in agreement with the findings previously.\

2.4. Review of Food Security

During the debates that preceded the World Food Summit (WFS) held in Rome in 1996, it was established that "*There is food security when all people at all times have sufficient physical andeconomic access to safe and nutritious food to meet their dietary needs including food preferences, in order to live a healthy and active life*"(USAID,2008). Food security is a broad and complex concept that is determined by agro physical, socio economic and biological factors (Maxwell and Frankenberger, 1992). According to this definition, food security has three

fundamental elements: food availability, food access and food utilization. Household food insecurity can be distinguished as *chronic and transitory.Chronic (permanent) food insecurity* is a continuously inadequate diet resulting from lack of resources to produce or acquire food, while *transitory food insecurity* is a temporary decline in the household to access enough food (World Bank, 1986).

Many empirical studies have been made in Ethiopia. Ramakrishna and Demeke(2002) made an assessment on food insecurity situation in Ethiopia. Accordingly, cereal production, educational status of the household head, fertilizer consumption, household size, land size, and livestock were found to be the most determining factors of household food security. Along with food availability and entitlement factors, the study suggested that attitudinal variables also influence food insecurity. A study by Felek*eet al*. (2003), technology adoption, farming system, farm size, land quality, household size, off farm income and wealth are considered to be determinants of food security. Kidane*et al* (2005) reported determinants of households' food insecurity that farm land size, ox ownership, fertilizer application, education level of household heads, household size, and per capita production were found to be significant predictors.

Many food security measurement tools have been developed through time so as to measure food security status of individuals, households, regions and nations. Among them, HDDS is of recent formulation in order to measure either individual, households, regions and nations food access scale to diversified diets. The Household Dietary Diversity Score (HDDS) was developed in 2006 as part of the FANTA II project as an indicator of household food access. Household dietary diversity can be described as the number of food groups consumed by a household over a given reference period, and is an important indicator of food security for many reasons. A more diversified household diet is correlated with caloric and protein adequacy, percentage of protein from animal sources, and household income. The HDDS indicator provides a glimpse of a household's ability to access food as well as its socioeconomic status (FANTA, 2006).

One of the strength of HDDS is that the standardized questions are simple and can be easily understood by both enumerators and respondents, and the questions usually take less than 10 minutes per respondent. The standardized questionnaire provided by the 2011 FAO guidelines is not culture or population specific, so it should be adapted appropriately in adherence with the

guidelines before use in a specific context. A drawback of the HDDS is that at the household level, it does not provide information on the adequacy of consumption for specific nutrients, nor does it include foods purchased and consumed outside of the home. In addition, the indicator does not take into account the consumption of fortified foods. Since this indicator uses 24-hour recall, it does not provide an indication of an individual household's habitual diet, but it can provide an assessment of usual diet at the population level (Hoddinott and Yohannes, 2002).

FAO has been a partner in the development, validation and use of food (in) security scales since 2006 and has had an important role in furthering the research on the Latin American and Caribbean Food Security Scale (EscalaLatinoamericana y Caribeña de SeguridadAlimentaria - ELCSA) through financial support for regional conferences on food security measurement and capacity-building in developing countries regarding validation and use of these tools. Because no single instrument measures food (in)security in all its dimensions, there has been substantial research devoted to developing, refining and validating different approaches for measuring the state of food insecurity. The development of measures of whether people are experiencing food insecurity because of limited access to food, and if so at what level of severity, constitutes an important addition to the suite of commonly used food security measures (Ballard, 2013).

Building on the experience of the Latin American scale, the FAO *Voices of the Hungry* project (VOH) has developed an experience-based food insecurity scale module called the Food Insecurity Experience scale (FIES), which is based on a short form of the ELCSA. The FIES will be used as a common metric for measuring food insecurity at several levels of severity, across different geographic areas and cultures. Many efforts are going into the search for global indicators capable of measuring food insecurity in a comparable manner across different parts of the world, as seen by current discussions on indicators for the post-2015 development agenda. The FIES has a potentially important role for monitoring food security within this process. It is particularly well-suited to monitoring systems that meet principles recently identified by the Committee on World Food Security in the 2012 Global Strategic Framework for Food Security and Nutrition (Ballard, 2013).

2.5. Conceptual Framework of the Study

Both adoption of agricultural technology and commercializationareaffected by factors related to producer's characteristics like sex, age, educational status, household size, off farm income and labor availability; ownership of assets like farm land, livestock holding and communication tools such as mobile; and market access and institutional characteristics such as access to credit, union membership, access to extension service and distance to market (Assefa andGezahegn, 2010; Solomon *et al*, 2011;Marteye*t al*, 2012; and Kirui and Njiraini, 2013). Technology adoption tends to increase agricultural productivity, and agricultural productivity influence farmers tendency of market participation or commercialization, and finally, commercialization gives economic power for the farmers to adopt technology (Nega and Senders, 2006; Hailu, 2008; Malumfashi and Kwara, 2013; Ahmed, 2017 and Tigist, 2017).Both increament in agricultural productivity and market participation in turn empower the farming households to buy food as a result improves dietary diversity (Malumfashi and Kwara, 2013; Magrini and Vigani, 2015 and Ismael *et al*, 2017).The details of each schematic description are presented in figure 1.

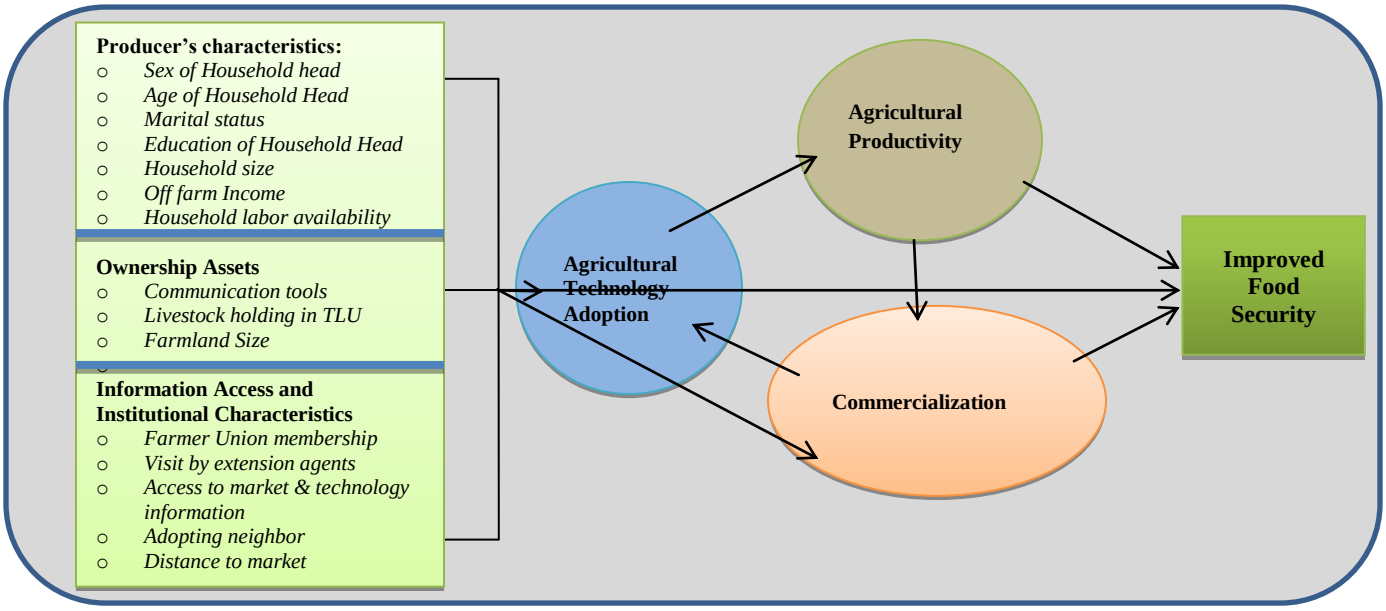

Figure1. Conceptual framework of the study.

3. DESCRIPTION OF THE STUDY AREA AND THE RESEARCH METHODS

3.1. Description of the Study Area

3.1.1. Demography and location

The study area, Boricha*woreda*, is located in Sidama zone about 30 km southwest of Hawassa, the capital of Southern Nation, Nationality, and People Regional State (SNNPR). Boricha is located between 6° 52' 10.63" N longitude and 38° 13' 17.15" E latitude (Ethio-GIS, 2017). The *Woreda* is divided into 39 rural and 4 city *kebele* administrations. The total population of the *Woreda* is 250,260; of which 125,524 are males and 124,736 are females. And also the total population in terms of household heads is 52, 384; of them 26,102 are male household heads and 26,282are female households(CSA, 2015; BANRD, 2016).

3.1.2. Agriculture in the wereda

The total area of land which is used for cultivation is 32,215 hectare out of which 20,638 hectare is used for annual crop and 11,577 hectare is utilized for perennial crops. The total area of range land is 3,231 hectare. The larger portion is conducive for agricultural activities with 77 percent of plain land topography. The climatic and ecological condition is dry temperate being 78 percent of woreda coverage.

The type of agriculture within the community is mixed-farming, i.e. animal raring and growing of different crops such as perennial and annual. Perennial plants are coffee, enset, banana, avocado, pumpkins, etc. Annual crops are maize, barely, sorghum, wheat, haricot bean, broad bean, potato, sweet potato, teff, etc.“Enset” is the dominant perennial stable food of the community which serves as food and fodder to animals. It is also drought resistant and has water retention capacity, especially local variety which is called “medicha”. Among annual crops maize is a stable crop used for home consumption and cash crop. On average, each individual farmer owns 0.5ha of cultivable land for production (ERCS, 2008).

Most of the community uses traditional farm tools such as oxen; spade and “Sharika” to plough their lands. The uses of these farm implements make the community poor in harvesting production. As a result of this, the productivity and production remains low. In addition to

growing of crops, the community of the area also engaged in raring of animals such as cattle, goats and sheep, equines and hens which have economic and social values (ERCS, 2008).

According to the woreda Agriculture and Rural Office, the area has two crop seasons, "Belg" and "Meher". The "Belg" stays from mid-February to May which accounts 80percent of the total production of the area. Moreover, time of sowing begins from mid-Februaryto mid-April. In addition to this, the "Meher" season is also the second crop period which accounts 20percent of the total production of the woreda. In Belg season, the period of land preparation ranges between January and March; and sowing period ranges between March and April. In ''meher'' season, preparation of land starts in June and stays up to August while sowing period ranges between July and August. The weeding period of ''Belg'' season lies on the month of March, April and May andharvesting time of "belg" ranges between the month of October and November. On the other hand, the weeding time of the ''meher'' season lies between the month of August and September, and the harvesting time is between the month of November and December.

3.1.3. Food security situation of the wereda

Food shortage continuously occurs in the woreda due to shortage and erratic distributionof rain fall, and lack of farming land which is caused by an ever increasing number ofpopulation sizes. In addition to this, inability of the society to use the improvedtechnologies is also cited as the causes of food shortage. Traditional and backwardfarming system of the community has contributed to the problem of getting enough food (ERCS, 2008).

According to the Bureau of the agriculture and rural development (BANRD) (2016), only 20 percent of the community utilizes improved seeds and fertilizers. On the other hand, most members of the community do not possess oxen to plough with. A pair "Timad" of oxen serves for more than ten farmers. This shows people have faced shortage of farm tools. Due to this reason, time of sowing elapses. Besides, unwise consumption of what they have harvested and selling of their product with a very low price is the additional reason for the food shortage.

Even selling of livestock (bulls and huffers) is common with those who are under safety net packages. Shortage of rain fall at the time of flowering of maize, dependency of most productive age groups on few workers e.g. youths, ever increasing price of food, occurrence of African army worm, death of livestock by black leg diseases are also seen as the major reasons for food

shortage.‘’Temch’’ has repeatedly destroyed the maize belt as a result of this, the total production has been reduced by 20 percent. There is also maize dry crop disease which dried the entire crop at early stage. The production of ‘’enset’’ has been decreased from time to time as a result of drought (ERCS, 2008).

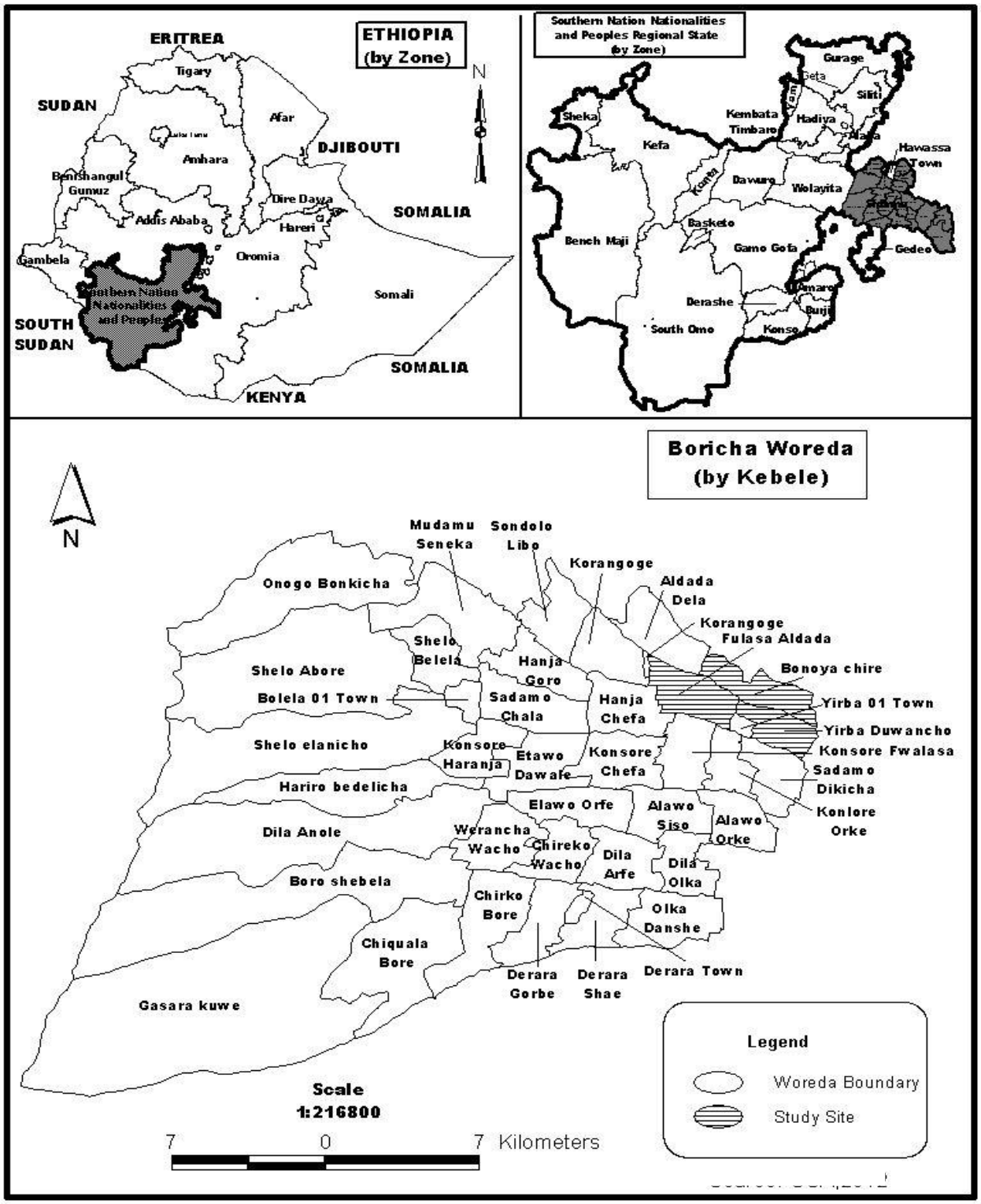

Figure 2: Map of study area in Sidama Zone (Source: Ethio-GIS 2017)

3.2. Research Design, Data Sources and Process

The research design of this research washousehold-based cross sectional research and the research approach will be quantitative**.**

3.3. Data types and sources

Both primary and secondary data wasused for this study. Primary data was collected using household survey. Secondary information from published and unpublished documents and reports from relevant organization was gathered and incorporated with the primary data.

3.4. Sampling technique

Multi-stage sampling procedure was used in the selection of representative samples. In the first stage,households who engage in farming activities in Borichawereda, Sidama zone were selected purposively based on prevalence of food insecurity (Zeleke*et al*, 2016) and availability of agricultural technology (BANRD, 2016) in the *wereda.* In the second stage, out of 39 rural *kebeles* under BorichaWereda, randomlythree*kebeles*were selected for this study based on simple random sampling technique. Finally, sample households who engage in farming among the three kebeleswere selected based on simple random sampling technique. The number of sample households was determined following Yamane (1967). Proportionate sample size of households in Boricha*wereda* is presented in Table 1. It was based on requiring estimation of tolerable error margin at 0.055 allowing 95% confidence level. Hence, the formula is stated below.

$$n = \frac{N}{1 + N(e^2)}$$

Where n is the minimum number of sample size within the range of acceptable error margin, *N* is the total number of household heads in the*wereda*, and $e$acceptable error margin (0.055).

$$n = \frac{52{,}384}{1 + 52{,}384(0.055^2)} \approx 329$$

*Note:*The calculated minimum sample size of households is approximately 329. Due to extra collected questionnaire at hand, and considering importance of their usage as long as it doesn't lower from the standard, five more data were used.

Table 1: proportionate sample size of households in Borichawereda

Kebeles	Sampling population size	Percentage of samples	Sample HH
BonoyaChire	12,168	42	140
FulfulaAldada	9,094	32	107
YirbaDuwancho	7,515	26	87
Total	**28,777**	**100**	**334**

Source: own computation result

3.5. Tools of Data Collection

Questionnaire: Close-ended questionnairewas used to gather information about producer's characteristics, technology adoption characteristics, ownership of assets and market access and institutional characteristics. The questionnaire was compiled by using information derived from measurements that have also been applied by other researchers, and from key informant interview carried out by the researcher. HDDS and HFIES questionnairewas used to collect information about household dietary habit and food insecurity experience, respectively.

*Key informant interview:*It was performed with government extension officials of Boricha*Weredat*o gather on ground information apart from literature support. This helped to collect more information from some key informants on pertinent issues, such as technology, crop production, commercialization and food security issues, and that was used for closed-ended questionnaire compilation (Justus, 2015).

3.6. Techniques of Data Analysis

Both descriptive and econometric analysis was employed to examine factors affecting agricultural technology adoption, commercialization, household dietary diversity and food insecurity experience of rural households, and also to identify impact of agricultural technology adoption on the level of productivity, commercialization and food security status of rural households. STATA 13 was used to analyze the overall statistical data.

3.6.1. Descriptive statistics

Descriptive statistics such as means, percentile and frequency distributions was employed to characterize sample responds in terms of technology adoption status. Moreover, t-test and chi-square statics was used to differentiate between adopter and non-adopter specific characteristics. Household dietary diversity status was identified by using Household Dietary Diversity Score

(HDDS). Household status of food insecurity was identified by household food insecurity experience scale (HFIES)

T-test statistics

Both demographic and socio-economic variables which are continues in nature like age, family size, educational status, labor availability, livestock holding, farmland size, and so on were tested by t-test statistics. Equation to compute t-test statistic is a follows (Hamilton, 2013). Where $\overline{x_1}$ and $\overline{x_2}$ are mean of the samples;μ_1 and $\mu_2$are mean of the population;σ_1^2 and $\sigma_2^2$are variance of sample distribution;n_1 and $n_2$are number of observation of the two sample; and d_f =(n_1-n_2)-2 is degree of freedom for t-statistic

$$t = \frac{(\overline{x_1}-\overline{x_2})-(\mu_1-\mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1}+\frac{\sigma_2^2}{n_2}}} \quad (1)$$

Chi-square test

The remaining demographic and socio-economic dummy and categorical variables like sex, off-farm income, adoption, having mobile phone and so onwere tested by chi-square statistics. The formula to calculate chi-square test as follows (McDonald, 2014). Where (*O*), observed number and (*E*), expected number.

$$X^2 = \sum \frac{(O-E)^2}{E} \quad (1)$$

Level of commercialization

This paper employed the household commercialization index (HCI) with modification to determine household specific level of commercialization (Strasberg et al., 1999). The index measures the ratio of the gross value of crop sales by household *i* in year *j* to the gross value of all crops produced by the same household *i* in the same year *j* expressed as a percentage:

$$HCI = \frac{Gross\ amount\ of crop\ markated\ in\ previous\ year}{Gross\ amount\ of\ crop\ prodeced\ in\ previous\ year}\ x\ 100 \quad (1)$$

Productivity

In order to measure productivity, a formula of harvested crop yield per hectare forwarded by Diskin (1999) was adopted.

$$productivity = \frac{crop\ output(kilogram)}{area\ planted(hectare)} \quad (1)$$

Household Dietary Diversity Score (HDDS)

Data for the HDDS indicator were collected by asking the respondent a series of yes or no questions concerning the food groups consumed by household members. The question format is presented in the Annex 2 (Swindale and Bilinsky, 2006). The formula to calculate HDDS is as follows;

$$\text{HDDS}\ (0-12) = \text{Sum}\ (\text{A} + \text{B} + \text{C} + \text{D} + \text{E} + \text{F} + \text{G} + \text{H} + \text{I} + \text{J} + \text{K} + \text{L}) \quad (1)$$

Table 2: Distribution of food group in their level of dietary diversity

Level of HDDS	**Range of food groups**
High HDDS	> 6
Medium HDDS	$4 \leq x \leq 6$
Low HDDS	< 4

(2)

Source: Adopted from Swindale and Bilinsky(2006) and Agada (2015)

Household Food Insecurity Experience (HFIES)

Data for HFIES indicator was collected by asking a series of eight yes or no questions about household's experience of food insecurity because of lack of money or other resources. The completed format is presented in the Annex 2 (Ballared et al, 2013).

3.6.2. Econometric model

Agricultural technology adoption status of householdsis defined as application of varies technology, particularly for the case of Borichawereda it implies improved seeds and fertilizer, in order to enhance productivity. Adoption status is a dummy variable that value 1 signified adopters while 0 representednon-adopters.

Propensity Score Matching (PSM)

The technology adopters were matched on the basis of probability, or propensity score, to non-adopters. The propensity is defined as the conditional probability of receiving the treatment given the pre-treatment variables (Rosenbaum and Rubin, 1983; Heckman, 1997). Let D_i denote a dummy variable such that *D* equals 1 if household *i* adopts technology and 0 otherwise, the propensity score can be defined as;

$$P(X) = \Pr(Di = 1/X) = E(Di/X) \quad (1)$$

The logit model was employed to estimate propensity scores. Gujarati (1995) stated that the logit model estimates the probability of the dependent variable to be 1. The specification of the logit model in this study is specified as:

$$P\left(Di = \frac{1}{X}\right) = P(adoption\ status) = X'\beta + \mathcal{E} \quad (2)$$

Where *i* is number of observation, *P(Di)* is the probability that the household adopts a technology, *X'* is explanatory variables indicating demographic and socio-economic attributes of households, β is a vector of logit index (coefficient), and $\mathcal{E}$ is the stochastic (error or disturbance) term.

ATT is the difference between the outcome variables of being treated and its counter factual (outcome variables such as productivity, commercialization, households level of dietary diversity and level of food insecurity). The average treatment effect on the treated (ATT) is given as;

$$ATT = E(Y1/D=1) - E(Y0/D=1) \quad (3)$$

Where E (Y1/D=1) is the adopters before they adopt technologies and it is reasonably be approximated by the output level of non-adopters during data collection. E (Yo/D=0) = is a counter factual and is not observed E is mathematical expectation operator. D is dummy variable that takes the value 1 if the individual is treated 0 otherwise. Now, the outcome of treated and non- treated individuals might differ leading to selection bias. To clarify the mean outcome of a program, we can further specify ATT as:

$$ATT = \{E[Y1/D = 1] - E[Y0/D = 0]\} - \{E[Y0/D = 1] - E[Y0/D = 0]\} \quad (4)$$

Where; E[Y1/D=1]-E[Y0/D=0] is the selection bias which will be equal to zero if the program was given randomly and at the event where adopter and non-adopters did not differ before the program implementation. The validity of the result of the PSM method depends on the satisfactions.

The two assumptions are: Conditional Independence Assumption (CIA): meaning outcomes of the adopters and non-adopters are independent of the treatment status or after controlling for observable characteristics. The treatment assignment is "as good as random", and Common support condition (CSC): Entails the existence of sufficient overlap in the characteristics of the treated and untreated units to find adequate matches (common support). Several matching methods have been developed to match adopters with non-adopters of similar propensity scores. Asymptotically, all matching methods should yield the same results. However, in practice, there are trade-offs in terms of bias and efficiency with each method (Caliendo, 2008). Here, nearest neighbour matching (NNM) was used. The basic approach is to numerically search for "neighbours" of non-adopters that had a propensity score that is very close to the propensity score of the adopters(Caliendo, 2008).

Multinomial logistic regression model

The multinomial logistic regression model is the most widely used multivariate approach to study the dynamics (Baulch, 2011). The content of this section draws extensively in Greene (2003).

The multinomial logistic regression model is defined as follows:

$$pji = \frac{e^{x_j^{!}\beta_j}}{\sum_{j=1}^{m} e^{x_j^{!}\beta_j}} \qquad j=1, \ldots, m \qquad (1)$$

Results 1, 2, 3... *m* are supposed for *y* and the explanatory variables are defined as *X*. It is also assumed that there are m = 3 results, which are unordered. This property of thecategorical variable *y* is typical of multinomial regressions.

In the multinomial logistic regression model, a set of coefficients $\beta^1, \beta^2, and\ \beta^3$ are estimated, corresponding to each result the following probabilities for each case of the value of the dependent variable (adoption and commercialization status at the same time):

$$pr(y = 1) = \frac{e^{\beta(1)}}{e^{\beta(1)} + e^{\beta(2)} + e^{\beta(3)}} \quad (2)$$

$$pr(y = 1) = \frac{e^{\beta(2)}}{e^{\beta(1)} + e^{\beta(2)} + e^{\beta(3)}} \quad (3)$$

$$pr(y = 1) = \frac{e^{\beta(3)}}{e^{\beta(1)} + e^{\beta(2)} + e^{\beta(3)}} \quad (4)$$

This model is indeterminate in the sense that there exists more than one solution for $\beta^1, \beta^2, and\ \beta^3$ which lead to the same probability for *y*=1, *y*=2 y *y*=3. If a value of 0 is assigned to β^1 , the remaining coefficients β^2 and β^3 will measure the relative change for *y*=1. On the other hand, if $\beta^2 = 0$, the remaining coefficients β^1 and β^3 will measure the relative change for *y* = 2. The coefficients may differ because they have different interpretations, but the odds of *y* = 1, 2 and 3 are the same.

Assuming$\beta^1 = 0$, the equations are as follows:

$$pr(y = 1) = \frac{1}{1 + e^{\beta(2)} + e^{\beta(3)}} \quad (5)$$

$$pr(y = 1) = \frac{e^{\beta(2)}}{1 + e^{\beta(2)} + e^{\beta(3)}} \quad (6)$$

$$pr(y = 1) = \frac{e^{\beta(3)}}{1 + e^{\beta(2)} + e^{\beta(3)}} \quad (7)$$

The relative probability (relative risk) of y = 2 relative to the base category is:

$$\frac{pr(y=1)}{pr(y=2)} = e^{x\,\beta(2)} \quad (8)$$

Assuming that *X* and $\beta_k^{(2)}$ are vectors equal to $x_1, x_2, \ldots, x_k$, and $\beta_1^{(2)}, \beta_2^{(2)}, \ldots, \beta_k^{(2)}$ the relative risk ratio for change of one unit in x_1 is:

$$\frac{e^{\beta_1^{(2)} x_1 + \cdots + \beta_i^{(2)}(x_i + 1) + \cdots + \beta_k^{(2)} x_k}}{e^{\beta_1^{(2)} x_1 + \cdots + \beta_i^{(2)}(x_i) + \cdots + \beta_k^{(2)} x_k}} = e_i^{\beta(2)} \quad (9)$$

Then the exponential value of a coefficient is the rate of relative risk explained by the change of one unit over some variable in particular.

According to Cameron and Trivedi (2005), care must be taken in the interpretation of the parameters of any nonlinear model, particularly for multinomial models where there is not necessarily a one to one correspondence between the sign and the probability of the coefficient. A positive coefficient means that if the independent variable increases the probability of choosing or falling into one of the categories increases.

$$\frac{dp_{ij}}{dx_{rik}} = \begin{cases} p_{ij}(1 - p_{ij})\beta_r & j = k \\ -p_{ij}p_{tk}\beta_r & j \neq k \end{cases} \qquad (10)$$

According to Escobar et al. (2010), the interpretation of the coefficients of the multinomial logistic regression model is not immediate, but we must resort to the transformation of these coefficients in odd ratios or in probabilities. In the case of the multinomial logistic regression model, the interpretation is further complicated by not having a single model, but as many models as the number of categories of the dependent variable minus one.

Ordered Logit Regression Model

Ordered logit regression model was used to econometrically identify demographic and socio-economic factors affecting household level of dietary diversity and food insecurity. The model is applied to perform analysis of ordinal and categorical variables (Long &Freese, 2003). This model was selected because, the two dependent variables are categorical and ordinal in nature as a result they fit to the model.

Suppose that Y is an ordinal dependent variable with *(c)* categories, and $pr(y \leq j)$ denotes the probability that the response on *(Y)* falls in category *(j)* or below (i.e., in category 1, 2… or j). This is called a cumulative probability. It equals the sum of the probabilities in category j and below:

$$pr(y \leq j) = pr(y = 1) + (pr(y = 2) + \cdots pr(y = j) \qquad (1)$$

A category*(c)* and dependent *(Y)* variable" has cumulative probabilities *(c):*$pr(y \leq 1)$, $pr(y \leq 2)$, …, $pr(y \leq c)$. The final cumulative probability uses the entire scale; as a consequence, therefore, $pr(y \leq c) = 1$. The order of forming the final cumulative probabilities reflects the ordering of the dependent variable scale, and those probabilities themselves satisfy:

$$pr(y \leq 1) \leq pr(y = 2) \leq \cdots \leq pr(y \leq c) = 1 \quad (2)$$

In an ordered logit model, an underlying probability score for an observation of being in the ith response category is estimated as a linear function of the independent variables and a set of cut points. The probability of observing response category i corresponds to the probability that the estimated linear function, plus random error, is within the range of the cut points estimated for that response.

$$pr(Response\ category\ for\ the\ j^{th}\ outcome = i) = pr(k_{i-1}) < b_1x_{1j} + b_2x_{2j} + b_kx_{kj} + u_j \leq k_j \quad (3)$$

It is necessary to estimate the coefficients$b_1, b_2, \ldots b_k$, along with cut points$k_1, k_2, \ldots, k_{i-1}$, where *(i)* is the number of possible response categories of the dependent variable. The coefficients and cut points are estimated using maximum likelihood.

Tobit Regression Model

An econometric model known as Tobit model was used to empirically identify the determinants of commercialization status of farming households. This model is also recognized as censored regression model in the sense that a sample in which information on the regressand (dependent variable) is censored. The Tobit model was selected because commercialization, which is the dependent variable, is continuous and censored. The value of the dependent variable ranges between 0 and 1. This made it a more appropriate econometric model for this paper (Maddala, 1983; Gujarati, 2004). The structural equation of the Tobit model is given as:

$$Y^* = X_i\beta' + \varepsilon_i \quad (1)$$

e ~ N [0,s]

Denoting Y_i as the observed dependent (censored) variable

$$Y_i = \begin{Bmatrix} LifY^* \leq L \\ Y^* = X\beta + \varepsilon_i ifL < Y^* < U \\ UifY^* \geq U \end{Bmatrix} \quad (3)$$

Where:

Y_i = the observed dependent variable, in our case commercialization

Y_i^*= the latent variable (unobserved for values smaller than 0 and greater than 1)

X_i = is a vector of independent variables postulated to influence commercialization.

β_i = are parameters associated with the independent variables to be estimated.

ε_i= Residuals that are independently and identically normally distributed with mean zero and a common variance.

i= 1, 2,…n (n is the number of observations).

L = lower limit

U = upper limit

3.6.3. Definition of Variables and Hypotheses

Based on the reviewed literatures, some of the common predictors that are expected to influence technology adoption status of households in the study area are presented in table below.

Table 3.A summary of explanatory variables, their measurement and expected sign.

Description of Variables	Measurement	Expected Sign on Adoption
Age of Household Head	Years	+
Household size	Number of families in the HH	-
Sex of Household head	Dummy,1=male,0 = female	+
Marital status	Dummy, 1=married, 0=otherwise	+
Education of Household Head	Level in number	+
Partners education status	Level in number	+
Maximum education status	Level in number	+
Off farm Income	Dummy,1=yes,0 = no	+
Household labor availability	In number (age <14, b/n 14&65, >65)	+
Technology Adoption	Dummy,1=adopters,0 = non-adopters	+
Adoption by neighbor	Dummy,1=yes,0 = no	+
Access to technology information	Dummy,1=yes,0 = no	+
Mobile usage	Dummy,1=yes, 0= no	+
Livestock holding	TLU	+
Farmland Size	Hectare	+
Annual farm output	Kilograms	+
Union membership	Dummy,1=yes,0 = no	+
Access to Extension Service	Number of contacts/year	+
Annual Market output	Kilograms	+
Market information	Dummy,1=yes,0 = no	+
Distance to market	Kilometers	-
Access to vehicular road	Dummy,1=yes,0 = no	+

Source: self-formulated based on extensive review and key informant interview

4. RESULT AND DISCUSSION

This chapter discusses both results of descriptive and econometric analysis. Under descriptive analysis, household head characteristics, technology adoption, commercialization and food security related variables were scrutinized by either t-test or chi-square. And econometric analysis was carried out using mlogit, ologit, tobit and propensity score matching (PSM).

4.5. Descriptive results

Out of the total of 334 respondents, 66% of them adopt agricultural technology while 34% of do not.

4.5.1. T-test distribution of household heads in terms of adoption status

Demographic and socio- economic characteristics of both adopters and non-adopters have been examined. The result revealed that no significance difference in the mean age, education level, maximum education attained in the household, family size and visit paid by the agricultural extension workers (Table 4).

The average age of the sampled household heads was 41.9 years with the minimum and maximum ages of 22 and 80 years, respectively and also, average age distribution of adopters and non-adopters were 41.7 and 42.3 years, respectively, with no statistically significant difference between them. This was further elaborated using three age clusters. The average number of members whose age less than 14, between 14 and 65 and greater than 65 was 1.7, 3.7 and 1.1, respectively. The majority is found in the cluster whose age is between 14 and 65. Based on the result mean of members whose age less than 14 and between 14 and 65 show statistical difference at 5% significant level. This indicates that families having household members whose age less than 65 years tends to adopt agricultural technology.

The result shows that the average education status of the sampled household heads was 4.2 with minimum and maximum education level of 0 and Diploma, respectively. Average education status of adopters and non-adopters were 4.4 and 3.9, respectively with no statistically significant difference. Similar to this, no significant difference was identified by maximum education status of household members. The average maximum education was found to be 7.4 with minimum and maximum level of 0 and BSc degree, respectively. This average between adopters and non-adopters were 7.6 and 7, respectively.

Apart from the above mentioned results, education status of the partner showed statistical difference between adopters and non-adopters at 5% significant level. The average education status of the partner among the respondents was 3 with minimum and maximum education level of 0 and Diploma, respectively, while the average level between adopters and non-adopters were 3.3 and 2.6, respectively. This implies that having educated marriage partner helps to increase the willingness to adopt agricultural technology.

The average family size of sample respondents was 5.5 with the minimum and maximum size of 2 and 10, respectively and also, average household size distribution of adopters and non-adopters were 5.4 and 5.6, respectively. Though, family size of non-adopters is greater than adopters, there is no statistically significant difference in their mean.

The result on the table shows the average livestock holdings of sample respondents was 1.4 with the minimum and maximum size of 0 and 5.5 TLU, respectively at 1% significant level. This implies livestock possession has significant impact on technology adoption. And also, average household livestock holdings distribution of adopters and non-adopters were 1.6 and 1.2, respectively. Households that adopt technology tend to have livestock holdings higher than non-adopters.

The average total farm income of sample respondents was 2350.2 birr with the minimum and maximum size of 0 and 13,800 birr, with no significant difference in their mean. Furthermore, average of household total farm income distribution of adopters and non-adopters were 2505.1 and 2055.3 birr, respectively. The average annual cash crop income of sample respondents was 1948.3 birr with the minimum and maximum size of 0 and 13,000 birr, with no significant difference in their mean. Furthermore, average of household total farm income distribution of adopters and non-adopters were 1923.9 and 1993.1 birr, respectively.

The result further indicated that farmland size shows statistical difference in terms technology adoption at 1% significant level. The average household farm land size of sample respondents was 0.5 with the minimum and maximum size of 007 and 2 hectare, respectively. The average household farm size distribution of adopters and non-adopters were 0.52 and 0.39, respectively. This implies that households who adopt technology tend to have higher firm size than their counter part.

Agricultural technology adoption has its own impact on productivity, commercialization and food security status of households. Table 2 indicated that there are mean differences on productivity and commercialization between agricultural technology adopters and non- adopters. In both situation, the adopters have higher figures implying that agricultural technology enable farmers to produce more and tend to engage in higher degree of commercialization. The average household farm productivity of adopters and non-adopters were 1137.1 kg/ha and 304.4 kg/ha, respectively. Their difference is really big. In the meantime, the average household's level of commercialization of adopters and non-adopters were 0.19 and 0.04, respectively. The average sum of HDDS was 6.7 with the minimum and maximum size of 3 and 11. The average sum of HDDS for adoptersand non-adopterswere 6.9 and 6.3 respectively, with significant difference in their mean at 1% significant level. The result shows that adopters consume more diversified diet that non-adopters.

The average number of visits paid by DAs was 4.7 times with the minimum and maximum size of 0 and 52 times per year, respectively. The average number of visits for adopters and non-adopters were 4.6 and 4.9 times per year respectively, with no significant difference in their mean.

Vicinity to market enabled farmers to adopt agricultural technology. This is evidenced by the fact that adopters on average are 4.9 km away from the nearest market center while the figure for non-adopters goes as high as 6.7 and their differences is significant at 1%. The interesting result of the analysis is that those households which have higher land size tend to adopt agricultural technology. Meanwhile, those households which have higher livestock have less affinity to agricultural technology adoption. This is basically linked to the fact that those who have higher livestock tend to spend much of their time on livestock production than agricultural production (Table 4). The average number of visits paid for adopters and non-adopters were 4.6 and 4.9 times per year respectively, with no significant difference in their mean.

The average sum of HDDS was 6.7 with the minimum and maximum size of 3 and 11. The average sum of HDDS for adopters and non-adopters were 6.9 and 6.3 respectively, with significant difference in their mean at 1% significant level. The result shows that adopters consume more diversified diet that non-adopters.

Table 4: T-test distribution of variables by technology adoption status

Variables	Mean (Adopters)	Mean (Non-adopters)	T-value
Age of HH	41.703	42.260	0.673
Household member age less than 14	1.817	1.522	0.018**
Household member age between14 and 65	3.511	3.991	0.015**
Household member age greater than 65	0.069	0.078	0.744
Education status of HH	4.429	3.887	0.142
Partner education status	3.343	2.583	0.043**
Maximum education status	7.603	7.009	0.102
Family size	5.397	5.591	0.351
Livestock holding (TLU)	1.586	1.164	0.000***
Farm size	0.517	0.388	0.001***
Productivity	1137.074	304.393	0.000***
Commercialization	0.191	0.040	0.000***
Visit paid by DAs	4.626	4.930	0.829
Nearest market distance	4.785	6.658	0.004***
Sum of HDDS	6.845	6.296	0.000***

*Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level
Source: Authors' estimates based on 2018 survey

The study further carried out chi square tests for dummy and scale variables in a bid to substantiate possible difference between adopters and non-adopters.

4.5.2. Chi-square distribution of household heads in terms of adoption status

The sample composed of both male and female household heads. Out of 334 sample household heads, female and male household heads take 11.98% and 88.02%. The majority of households in the sample are headed by males. Among female headed households, 30% and 70% are adopters and non-adopters of agricultural technology, respectively, while 70.41% and 29.59% were adopters and non-adopters, respectively. The result shows significant difference between the two discrete variables in terms of sex at 1% significant level. It implies that adopters are dominated by male household heads.

Based on the marital status report of Table 5, out of the total household heads single, married and widows comprise of 1.5%, 85.33% and 13.17%. The majority of household heads in the in the sample are headed by married couples followed by widows and singles. All singles were adopters. About 68.42% and 31.58% of married household heads were adopters and non-adopters, respectively. And also, about 43.18% and 56.82% of widow household heads were adopters and non-adopters, respectively. Statistical difference between adopters and non-

adopters was observed in terms of marital status at 1% significant level. The result infers that adopters are dominated by single household heads, followed by marrieds and widows.

Of the total sample of household heads, 67.66% fetched off farm income, while 32.34% did not have off farm income and the result is significant at 1%. Most of the respondents engage in off farm activities to earn money. Among those who have off farm income, 75.93% and 24.07% were found to be adopters and non-adopters, respectively. About 60.62% and 39.38% of those who confirmed having no off farm income were found to be adopters and non-adopters, respectively. This shows that adopters fetched were more off farm income than non-adopters.

Household heads who have neighbors adopting technology and those who do not take 64.37% and 35.63% of the total respondents, respectively. About 80.93% and 19.07% of households with technology adopting neighbors were found to be adopters and non-adopters, respectively. While 37.82% and 62.18% of households with neighbors who do not adopt technology was found to be adopters and non-adopters, respectively. This shows that having neighbors who adopt technology urges households to adopt agricultural technology.

Information about new technology is one variable used to explain technology adoption. About 75.15% and 24.85% of respondents were those who have information about new agricultural technology and those who do not, respectively. Many of the respondents have information about agricultural technologies in their community. Among those who have information about any new agricultural technology, 81.67% and 18.33% were adopters and non-adopters, respectively, while 16.87% and 83.13% of those who do not have information were adopters and non-adopters. The result indicates that there is significant difference between the two groups adoption status in terms of new technology information at 1% significant level. This shows that adopters were dominated by household heads that have information about new agricultural technology in their local community.

Mobile phone distribution among sample respondents seams fair that about 56.59% of household heads have cell phone. Among the total respondents who have mobile phone, 74.04% and 25.93% were adopters and non-adopters, respectively. And also about 54.48% and 45.52% of those who do not have mobile phone were adopters and non-adopters. The result indicates significant difference in terms of adoption status at 1% significant level. This shows adopters were dominated by household heads with mobile phone.

Farmers' union membership is also another factor under consideration. Among the total respondents, only 6.89% were found to have union membership, and the rest 93.11% do not. Therefore, the majority do not have union membership. About 82.61% and 17.39% of those who have union membership were adopters and non-adopters, respectively. And also, about 64.31% and 35.69% of those who do not have membership were adopters and non-adopters, respectively. The result indicates significant difference in terms of adoption status at 10% significant level. This shows adopters were dominated by household heads with union membership.

Table 5: Chi-square distribution of variables by technology adoption status

Variables	Categories	% of Sample proportion	Percentage distribution		Chi-square
			Adopters	**Non-adopters**	
Sex of HH	Female	11.98	30.00	70.00	0.000***
	Male	88.02	70.41	29.59	
Marital status of HH	Single	1.50	100.00	0.00	0.001***
	Married	85.33	68.42	31.58	
	Widow	13.17	43.18	56.82	
Off farm income	No	67.66	60.62	39.38	0.006***
	Yes	32.34	75.93	24.07	
Neighbor adoption	No	35.63	37.82	62.18	0.000***
	yes	64.37	80.93	19.07	
Technology information	No	24.85	16.87	83.13	0.000***
	Yes	75.15	81.67	18.33	
Mobile phone	No	43.41	54.48	45.52	0.000***
	Yes	56.59	74.07	25.93	
Market information	No	26.65	35.96	64.04	0.000***
	Yes	73.35	76.33	23.67	
Union membership	No	93.11	64.31	35.69	0.075*
	Yes	6.89	82.61	17.39	
Vehicular road	No	15.27	11.76	88.24	0.000***
	Yes	84.73	75.27	24.73	

Source: Field survey 2018

*Note: ** and *** indicate the level of significance at 1and 10 percent, respectively.*

4.5.3. Chi-square distribution of household dietary diversity and food insecurity experience in terms of adoption status

Out of the total number of respondents who adopt agricultural technology (Figure 3), 91.4%, 7.3% and 0.9% were found to consume high, medium and low diversity food, respectively, while 47.7%, 31.4% and 15.5% were food to be severely, moderately and mildly food insecure households, respectively. On other hand, out of the total sample respondents who did not adopt agricultural technology, 71.9%, 21.05% and 7.9% were found to consume high, medium and low diversity food, respectively, while 50%, 33.3% and 4.4% were food to be severely, moderately and mildly food insecure households, respectively. According to this result, adoption is related with high diversity diet and minimal food insecurity experience. Therefore, one can infer that technology adoption can be taken as effective tool to ensure household food security.

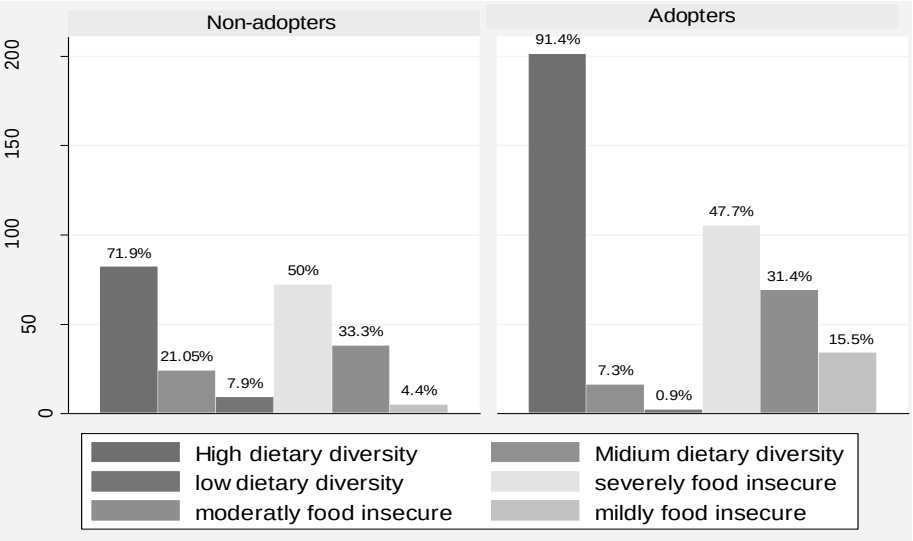

Figure 3: chi-square distribution of household dietary diversity and food insecurity experience in terms of adoption status (Source: survey result of 2018)

4.6. Econometrics result

4.6.1. Estimating determinants of technology adoption

In order to compute propensity score, logit model has been used. The likelihoodratio of the model which is $chi^2(13) = 107.23$, $Prob > chi^2 = 0.0000$ and Pseudo $R^2 = 0.3363$shows that the independent variables included in the model have been adequately estimated the propensity scores. In addition to this, goodness-of-fit test were carried out to identify determining factors of households' estimated probability of adopting farm yield enhancing technology, and to examine whether the model fit to this type of regression or not, respectively. The result shows that the pearson chi^2 (314) = 325, and Prob> chi^2 =0.7015. This signifies that the model is found to be to carry out the regression analysis.

Table 6: Factors affecting technology adoption

Treated	Coef.	Std. Err.	z
Sex of HH	20.206	2499.426	0.01
Age of HH	-0.005	0.017	-0.29
Education status of HH	-0.088	0.059	-1.49
Family size	-0.284	0.109	-2.62***
Marital status	-19.219	2499.426	-0.01
Off farm income	0.242	0.367	0.66
Adoption by neighbor	1.229	0.351	3.50***
Technology information	3.225	0.426	7.57 ***
Mobile usage	1.057	0.364	2.91***
Livestock holding	0.665	0.227	2.93***
Farm size	1.7	0.724	2.35*
Union membership	0.668	0.668	1.00
Visit by DA	-0.020	0.014	-1.48

*Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level
Source: Authors' estimates based on 2018 survey

The result of logistic regression shows that the probability of a farming household being technology adopter was negatively related to family size at 1% significant level, and positively related to attributes like neighbor's adoption status, technology information, mobile usage and livestock holding at 1% significant level, and with farm land size at 10% significant level.

The above table indicated that a unit increase in neighbor's adoption status, technology information, mobile usage, livestock holding and farm size, increase the probability of adopting technology compared to non-adopters by 1.23, 3.23, 1.06, 0.67 and 1.7, respectively. Unit increment in family size, de-escalate the probability of household technology adoption by 0.28. Based on comparative analysis of this result, probability of adopting technology can be intensified by assimilating enough awareness about the new technology since technology information takes the biggest role in this regard.

Many studies have reported a positive relation between information and adoption of agricultural technology (Bonabana- Wabbi, 2002; Mignouna*et al*, 2011). It enables farmers to learn the existence as well as the effective use of technology and this facilitates its adoption. Farmers will only adopt the technology if they are aware of or have heard about it. Access to information reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time. This information can be found from institutes or from a neighbor that adopt technology. Even more, having mobile phone might help at the process of being informed about what is going on around relatives and in institutions concerning farming activities. It enables farmers to learn the existence as well as the effective use of technology and this facilitates its adoption. Bonabana- Wabbi (2002) showed thatfarmers might only adopt the technology they are aware of or have heard about it , as a result it reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time.

In conformity with this finding, Hiwot et al (2016) stated that size of livestock owned measured in TLU will increase the probability of adoption of improved groundnut seed, inorganic fertilizer, and organic fertilizer in eastern Ethiopia by 0.14. Aman (2014) related the reason with livestock providing manures as main compost used by farmers for crop production in rural areas as a result increase in the number of livestock owned would improve the crops productivity and hence increases the marketable surpluses.

Farm size was one of the attributes where significant impact on technology adoption exhibited. In support of this finding, many previous studies reported a positive relationship between extent of farm size and technology adoption. According to Uaiene et al. (2009), farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new

technology unlike those with less farm size. Another study by Obsisan (2015) a unit increases in cultivated land was reported to increase adoption level of improved production technology by 0.6345. The reason being land is a base for any economic activity especially in rural and agricultural sector.

Family size the only factor, in this study, that affected technology adoption negatively that a unit increment in the size of family reduced the probability of adopting new agricultural technology. In other empirical findings family size tend to increase technology adoption. The negative relationship might be that household's engagement in off farm activities as a result it avoids pressure of the need to produce more food for large family size consumption(Obsisan, 2015; Wabwil, 2016).

4.6.2. Impact of adoption on productivity, commercialization and food security

The logit model results calculated individual propensity scores that were used to match adopters and non-adopters farm households. The indicators for household food security used in the analysis were household dietary diversity score and household food insecurity experience scale. PSM controls for all confounding factors that correlate with both the outcome variables and adoption status. Before assessing the impacts of adoption, the quality of matches were tested in order to check for the fulfillment of common support condition and ensure that the distribution of the variables between the adopters and non-adopters is balanced. The density distribution of estimated propensity scores for the two groups of farmers is presented in Figure 4. The figure demonstrates that the condition for common support is fulfilled because of substantial overlap in the propensity score distributions for the two groups. In addition it also indicates a good comparability between the adopters and non-adopters.The existence of common support enables us to compute the impact of technology adoption on selected outcome variables. The result of the analysis is portrayed in Table 7.

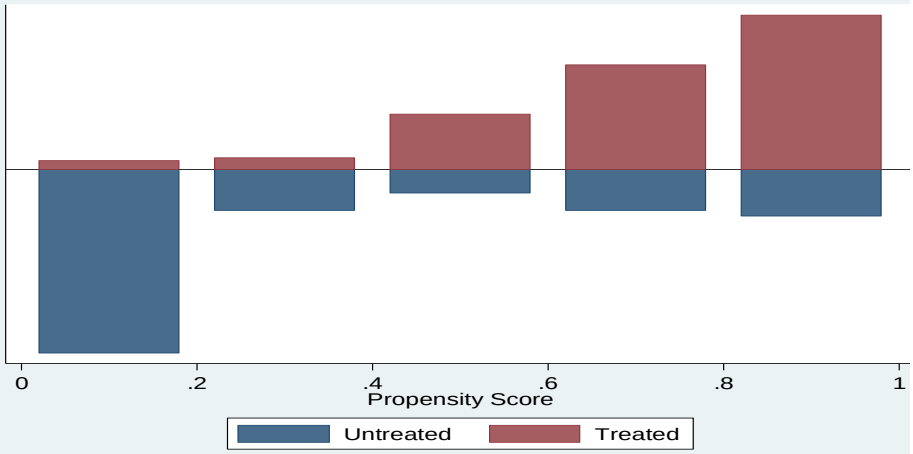

Figure 4: Propensity score distribution and common support for propensity score estimation of adopters and non-adopters

Table7: Impact of adoption over productivity, commercialization, HDDS and food insecurity

Variables	Treated	Control	Difference (ATT)
Productivity	1017.212	304.394	712.819***
commercialization	0.181	0.040	0.141***
HDDS	6.6	6.296	0.304*
Severe food insecurity	0.504	0.626	-0.122*

*Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level
Source: Authors' estimates based on 2018 survey

The results suggested that adoption has positiveeffect on productivity and commercialization at 1% significant level, and on household dietary diversity at 10% significant level. While it showed negative relationship with sever food insecurity experience at 10% significant level. The impact increased productivity, commercialization level and dietary diversity of treated households by 712.8, 0.14 and 0.3, respectively; while it reduced prevalence of severe food insecurity of the treated by 0.12.

The result goes in line with previous studies. Abadi (2014) stated that adoption of improved maize varieties had a robust and positive impact on farmers' marketed surplus maize as a result of magnified productivity scale which leads to the active market participation. Solomon *et al* (2011) and Wabwil (2016) confirmed the potential direct role of technology adoption on market participation among rural households, as higher productivity from improved technology translates into higher output market integration.

Salazar et al (2015) indicated the same result that smallholders' food security and income was improved through productivity increase triggered by technological adoption as a result of

agricultural development program. Tigist (2017) suggested strong relationship between agricultural technology adoption and farm households' well-being. The concept of well-being implies households having enough financial strength to secure its food both qualitatively and quantitatively.

4.6.3. Determinants of households dietary diversity score

The other most important issue that should be addressed here is analyzing the effect of technology adoption on different food insecurity status of households. Since the dependent variable is ordered in nature, ordered logit model was used to run the regression. The estimated results of the model of the maximum likelihood, multicollinearity test result and the marginal effects are tabulated in Appendix 11, Appendix 12 and Table 8, respectively. The dependent variable was obtained by making use of food security measurement tool called household dietary diversity score, and the households were organized in to three groups; namely high , medium and low dietary diversity. A total of 12 explanatory variables were used to compute the econometric model in order to identify factors that determine household's level dietary diversity. Among those explanatory variables, only marital status, livestock holding and adoption status was found to have significant relationship with the level of HDDS.

Table8: Distribution table for Household Dietary Diversity Score (HDDS)

Variables	High HDDS	Medium HDDS	Low HDDS
Sex of HH	-0.043(0 .055)	0.031 (0.039)	0.013 (0.016)
Age of HH	0.001 (0.002)	-0.000 (0.001)	-0.000 (0 .001)
HH Educ.	-0.005 (0.006)	0.003 (0.004)	0.001 (0.002)
Marriage Status	0.174 (0.042)***	-0.123 (0.033)***	-0.051 (0.015)***
Family Size	-0.005 (0.010)	0.003 (0.007)	0.001 (0.003)
Off Farm Income	0.010 (0.041)	-0.007 (0.029)	-0.003 (0.012)
Farm Land	-0.061 (0.049)	0.043 (0.035)	0.018 (0.015)
Livestock Holding	0.130 (0.027)***	-0.091 (0.019)***	-0.038 (0.013)***
Adoption Status	0.139 (0.038)***	-0.098 (0.027)***	-0.041 (0 .015)***

Numbers in brackets are standard errors
*Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level
Source: Authors' estimates based on 2018 survey

The regression result has revealed that technology adoption was one of the most important factor that took its place of influence on improvement of household dietary diversity. Previous studies

reported positive impact of yield enhancing technologies, like fertilizer, on household food security status (Misgina, 2014).

According to the estimated result in table, attributes such as marital status of household head, livestock holding and adoption status showed positive and significant relationship with high dietary diversity score at 1% significant level. In contrast to the case of high dietary diversity score, the variables showed negative relationship with medium and low HDDS, still at 1% significant level.

Being married, adopting technology and a unit increase in TLU of livestock holding increased the probability of consuming highly diversified diet by 0.17, 0.14 and 0.13, respectively; but it decreased the probability of consuming medium diversified diet by 0.12, 0.10 and 0.09, respectively; and it also decreased the probability of consuming low diversity diet by 0.05, 0.04 and 0.04, respectively.

The result indicated that having marriage partner, surely women, reduces consuming low and medium diversified diet, and promotes high diversity of diet on table. These might be due to the fact that women involve in food preparation, food selection is therefore expected to be influenced by women`s knowledge regarding nutritional benefits of different foods and their power to allocate household family budgets towards high quality foods (Quisumbing*et al*, 1998). Previous studies by Rogers, (1996, p. 113) noted that female headed households spent more on higher-quality, more expensive, and protein-rich foods. Therefore, having women partner in marriage might be the reason behind high dietary diversity score.

The model result indicated that those who had better livestock ownership measured in TLU were food secure, in a sense that they consume more diversified diet than their counterpart. This finding was crystalized by the report of Goshu*et al* (2013) that household's dietary diversity increased by 0.11 as a result of a unit increase in TLU of livestock possession. The herd size being a proxy for farmer's resource endowment, larger holding increases household's income level and this in turn could be used to purchase diversified items of food from market (Misgina, 2014).

4.6.4. Determinants of household food insecurity experience scale

The estimated results of the ologit model of the maximum likelihood, multicollinearity test result and the marginal effects are tabulated in Appendix 9, Appendix 10 and Table 9, respectively. The dependent variable was derived by making use of food security measurement tool called Household Food Insecurity Experience Scale, and the households were organized in to three groups; namely severely, moderately and mildly food insecure households. A total of 12 explanatory variables were used to compute the econometric model in order to identify factors that determine household's level of food insecurity.

Table9: Distribution table for household food insecurity experience (FIES)

Variables	Severely Food Insecure	Moderately Food Insecure	Mildly Food Insecure
Sex of HH	0.034 (0.161)	-0.018 (0.082)	-0.017 (0.079)
Age of HH	0.011 (0.003)***	-0.006 (0.001)***	-0.005 (0.002)***
HH Educ.	-0.013 (0.009)	0.007 (0.005)	0.006 (0.005)
Partner's Educ.	0.012 (0.009)	-0.006 (0.004)	-0.006 (0.005)
Maximum Educ.	-0.028 (0.010)***	0.014 (0.005)***	0.013 (0.005)*
Marriage Status	-0.253 (0.137)**	0.130 (0.068)*	0.123 (0.072)*
Family Size	-0.040 (0.016)*	0.020 (0.009)*	0.019 (0.008)*
Productive Labor	-0.226 (0.128)*	0.116 (0.068)*	0.110 (0.062)*
Off Farm Income	-0.043 (0.051)	0.022 (0.026)	0.021 (0.025)
Farm Land	-0.153 (0.113)	0.079 (0.059)	0.074 (0.055)
Livestock Holding	-0.047 (0.029)	0.024 (0.015)	0.023 (0.015)
Adoption Status	-0.091 (0.050)*	0.047 (0.025)*	0.044 (0.026)*

Numbers in brackets are standard errors
*Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level
Source: Authors' estimates based on 2018 survey

The results of the regression has shown that technology adoption reduces the probability of households to be severely food insecure and increases the probably of households to be in a better food insecurity status.

Household head's age is the one factor that had positive influence on severely food insecure households, while it showed negative relationship with moderately and mildly food insecure households at 1% significant level. The result revealed that increment in the age of the household head increased the probability of households being severely food insecure by 0.011, and decreased the probability of households becoming moderately and mildly food insecure by 0.006 and 0.005, respectively. Even though, the effect is not worthy of consideration, it signifies that old people are the one that are susceptible to severe food insecurity.

Maximum education status attained by any of the household member was the other factor that negatively influenced the probability of households being severely food insecure at 1% significant level, while it showed positive effect on moderately and mildly food insecure household at 1% 1nd 10% significant level, respectively. Achieving a good level of education as a household member decreased the probability of severely food insecure by 0.028, and increased the probability of being moderately and mildly food insecure by 0.014 and 0.013, respectively. As the computed report showed education reduced severity and by promoting moderate and mild food insecurity, it works towards achieving food security. The negative effects of these variables indicate that the importance of the household's education in terms of avoiding food insecurity. Thus, the possible explanation is that education is a fundamental instrument to develop their skills how to use and control farm lands, apply farm inputs and adopting new technologies, applying family planning, and others (Ermias, 2011).According to Farhadian (2015) tried to explain the fact that a person with a diploma or a degree holder is able to secure a good job and has a higher income. It can also be observed that the households with household heads that have a low level of education (never attend school, primary school, and secondary school) tend to have the worst scores in comparison to the households with a better schooled household head (institution of higher education).

Marital status showed negative relationship on being severely food insecure household at 5% significant level, while the opposite being true on the case of being moderately and mildly food insecurity at 10% significant level. The result indicated that being married reduced the probability of being severely food insecurity by 0.253, and increased the probability of being moderately and mildly food insecurity by 0.13 and 0.123. This might imply that household led by married parents support each other all their way to food sufficiency while the singles and widows lake mutual support. Single headed households were reported to be vulnerable to severe food insecurity as compared to married ones (Nord *et al*, 2004)

Based on this paper, severe food insecurity has negative relationship with attributes like family size, productive labor and technology adoption at 10% significant level that it reduces prevalence of severe food insecurity by 0.04, 0.23 and 0.09, respectively. Furthermore, the probability of households being both moderately and mildly food insecure was positively influenced by factors like family size, productive labor and technology adoption at 10% significant level. Based on the figure in the table, the probability of households being moderately food insecure was increased

by 0.02 and 0.12 as a result of increment in family size and productive labor, and also it was increased by 0.05 if the household adopt agricultural technology. And also, the probability of households being mildly food insecure was increased by 0.02 and 0.11 as a result of increment in family and productive labor size, and also it was increased as a result of technology adoption by 0.04.

The result of the survey may also indicate that large households who share a common dish tend to be food insecure compared to smaller family size. It shows that additional household members' shares the limited resources; this leads the existing households to become more foodinsecure. This result is in line with the result of (Mesfin , 2010; Taye, 2014). On an article produced by Hussaini and his research partners (2016), dependency ratio, the reverse of productivity labor ratio, was reported to affect households food security status negatively (reduced it by 3.4%). From this report, one can conclude that having independent, productive and self-supporting household member within the household would promote food security, or else greatly deduct the challenge of severe food insecurity. In line with this paper, a report by Ermias (2011), the relationship was found to be negative and significant. The explanation is that use of improved seed or else adopting yield enhancing farm inputs is likely to increase productivity, as a result it tend to decrease the probability of being food insecure.

4.6.5. Determinants of household's Adoption and Commercialization dynamics

In this study the dependent variable is "adoption with commercialization", for which there are three possible outcomes. These are households who adopt technology at the same time commercialize their crop, those who adopt technology but do not sell their crop, and those who neither adopt technology nor commercialize their crop.

The multinomial logistic regression model was used to run the regression as it is the best multivariate approach to study the dynamics of technology adoption and commercialization (Baulch, 2011). Due to the mentioned limitations of the multinomial logistic regression model, marginal effects were used for a better interpretation of the results. According to Cameron and Trivedi (2005), the marginal effect is the effect caused by a change in one unit of a dependent variable upon the probability of falling into any of the possible outcomes. The marginal effect is tabulated in Table 10.

A total of six explanatory variables were considered in the econometric model, all related to both demographic and socio-economic characteristics and selected as to the interest of the author, in order to identify factors that affect households' technology adoption and commercialization dynamics. Marital status, family size, off farm income, livestock holding and farm size were found to be significantly associated with the dependent variable.

Table 10: factors affecting dynamics of adoption and commercialization

Variables	ADOCOM dx/dy	ADOPT dx/dy	NONE dx/dy
Age of HH	-0.003 (0.002)	0.003 (0.003)	0.002 (0.002)
Marital status	-0.033 (0.093)	-0.147 (0.085)*	-0.283 (0.069)***
Family size	0.003 (0.012)	-0.040 (0.017)*	0.014 (0.015)
Off farm income	0.103 (0.046)*	0.013 (0.056)	-0.101 (0.053)*
Farm size	0.205 (0.080)**	0.074 (0.109)	-0.242 (0.127)*
Livestock holding	0.144 (0.023)***	-0.050 (0.031)*	-0.105 (0.027)***

Numbers in brackets are standard errors
*Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level
Source: Authors' estimates based on 2018 survey

It can be seen in the above table that the higher the amount of livestock possession, farm size of the household head, and participation in off farm activity, the probability of adopting technology at the same time commercializing farm output increased by 0.14, 0.21 and 0.1,respectively. As a result of being married, and a unit increment in family size and livestock holding, the probability of households who adopt technology could not commercialize their crop, and decreased by 0.15, 0.04 and 0.05, respectively. And also, being married, having off farm income, and a unit increase in farm size and livestock holding, the probability of none-adoption and none-commercialization decrease by 0.3, 0.1, 0.2 and 0.1, respectively.

The result indicated that the effect would be great for households who had large farm size followed by them having livestock possession, and being employed in off farm jobs. Even if it is well understood that technology adoption promotes commercialization, the elements that play great role behind the sine are the above attributes.

As the report in the above table indicates, marriage showed significant influence on adoption and commercialization status of households. As a result of adoption, an urge for commercialization could be realized by increased productivity. Married people are the one who take responsibility of people under their shelter (Dauda*et al*, 2014). Elemasho*et al* (2017) reported that married

people were willing to adopt postharvest technologies than singles in pursuit of fulfilling family responsibilities.

Livestock provides manures as main compost used by farmers for crop production in rural areas as a result increase in the number of livestock owned would improve the crops productivity and hence increases the marketable surpluses, and financial growth indirectly provoke farmers to try technology adoption (Solomon *et al*, 2010, Aman, 2014).

It is true beyond doubt that having an additional *timad* (0.125 ha) is critical production asset having a direct bearing on production of surplus and would increase the amount of horticultural output sold (Angula, 2010; Aman, 2014; Obisesan, 2015 and Mengistu*et al*, 2016).

Off farm activity was the other factor with positive impact on promotion of adoption with commercialization. A study by Kabiti et al (2015) bore witness to the fact that household income can impact on the size (land size cultivated) and operations (type of cultivation, inputs, access to transport) of the agricultural enterprise which thus impact on commercialization. And also, it has the potential of reducing the dependency on agricultural produce as food and income sources; and hence increased commercialization.

4.6.6. Determinants of Commercialization status of Households

Since the values of commercialization falls in between 0 and 1, tobit model has been used. The estimated results of the model of the maximum likelihood, multicollinearity test result and the marginal effects are shown in Appendix 13, Appendix 14 and Table 11, respectively. A total of 16 explanatory variables were used to compute the econometric model in order to identify factors that determine household's market participation level. Out the total variables, only eight of them were able to significantly market engagement.

Based on the result presented below, households' commercialization status were negatively affected by Education status of household head, ratio of productive labors and market distance at 10%, 10% and 1% significant level, respectively. It was positively influenced by market information, vehicular road, farm size, livestock holding and adoption at 1%, 10%, 10%, 1% and 1% significant level, respectively.

Table 11: Determinants of commercialization level of households

Variable	Marginal effect	Std. Err	Z
Sex of HH	-0.075	0.121	-0.62
Age of HH	-0.002	0.003	-0.66
HH Educ.	-0.027	0.011	-2.37*
Partner's Educ.	0.006	0.012	0.56
Maximum Educ.	0.003	0.012	0.26
Productive Labor	-0.328	0.182	-1.80*
Family Size	-0.009	0.065	-0.14
Market Information	0.280	0.093	3.00***
Union Member	-0.067	0.106	-0.63
Visit by DA's	0.004	0.002	1.54
Market Distance	-0.017	0.006	-2.84***
Vehicular Road	0.266	0.138	1.92*
Off Farm Income	0.063	0.061	1.02
Farm Size	0.169	0.081	2.08*
Livestock Holding	0.182	0.037	4.89***
Adoption	0.226	0.085	2.65***

*Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level
Source: Authors' estimates based on 2018 survey

As the result indicated, each additional number of years on education status of household head decreases the probability of selling the product on market by 0.03. In support of this finding, Paul and Mauch (2017) showed that the probabilities of market participation by farmers who produce improved chickpea were reduced by 0.5%. This might indicate that educated household heads have their earnings from employment that they barely participate in market transaction. In contrary to this result, the study done Justus *et a*l (2015), the likelihood of becoming commercial oriented, increased by 5% for every additional year of education attained by the household head. It revealed education level increases many household heads becomes more commercial oriented and focus on commercial production to make profits.

Labor productivity negatively affected commercialization status that increment in number of households in a productive age groups decreased market participation by 0.33. This might be due to the fact that productive member are those that could generate their own income, independent of the family, as a result the household becomes relieved from the burden of providing to its dependants by way of product sale. Contrary to this result, other literatures show that

availability of larger family labor for agriculture affects the likelihood of being a net seller in crop markets positively (Tigist, 2015; Abafita*et al*, 2016).

Distance to the nearest market negatively affected commercialization status of the farming households by 0.02. A study by Kirui and Njiraini (2013), and Justus (2015) stated that market participation was negatively influenced by market distance the ultimate cause to be the transaction costs associated with time taken to reach markets outweighed the benefits of market participation.

Market information positively influenced commercialization that having information about market transaction increased the tendency of presenting agricultural products to market by 0.28. A study done by Justus *et al* (2015) confirmed the great importance of market information in farming since it informs the farmers about the market prices and potential buyers, thereby facilitating decisions on the quantity and quality to sell.

Dwelling in*kebeles* that have vehicular road showed positive influence that it increased commercialization by 0.27. In support of this finding, all-weather road increased market participation by 0.54 (Abafita*et al*, 2016). Rural infrastructure is severely limited inEthiopia where, nearly half of the rural population does not have access to all weatheredroads which are conducive for vehicular transportation. This highly challenges appropriate, even, long distance trades. Thus, around 72 percent of the grain production is retained for on-farm use (Gabremadhin, 2001).

Each unit increment in the amount of farm size in hectare brought significant increment in households' commercialization status by 0.17. This was empirically justified by a number of studies Possession of large farms is helpful to produce surplus as a result households easily become market oriented compared to smaller ones. (Marteye*t al*, 2012: Justus, 2015).

Livestock possession influenced commercialization positively that it bring about 0.18 increment. Livestock endowment strongly determines either the net position households assume in live animal market (Moti and Birhanu, 2012) or it brings economic empowerment as a result the households will be enabled to adopt yield enhancing technologies to attain surplus.

Agricultural technology adoption showed positive relationship with commercialization that the tendencies of commercializing farm goods were increased by 0.23 for those who adopt

technology. The use of productivity enhancing inputs will improve the ability of smallholder farmers to produce sufficient marketable surplus (Kirimi*et al*, 2013; Paul *et al*, 2017). To take it further, application of high-yielding varieties increases surplus crop production by 7.39% per year, whereas chemical fertilizer use increases surplus by 2.32%. When farmers apply the two inputs jointly, marketed surplus increases by 6% which establish the complementarity of the two technologies (Tigist, 2017).

5. CONCLUSION AND RECOMMENDATION

5.5. Summary and conclusion

This study was conducted to identify impact of agricultural technology adoption on agricultural productivity, level of commercialization and household food security status of farming households; and also to examine determinants of technology adoption, commercialization, household dietary diversity and level of food insecurity of rural farming households in Boricha*Wereda*, Sidama Zone southern Ethiopia. Both primary and secondary sources were used to carry out the study. A total of 334 household heads from the *wereda* were selected by random sampling method from three *kebeles* of the city. The descriptive statistics results showed that out of the total respondents, 66% of them adopted agricultural technology while 34% of did not.

The t- test showed that there was a significant difference between adopters and non-adopters in terms of household labor whose age less than 14 and whose age in between 14 and 65, partner education status, livestock holding (TLU), farm size, productivity, commercialization, nearest market distance and dietary diversity score. The chi-square test also revealed a significant difference between adopters and non-adopters in terms of sex, marital status, off farm income, adoption by neighbor, information about new technology, usage of mobile phone, market information, union membership, having access to vehicular road, household level of diet diversity and food insecurity experience score.

Propensity score matching model (PSM) was employed to examine impact of agricultural technology adoption on outcome variables of productivity, commercialization, household level of dietary diversity and food insecurity experience. The model showed statistically significant influence on the upper mentioned outcome variables.

The result revealed that adoption positively influenced productivity, commercialization and household dietary diversity. While it showed negative relationship with sever food insecurity experience. This is due to the fact that adoption of agricultural technology exacerbates market participation as a result of surplus brought by huge productivity which in turn leads to the active market participation, and by then households would have enough financial strength to secure its food possession both qualitatively and quantitatively.

Logitic regression model was used to identify factors affecting agricultural technology adoption. Variables such as adoption by neighbor, technology information, mobile usage, livestock holding

and farm size were found to have positive effect on technology adoption, while family size showed negative relationship with adoption.

All being a tool to assume information about new technology, attributes like neighbor's technology, information about new technology and mobile usage showed role play. It enables farmers to learn the existence as well as the effective use of technology and this facilitates its adoption due to the fact that farmers will only adopt the technology they are aware of or have heard about it. Therefore, access to information reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time.

Livestock holding positively affected adoption status of households. This is due to the fact that livestock provides manures as main compost used by farmers for crop production in rural areas as a result increase in the number of livestock owned would improve the crops productivity and hence increases the marketable surpluses. Commercializing farm output eventually brings economic empowerment as a result the farmer could have enough money to buy new yield enhancing technologies.

Farm size also exhibited a positive relationship with technology adoption. This is due to the fact that farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new technology unlike those with less farm size.

Family size showed negative relationship with adoption. This might be due to the fact that large families pressured by the need to provide more food for family consumption than spending their money trying out new technologies.

Multinomial logitic regression model was used to identify factors affecting those households who adopt and commercialize; those who adopt but do not commercialize; and those neither adopt nor commercialize their product. Adoption at the same time commercialization was positively affected by factors like off farm income, farm size and livestock holding. This is probably due to the fact that increments in cultivated land size boost production of crops which in turn makes surplus marketing possible.

This can be further exasperated by having high amount of livestock, as their excreta could be used as compost to intensify yield. And also, off farm employment provides the family with

good some of finance and reduce burden, as a result the household will be able to buy new technologies, and also their market share over in home consumption tend to increase. Adopters but not commercializes are challenged by marital status, family size and livestock holding because of the burden of nursing dependants and limited number of cattle but, because of enormous farm size, households, even though non-adopters will be able to present their produce to market.

Tobit regression model was employed in order to identify factors affecting commercialization status of households. Households' commercialization status was negatively affected by ratio of productive labors and market distance. Labor productivity negatively affected commercialization status. This might be due to the fact that productive member are those that could generate their own income, independent of the family, as a result they might not be interested to involve in market transaction. And also, very far households from the market center might find market vending very tedious.

Commercialization was positively influenced by market information, vehicular road, farm size, livestock holding and technology adoption. Market information has great importance in farming since it informs the farmers about the market prices and potential buyers etc. The rural population does not have access to all weatheredroads which are conducive for vehicular transportation. This highly challenges appropriate, even, long distance trades. Therefore, having vehicular road will facilitate market transaction. Possession of large farm is helpful to produce surplus as a result households easily become market oriented. Its effect was escalated by livestock possession and technology adoption. The use of productivity enhancing inputs improved the ability of smallholder farmers to produce sufficient marketable surplus.

Ordered logit regression model was used to identify determinants of household dietary diversity and food insecurity experience. Marital status, livestock holding and technology adoption showed its contribution for consumption of high diversity diet, at the same time reducing eating medium to low diversity food. These might be due to the fact that women as marriage partner, involve in food preparation, food selection is therefore expected to be influenced by women`s knowledge regarding nutritional benefits of different foods and their power to allocate household family budgets towards high quality foods. The herd size being a proxy for farmer's resource endowment, larger holding increases household's income level and this in turn could be used to

purchase diversified items of food from market. And at last, but not the least, productivity enhancing inputs bring food and monetary sufficiency as a result what they produce they eat, what they lack they buy to diversify their diet.

Maximum education with in the household, marital status, family size, productive labor and technology adoption had negative relationship with severe food insecurity as a result it reduce it and in turn promote moderate and mild food insecurity working its way towards security. The opposite is true for old household head's. The remaining possible explanations are; education is an instrument to develop their skills how to use and control farm lands, apply farm inputs and adopting new technologies, applying family planning, and drive away food insecurity; household led by married parents support each other all their way to food sufficiency; additional household members' shares the limited resources that leads to resource exhaustion and foodinsecure; self-supporting household member within the household would promote food security; and adopting yield enhancing farm inputs is likely to increase productivity, as a result it tend to decrease the probability of being food insecure.

5.6. Recommendations

The following recommendations have been forwarded based on the results of the research.

- Adoption of yield enhancing agricultural technologies has great impact on enhancement of farm productivity, initiating market participation, alleviating food insecurity experience and improving dietary diversity. Its multidimensional impact worthy of consideration to be incorporated in policy intervention by NGOs or government designed projects. It is evident that technological package distribution has been insufficient in the study area. Therefore, above all, care taking institutes, especially BoANRD of boricha*wereda*and AGP's should work extra hard to actualize satisfactory distribution of the package, not just in term coverage but also in terms of extent as per the need of the farming system.
- Technology adoption showed positive impact on food security status of farming households. Comparatively, its impact on dietary diversity seems better than its impact on alleviating severe food insecurity. Even though households adopt technology, there are still those who consume medium to low diversity diet. This is due to the fact that adoption enhance productivity, but the ability to consume balanced diet is might be the matter of nutrition education. Along with the package of yield enhancing technologies, the food security issue will be addressed by nutrition education. Therefore, the package should be accompanied by health education.
- Technology adoption is affected by determining factors highly relate to information and asset possession like livestock holding and farm size. Information played great role on household's condition of technology adoption. Development agents of the *wereda* or other project officers should give maximum attention to dissemination of information about any new technology at door.
- In some cases, even though households adopt and commercialized at the same time, their food security situation was greatly challenged by the number of people under their shelter. The issue of food security could not be solely dealt by farm activities so that family planning has to take its place. Even more, an opportunity of employment has to be created by the regional government as it helps in the battle with food insecurity. Therefore, bureau of family guidance together with *wereda* administration has to work closely.

- Market participation tendency of farmers were positively influenced by vehicular road access. It true those rural areas, the majority of rural kebeles of borichawereda, were disadvantaged of all weatheredroads which are conducive for vehicular transportation. This highly challenges appropriate, even, long distance trades since vehicular road will facilitate market transaction. Therefore, the responsible authority should work on this matter as it greatly help to improve holistic feature of rural life, most importantly food security.

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APPENDICES

Appendix 1: Survey questionnaire

ADDIS ABABA UNIVERSITY
COLLEGE OF DEVELOPMENT STUDIES
CENTER FOR FOOD SECURITY STUDIES
REGULAR PROGRAM

Dear respondent,

Your response to this Questionnaire will serve as source of information to the research paper to be done for thesis entitled ***'Agricultural Technology Adoption, Commercialization and Food SecurityLinkage: Micro Evidence from BorichaWereda, Sidama Zone Ethiopia'.*** Any response you provide here is strictly confidential and will be used exclusively for the research purpose. No individual's responses will be identified as such and the identity of persons responding will not be published or released to anyone. Your honesty in responding the right answer is vital for the research outcome to be reliable. Thank you in advance for your kind cooperation and dedicating your time.

Sincerely,
TagelAlemuTafese

A. PRODUCER'S CHARACTERISTICS:

A01 What is the **SEX** of the household head?

a. Male
b. Female

A02 How old is the **AGE** of the household head in years? _____

A03 How is **EDUCATIONAL STATUS** of household head? _____

A04 How is **MARITAL STATUS** of the household head?

a. Single
b. Married
c. Widow/Widower
d. Divorced

A05 **HOUSEHOLD SIZE** or people who live under the shadow of the household head_____

A06 Do you have other employment or **OFF FARM INCOME**?

a. Yes
b. No

A07 **LABOR AVAILABILITY** or individuals whose age is;

Age group	**How many individuals?**
Less than 14	
B/n 14 and 65	
Greater than 65	

B. TECHNOLOGY ADOPTION CHARACTERISTICS:

B01 Type of **AGRICULTURAL TECHNOLOGY** among the list below do you adopt?

a. Improved seed
b. Fertilizer
c. Both

B02 What kind of **IMPROVED SEED**? _____

B03 Does your **NEIGHBOR ADOPT** technology?

a. Yes
b. No

B04 Do you have **ACCESS TO INFORMATION** about any agricultural technology?

a. Yes
b. No

B05 Which **COMMUNICATION TECHNOLOGY** do you use?

Communication tools/ technology	**Yes or No**
Mobile	
Television	

Radio	
Newspaper	
Internet	

C. OWNERSHIP OF ASSETS:

C01 LIVESTOCK HOLDING

Livestock Holding	How many?
Oxen	
Cows	
Goat	
Sheep	
Donkey	
Chicken	

C02 **FARMLAND SIZE** _____ hectare

C03 How many hectare is used to grow the improved seed?_____

C04 Do you grow **OTHER CROPS** like coffee, chat and enset?

a. Yes

b. No

C05 Annual **FARM OUTPUT** in kilograms (this year)_____

C06 Annual **MARKET OUTPUT** in kilograms (this year)_____

C07 **UNITE PRICE** at which each kg of output is normally sold (ETB)_____

D. MARKET ACCESS AND INSTITUTIONAL CHARACTERISTICS:

D01. Amount of **CREDIT BENEFITED** from microfinance or other institutions?_____

D02. Do you have access to **MARKET INFORMATION**?

a. Yes

b. No

D03. Are you a **MEMBER OF FARMER'S UNION** or any other union?

a. Yes

b. No

D04. How many times you have been paid a **VISIT BY ANY EXTENSION AGENT** this year?_____

D05. Are you beneficiary of productive safety net program **(PSNP)?**

c. Yes

d. No

D06. **MARKET DISTANCE** between the residence of the household head and the nearest market in kilometers._____

D07. Do you have **ACCESS TO VEHICULAR** ROAD to convey produce to market?

a. Yes

b. No

E. HOUSEHOLD DIETARY DIVERSITY SCORE (HDDS)

✓ *Information on household food consumption should be collected using the previous 24hours as a reference period (24-hour recall).*

Questions	Scores	
1. Any CEREALS sorghum, maize, rice, wheat?	Yes	No
2. Any PULSES and LEGUMES like beans, peas, lentils,or nuts?	Yes	No
3. Any ROOT and TUBERS like ensut, potatoes, yams, cassava or ?	Yes	No
4. Any VEGETABLEs?	Yes	No
5. Any FRUITS?	Yes	No
6. Any MEAT beef, pork, lamb, goat, chicken?	Yes	No
7. Any EGGS?	Yes	No
8. Any FISH?	Yes	No
9. Any DAIRY products like yogurt, milk or other milk products?	Yes	No
10. Any foods made with oil, fat, or butter?	Yes	No
11. Any sugar or honey?	Yes	No
12. Any other foods, such as condiments, coffee, tea?	Yes	No

F. HOUSEHOLD FOOD INSECURITY EXPERIENCE SCALE(HFIES)

- *The questions are provided to gather information within the time frame of the last 6 months; from September to February.*

Question	Score	
E. Was there a time when You were **worried you would not have enough food to eat** because of a lack of money or other resources?	Yes	No
F. Was there a time when you were unable to eat **healthy and nutritious food** because of a lack of money or other resources?	Yes	No
G. Was there a time when you ate **only a few kinds of foods** because of a lack of money or other resources?	Yes	No
H. Was there a time when you had to **skip a meal** because there was not enough money or other resources to get food?	Yes	No
I. Was there a time when **you ate less than you thought** you should because of a lack of money or other resources?	Yes	No
J. Was there a time when your household **ran out of food** because of a lack of money or other resources?	Yes	No
K. Was there a time when you were **hungry but did not eat** because there was not enough money or other resources for food?	Yes	No
L. Was there a time when **you went without eating for a whole day** because of a lack of money or other resources?	Yes	No

Appendix 2: Key informant interview

Good morning or afternoon sir/madam.

I am carrying out a study on the ***Agricultural Technology Adoption, Commercialization and Food SecurityLinkage***. Thank you for having granted me permission to interview you. I would like to assure you that I will stick to all ethical codes of conduct with regard to conducting research as stated in my introduction letter.

1. Demographic related questions
    a. How the farmer's family status is looks like? Who is mostly the head? What about family size? Are they educated? Is there off farm income opportunity?
    b. Which religion is the most dominant in the community?
    c. Is there any difference in food consumption habit in terms of the religion type?
2. Technology adoption related question
    a. What kind of technology do the farmers adopt?
    b. What are those factors that affect technology adoption status of farmers in Boricha*wereda*?
    c. What type of food crop and cash crop do the farmers grow?
3. Commercialization related question
    a. Do the farmers present their produce to market?
    b. Is there any technology adoption, market related and farming system related support or training for farmers in the *wereda*?
4. Food security related question
    a. Do you think their food consumption pattern is diversified?
    b. What kind of food do the farmers used to consume? Can you list your cultural foods consumed by the farmers

Appendix 3: Adoption status of households

Adoption status	**Frequency**	**percent**	**Cumulative**
Non-adopters	115	34.43	34.43
Adopters	219	65.57	100.00
Total	334	100.00	

Appendix 4: chisquare distribution of agricultural technology types in the *wereda*

Variables	Categories	Sample proportion (%)	Percentage distribution		Chi-square
			Adopters	Non-adopters	
Improved seeds	No	34.73	3.45	96.55	0.00***
	Yes	65.27	98.62	1.38	
Fertilizer	No	35.93	5.83	94.17	0.00***
	Yes	64.07	99.07	0.93	

Appendix 5: Cash crops and Food crops grown in the *wereda*

Variables	Categories	Percentage distribution		Chi-square
		Adopters	Non-adopters	
Do you grow maize?	No	12.24	87.76	0.000***
	Yes	74.74	25.26	
Do you grow haricot bean?	No	54.22	45.78	0.000***
	Yes	75.97	24.03	
Do you grow chat?	No	67.41	32.59	0.439
	Yes	63.35	63.35	
Do you grow coffee?	No	67.90	32.10	0.299
	Yes	62.42	37.58	
Do you grow *enset*?	No	91.30	8.70	0.000***
	Yes	60.85	39.15	

Appendix 6: Chisquare distribution of dietary groups in terms of adoption

Food groups	Categories	Sample proportion (%)	Percentage distribution		Chi-square
			Adopters	Non-adopters	
carbohydrate based food	No	0%	100.00	100.00	
	Yes	100%	100.00	100.00	
protein based food	No	6.59	31.82	68.18	0.001***
	Yes	93.41	67.95	32.05	
vitamin based food	No	16.77	62.50	37.50	0.596
	Yes	83.23	66.19	33.81	
plant based food	No	100%	100.00	100.00	
	Yes	100%	65.57	34.43	
animal based food	No	23.05	49.35	50.65	0.001***
	Yes	76.95	70.43	29.57	
Sea based food	No	95.81	94.98	97.39	0.296

Appendix 7: Chisquare distribution of food insecurity experience of households in terms od adoption

Variables	Percentage distribution		Chi-square
	Adopters	Non-adopters	
Households with mild food insecurity	64.60	35.40	0.053*
Households with moderate food insecurity	62.18	37.82	0.005***
Households with severe food insecurity	59.32	40.68	0.011**

Appendix 8: Chisquare distribution of household dietary diversity score in terms of adoption

Variables	Categories	Percentage distribution		Chi-square
		Adopters	Non-adopters	
Any CEREALS like sorghum, maize, rice, wheat?	No	0.00	100.00	0.000***
	Yes	66.97	33.03	
Any PULSES and LEGUMES like beans, peas, lentils,or nuts?	No	36.36	63.64	0.000***
	Yes	72.76	27.24	
Any ROOT and TUBERS like ensut, potatoes, yams, cassava or ?	No	100.00	0.00	0.468
	Yes	65.47	34.53	
Any vegetables?	No	63.64	36.36	0.712
	Yes	66.04	33.96	
Any FRUITS?	No	67.34	32.66	0.248
	Yes	60.47	39.53	
Any MEAT beef, pork, lamb, goat, chicken?	No	64.29	35.71	0.089*
	Yes	80.77	19.23	
Any EGGS?	No	65.77	34.23	0.167
	Yes	0.00	100.00	
Any FISH?	No	65.00	35.00	0.296
	Yes	78.57	21.43	
Any DAIRY products like yogurt, milk or other milk products?	No	51.25	48.75	0.002***
	Yes	70.08	29.92	
Any foods made with oil, fat, or butter?	No	68.12	31.88	0.617
	Yes	68.12	64.91	
Any sugar or honey?	No	63.18	36.82	0.043**
	Yes	77.19	22.81	
Any other foods, such as condiments, coffee, tea?	No	70.00	30.00	0.765
	Yes	65.43	34.57	

Appendix 9: Likelihood ration of level of food insecurity experience score for ordered logistic regression model

```
Ordered logistic regression                     Number of obs   =        323
                                                Wald chi2(12)   =      43.69
                                                Prob > chi2     =     0.0000
Log pseudolikelihood = -272.18983               Pseudo R2       =     0.1138
```

FOODinsec	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
SEX	-.1723218	.7950854	-0.22	0.828	-1.73066	1.386017
AGE	-.0532087	.0139903	-3.80	0.000	-.0806293	-.0257881
HHEDU	.0633657	.0456457	1.39	0.165	-.0260983	.1528297
PAREDU	-.0575548	.0426884	-1.35	0.178	-.1412225	.0261129
MAXEDU	.1365375	.0526811	2.59	0.010	.0332845	.2397905
married	1.252577	.6932129	1.81	0.071	-.1060955	2.611249
HHSIZE	.1955337	.0835622	2.34	0.019	.0317548	.3593125
LABOR_productive	1.117978	.6455847	1.73	0.083	-.147345	2.383301
OFFFARM	.2159279	.2522186	0.86	0.392	-.2784115	.7102674
FLAND	.7569893	.5662881	1.34	0.181	-.352915	1.866894
LVSTOK	.2338751	.1449856	1.61	0.107	-.0502915	.5180417
adopt	.4515496	.2509455	1.80	0.072	-.0402945	.9433936
/cut1	2.869547	.8608964			1.182221	4.556873
/cut2	4.952888	.9318656			3.126465	6.779311

Appendix 10: Multicollinearity of level of food insecurity experience score for ordered logistic regression model

Variable	VIF	1/VIF
married	3.48	0.287450
SEX	3.39	0.295042
MAXEDU	2.00	0.500911
PAREDU	1.67	0.600107
HHEDU	1.65	0.607882
AGE	1.52	0.659642
LABOR_prod~e	1.43	0.699872
HHSIZE	1.38	0.725029
LVSTOK	1.29	0.776701
adopt	1.23	0.814388
FLAND	1.15	0.870983
OFFFARM	1.09	0.919305
Mean VIF	1.77	

Appendix 11: Likelihood ration of level of household dietary diversity score for ordered logistic regression model

```
                                                Wald chi2(12)   =      61.32
                                                Prob > chi2     =     0.0000
Log pseudolikelihood = -113.49911               Pseudo R2       =     0.3297
```

DIETdhh	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
SEX	2.094595	.9056966	2.31	0.021	.3194626	3.869728
AGE	.0212353	.0164568	1.29	0.197	-.0110195	.0534901
HHEDU	.0186499	.0803928	0.23	0.817	-.138917	.1762168
PAREDU	.0435471	.0846718	0.51	0.607	-.1224065	.2095008
MAXEDU	-.0850827	.1136915	-0.75	0.454	-.3079141	.1377486
married	-3.597811	.8391533	-4.29	0.000	-5.242521	-1.953101
HHSIZE	-.0069351	.118301	-0.06	0.953	-.2388007	.2249306
LABOR_productive	-6.573148	1.52521	-4.31	0.000	-9.562504	-3.583792
OFFFARM	-.7910014	.4989106	-1.59	0.113	-1.768848	.1868455
FLAND	1.153331	.5762263	2.00	0.045	.0239487	2.282714
LVSTOK	-1.220931	.3729572	-3.27	0.001	-1.951914	-.4899483
adopt	-2.009905	.5149822	-3.90	0.000	-3.019252	-1.000559
/cut1	-5.218085	1.342798			-7.849921	-2.586249
/cut2	-2.631434	1.247193			-5.075888	-.1869811

Appendix 12: Multicollinearity of level household dietary diversity score for ordered logistic regression model

Variable	VIF	1/VIF
married	3.47	0.288584
SEX	3.38	0.295819
MAXEDU	1.94	0.516680
PAREDU	1.73	0.576892
AGE	1.52	0.657477
HHEDU	1.51	0.663690
LABOR_prod~e	1.38	0.722327
HHSIZE	1.36	0.734103
LVSTOK	1.29	0.776524
adopt	1.24	0.807357
FLAND	1.15	0.868170
OFFFARM	1.10	0.910320
Mean VIF	1.76	

Appendix 13: Likelihood ration of commercialization for tobit regression model

```
                                                  LR chi2(16)     =     125.71
                                                  Prob > chi2     =     0.0000
Log likelihood = -145.19917                       Pseudo R2       =     0.3021
```

commerce	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
SEX	-.0744517	.1206655	-0.62	0.538	-.3118553	.1629519
AGE	-.002091	.003167	-0.66	0.510	-.0083219	.0041398
HHEDU	-.0265978	.0112426	-2.37	0.019	-.0487172	-.0044785
PAREDU	.0064244	.0115139	0.56	0.577	-.0162286	.0290774
MAXEDU	.0030759	.0120154	0.26	0.798	-.0205637	.0267156
LABOR_productive	-.3284024	.1820995	-1.80	0.072	-.6866743	.0298695
MOBILE	-.009121	.0651242	-0.14	0.889	-.1372497	.1190077
MRKTINFO	.2796358	.093295	3.00	0.003	.0960824	.4631892
UNION	-.0665791	.1062937	-0.63	0.532	-.2757068	.1425487
visit	.0035166	.0022781	1.54	0.124	-.0009654	.0079986
DISTANCE	-.01664	.0058668	-2.84	0.005	-.0281827	-.0050973
VROAD	.2656968	.1380681	1.92	0.055	-.0059455	.5373391
OFFFARM	.0625944	.0612662	1.02	0.308	-.057944	.1831327
FLAND	.1690291	.0813058	2.08	0.038	.0090639	.3289943
LVSTOK	.182121	.0372095	4.89	0.000	.1089131	.2553288
adopt	.2255707	.0852079	2.65	0.009	.0579284	.3932131
_cons	-.6284085	.2317957	-2.71	0.007	-1.084455	-.1723615
/sigma	.4008679	.0308814			.3401103	.4616255

```
  Obs. summary:        222  left-censored observations at commerce<=0
                       112     uncensored observations
                         0 right-censored observations
```

Appendix 14: Multicollinearity of commercialization for tobit regression model

Variable	VIF	1/VIF
MAXEDU	1.93	0.517775
PAREDU	1.64	0.610739
adopt	1.61	0.619954
HHEDU	1.59	0.628517
VROAD	1.48	0.674377
AGE	1.43	0.700624
SEX	1.35	0.738284
LVSTOK	1.35	0.742783
MRKTINFO	1.34	0.745186
LABOR_prod~e	1.30	0.766601
MOBILE	1.25	0.800337
DISTANCE	1.18	0.846051
FLAND	1.15	0.866356
UNION	1.11	0.897648
OFFFARM	1.10	0.908794
visit	1.10	0.909873
Mean VIF	1.37	

Appendix 15: Table of conversion factor to estimate TLU

Animal	**TLU**
Cattle	1
Sheep and goat	0.15
Horse	1
Mule	1.15
Donkey	0.65
Camel	1.45
Poultry	0.005

Source: Ramakrishna and AssefaDemeke, 2002