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SEED SYSTEMS, ADOPTION, AND IMPACT OF IMPROVED CROP VARIETIES ON HOUSEHOLD FOOD SECURITY IN CENTRAL ETHIOPIA

BY

TEKESTE KIFLE

A DISSERTATION SUBMITTED TO THE CENTER FOR FOOD SECURITY STUDIES, COLLEGE OF DEVELOPMENT STUDIES, PRESENTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN FOOD SECURITY AND DEVELOPMENT

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ADDIS ABABA UNIVERSITY
COLLEGE OF DEVELOPMENT STUDIES
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COLLEGE OF DEVELOPMENT STUDIES

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This is to certify that the dissertation prepared by **Tekeste Kifle** entitled **"*Seed Systems, Adoption, and Impact of Improved Crop Varieties on Household Food Security in Central Ethiopia*"** and submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in Food Security and Development complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Dedication

This dissertation is dedicated to my family and God, for without their love and support none of this would be made possible. The Almighty God, for giving me a healthy life, a source of inspiration, strength, wisdom, understanding, and patience. My wife Adey, the love of my life and for always supporting me. My daughter Yohana, for being one of the most beautiful gifts in my life. My mother Almaz, for giving me insatiable love and advice.

Declaration

I, the undersigned, hereby declare that this Ph.D. dissertation is a result of my research investigations and findings. It has not been submitted to any other University for any academic degree and all the resources and materials used have been fully acknowledged.

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Abbreviations/ Acronyms

AGP	Agricultural Growth Project
AISCO	Agricultural Input Supply Company
ANRS	Amhara National Regional State
APARI	Afar Pastoral Agricultural Research Institute
ARARI	Amhara Regional Agricultural Research Institute
ASE	Amhara Seed Enterprise
ATA	Agricultural Transformation Agency
ATT	Average Treatment effect on Treated
CADU	Chillalo Agricultural Development Unit
CAPI	Computer Assisted Personal Interview
CC	Contingency Coefficient
CSA	Central Statistics Agency
CSB	Community Seed Bank
DAs	Development Agents
DBoA	District Bureau of Agriculture
EABC	Ethiopian Agricultural Business Corporation
EGS	Early Generation Seed
EHNRI	Ethiopian Health and Nutrition Research Institute
EIAR	Ethiopian Institute of Agricultural Research
EIBC	Ethiopian Institute of Biodiversity Conservation
ESE	Ethiopian Seed Enterprise
FAD	Food Availability Decline
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agricultural Organization
FCS	Food Consumption Score
FED	Food Entitlement Decline
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GFSI	Global Food Security Index
GHI	Global Hunger Index
GIZ	Gesellschaft für Internationale Zusammenarbeit
HFBM	Household Food Balance Model
HFIAS	Household Food Insecurity Access Scale
HLIs	Higher Learning Institutions
IAR	Institute of Agricultural Research
IBCR	Institute of Biodiversity Conservation and Research
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ISSD	Integrated Seed Sector Development

ISTA	International Seed Testing Association
KBM	Kernel-Based Matching
KII	Key Informant Interview
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
MRA	Minimum Recommended Allowance
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
NNM	Nearest Neighbor Matching
NSIA	National Seed Industry Agency
NVRC	National Variety Release Committee
OARI	Oromia Agricultural Research Institute
ONRS	Oromia National Regional State
OSE	Oromia Seed Enterprise
PBR	Plant Breeder Right
PSCs	Private Seed Companies
PSM	Propensity Score Matching
RARIs	Regional Agricultural Research Institutes
RBoA	Regional Bureau of Agriculture
RM	Radius Caliper Matching
RQCAA	Regional Quality Control Assurance Agency
RSEs	Regional Seed Enterprises
SARI	South Agricultural Research Institute
SDG	Sustainable Development Goals
SoPARI	Somali Pastoral Agricultural Research Institute
SPCUs	Seed Producer Cooperative Unions
SPSS	Statistical Package for Social Science
SQIL	Seed Quality Inspection Laboratory
SSA	Sub-Saharan Agriculture
SSE	South Seed Enterprise
STATA	South Texas Art Therapy Association
TARI	Tigray Agricultural Research Institute
TLU	Total Livestock Unit
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
UN-OCHA	United Nations Office for the Coordination of Humanitarian Affairs
VIF	Variance Inflation Factor
WB	World Bank
WFP	World Food Program
WHO	World Health Organization

List of published and unpublished papers

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Abstract

Seed systems encompass a variety of technologies, organizational structures, and market and non-market institutions that allow seeds to be accessed and used by smallholder farmers through both formal and informal systems. The role of seed systems in ensuring the food security of smallholder farmers has received little attention, and the factors that influence household food security are seed supply and adoption of certified seeds. Therefore, the aim of this study is to examine the seed systems, adoption, and impact of improved wheat, teff, and maize varieties on household food security in central Ethiopia. A pragmatism philosophical approach used both quantitative and qualitative data to deliver the best understanding of the research problem and research questions. The primary data was generated from 299 sample respondents selected using systematic random sampling techniques, 25 key informant interviews, and six focus group discussions. Secondary data was also used to supplement the primary data. The data were analyzed using econometric models and descriptive statistics. The logit model, multinomial logit model, and binary probit model were among the econometric models used to analyze the quantitative data. A propensity score matching (PSM) method was also used to estimate the impact of improved variety adoption on household food security. The Household Food Balance Model (HFBM), Household Food Consumption Score (FCS), and Household Food Insecurity Access Scale (HFIAS), were used to investigate the status of household food security. The qualitative data were analyzed using stakeholder analysis to describe, categorize, narrate, and discuss. The findings revealed that a gap in the seed systems was inadequate certified seeds, inefficient extension service, limited seed distribution and marketing mechanisms, weak linkage among seed actors, low private sector participation, and a lack of a clear seed policy. The findings indicate that farmers have limited access to seeds from formal systems. It implies that about 18% of the households were food secure, 32% mild, 41% moderate, and 9% severely food insecure. The result showed that the mean daily calorie intake was 73% of the MRA. The PSM result revealed that the adoption of improved crop varieties had a significant and positive impact on food availability an average of 414 kcal/ day, a food consumption score of 5.14, and the yield increased by about 9.87 quintals per hectare than the non-adopters. In conclusion, the seed system has encountered numerous constraints that should be investigated further in order to decrease the limits and gaps, all actors' linkages must be strengthened. The government should prioritize extension services, expanding access to certified seeds, market opportunities, and equipping competent farmers with knowledge. Policymakers and development partners are focusing on providing more effective agricultural services to overcome low adoption rates. In order to address food insecurity and strengthen the resilience of smallholder farmers, seed accessibility and the seed supply chain needed to be improved in the study area.

Keywords: Seed systems, Adoption, improved crop varieties, food security, Ethiopia

Chapter 1: General Introduction

1.1. Background of the Study

In the world, food security integrates a measure of resilience to food supply disruptions and the lack of income due to various risk factors including droughts, shipping disruptions, fuel shortages, economic instability, and wars (WHO *et al.*, 2020). Household food security is considered to exist when all members, at all times, have access to enough food for an active and healthy life, contrarily, food insecurity refers to a state in which there is a lack of access to safe, nutrient-dense foods, as well as a limited or uncertain ability to do so (FAO, 2020; WHO, 2020). Globally, 820 million people are food insecure, and two billion people experienced moderate to severe food insecurity and do not have consistent access to nutritious and sufficient food, even if they do not go hungry (FAO, 2021). Hence, even without the negative consequences that COVID-19 is likely to have on hunger, the world is off track to achieving Zero Hunger (FAO, 2021).

The distribution of the total number of people suffering from food insecurity, 1.03 billion are in Asia, 205 million in Latin America and the Caribbean, 88 million in Northern America and Europe, 5.9 million in Oceania, and 675 million in Africa (FAO, 2021). In Sub-Saharan Africa (SSA), food security is a critical part of the sustainable development goals (SDG) and government policies (Bjornlund *et al.*, 2022). The current projection shows that Africa is not on track to achieve SDG 2.1 of Zero Hunger "end hunger and ensure access by all people, in particular, the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round" by 2030 (FAO, 2021; Oluwole and Olagunju, 2022).

In Ethiopia, over 20.1 million people are food insecure in various regions, accounting for nearly 16.7% of households, more than 20 million people are affected by conflict, violence and natural hazards, including 13 million people suffering from the most severe drought, over 17.5 million people need assistance in agriculture (OCHA, 2023). The extended drought has been devastating to herds, crops, water availability, and household incomes in the region, pushing the number of people facing acute food insecurity (UN-OCHA, 2022). Ethiopia is one of the world's most hungry countries, ranked 104th out of 116 countries (GHI, 2022). However, according to the Global Food Security Index (2022), it is placed 100th out of 113 nations. This index measures food security based mainly on the accessibility, quality, safety, and sustainability of food (GFSI, 2022).

The agricultural sector is the most important economic activity in developing countries providing food, employment, foreign exchange, and raw material for industries. It accounts for a comparatively small share of the global economy but remains central to the lives of majority of the people in the countries. Out of the world’s 7.1 billion people, an estimated 19% were directly engaged in farming, and just represented 2.8% of the overall global income during the time (World Bank, 2018). Agriculture is important for food security and a core driver of Ethiopia's economy, recently accounting for about 35% of the national gross domestic product (GDP), supporting 80% of the population's livelihoods, and 84% of total export earnings of the country (World Fact Book, 2021). The sector is dominated by over 15 million smallholder farmers producing about 95% of the national agricultural production. This shows that the overall economy of the country and the food security of the majority of the population depend on smallholder agriculture (CSA, 2020). Subsistence and rain-fed agricultural production is the main source of livelihood for more than 85% of the population in the country. However, the agricultural sector is incapable of feeding its population, and hence the country faces great trouble in its struggle to manage its food insecurity problem.

Ethiopian agriculture faces several challenges, including climate change, fragmentation and deterioration of farmland, pests, a lack of integration among stakeholders, and political instabilities, unplanned urbanizations (MoA, 2021). Insufficient yields due to inefficient/ineffective input use and service provision, inadequate investment in rural development, undeveloped irrigation, marketing and logistical issues, and a lack of agriculture-specific finance services are the sector's key binding constraints (Gebisa, 2021; MoA, 2021). In addition, undeveloped mechanization, non-commercial, subsistence production and smallness of farm size with no clear pathways of transformation are challenges of the sector. However, this study concentrated on the gaps in specific crops (wheat, teff, and maize).

Wheat (*Triticum aestivum L.*) is one of the major food and cash crops for smallholders in Ethiopia, dominating food habits and dietary practices, and a major source of energy and protein in the country (Wordofa *et al.*, 2021). It is important cereal crop with annual production of about 5.78 million tons and cultivated on an area of 1.9 million hectares (CSA, 2021). According to CSA (2021), it accounts about 19% of the total cereal production and contribute the grain production about 17 %. The national average wheat yield in Ethiopia was 1.83 tons/ha in 2009 and increased to 3.1 tons/ha in 2021. This production is below the average global yield of 4 tons/ha. However, the primary rain-fed wheat yields for smallholder farmers in Ethiopia are still low and lagging behind other countries. The utilization of wheat has increased due to the growing of urbanization and the expansion of agro-industries used as raw material, and also considered to attain food security (Bedilu *et al.*, 2021). To feed the rapidly growing population and meet the high demand of wheat in the country, it needs to increase the production and yield of wheat. Though, increasing yield requires successful adoption of improved wheat varieties (Karolina and Malgorzata, 2020). Low yield due to low adoption of improved varieties is believed to be the main factor that prevented agricultural production from coping with the country's fast population expansion.

Teff (*Eragrostis Teff*) is an ancient grain, central to the Ethiopian diet and culture. It is also gluten-free and high in iron and fiber, which in recent years has caused its demand to surge on the international market (Abate *et al.,* 2019). However, until teff is considering as an orphan crop, no receiving international attention regarding research on breeding, agronomic practice, and other technology application to smallholder farmers. According to CSA (2021), annual production of teff was about 5.5 million tons and cultivated on an area of 2.9 million hectares. It contributes 16% of the nation's overall grain production and 18% of the total cereal crops. Approximately 25 to 30 million people rely directly on teff production. The teff yield was 1.9 tons/ha, which is associated with low utilization of modern ideas, outdated seed sources, post-harvest damage, and lack of high-yielding cultivars (Hailu *et al.,* 2022). However, various region-specific pieces of evidence suggest low adoption of improved teff varieties in the nation. This low rate is typically caused by a number of problems, including the expensive cost of seeds and desired cultivars, ignorance, and farming practices.

Maize (*Zea mays L*) is a major cereal crop in Ethiopia that is widely produced and consumed by smallholder farmers, who makeup around 80% of the population (CSA, 2021). It is vital to maintain farm household food security, particularly in drought prone areas, leading all other cereals in terms of production and productivity (Dawit *et al.*, 2018). According to CSA (2021), approximately 10.6 million tons of maize were produced and cultivated on an area of 2.5 million hectares with yields of 4.2 tons/ha. To increase the maize productivity, Ethiopia has pursued the application of certified seeds of improved variety and accompanying inputs, focusing on high rainfall areas. As far as Open Pollinated Varieties (OPVs) and hybrid maize are concerned, each has its own advantages and disadvantages. OPVs are composed of plants of different genetic makeup that respond differently to environmental stresses, such as drought, and they are more stable in yield. The seed of OPVs can be recycled for an average of three years without considerable yield reduction thus, suitable for small scale farmers. On the other hand, hybrids are high yielders, needing more stable moisture conditions and intensive management. Hybrids have uniform flowering dates and are highly affected by any window of drought particularly during flowering, therefore less stable in yield than OPVs. Furthermore, hybrid seed has to be renewed every year. In this aspect, OPVs of maize seed is a high priority over hybrids. However, the average productivity of maize is still low in drought prone areas, because the adoption rate of improved maize varieties is low and farmers using old varieties that do not have drought tolerance traits.

Seed is one of the basic agricultural inputs, and access to improved and adapted seeds is a necessary for production (Sperling and McGuire, 2010). Improving the availability of high-quality seeds of well-adapted varieties is important to boost agricultural productivity, leading to higher farm income, reduced poverty, and improved food security (Abdoulaye *et al.*, 2009). Even if seed is a basic input in crop production, poor farmers cannot get adequate access to it due to lack of improved and adapted seed varieties, lack of seed supply, lack of extension support services, non-affordable seed prices, and poor farmers' seed-saving practices (Marja *et al.,* 2008). Given the significant current and future role of the agriculture sector, a vibrant seed system that provides quality seed to meet farmers' demands is an essential facilitator to Ethiopia's economic and social development.

A seed system refers to physical, organizational, and institutional components, their actions, and interactions that determine seed conservation, improvement, supply, and use (Teshome, 2021). According to FAO (2020), the seed system is the economic and social mechanism by which farmers' demand for seed and other desirable seed traits is met by various sources of supply. De Boef *et al.* (2010) described a seed system as a collection of dynamic interactions between seed supply and demand that lead to the use of seeds and subsequently plant genetic resources at the farm level. Different authors classified seed systems into different types: formal and informal, while others classified as local and formal (World Bank, 2018). Dejen (2021) noted that the seed system is divided into traditional, commercial, and alternative seed systems. ATA (2017) classifies it as a formal, informal, and intermediate seed system. Currently, the share of the formal seed system is estimated to be about 10-20% of the actual demand of the country and less than 5% of the cultivated area is covered by certified seed (Dejen, 2021). About 60-70% of seed used by smallholder farmers is saved on-farm and exchanged among farmers, and the remaining 20-30% is borrowed or purchased locally (ATA, 2017). According to CSA (2021), the informal seed system accounts for 90% of the seed used by smallholder farmers while the share of certified seed is less than10%.

Adoption of improved varieties is the means for boosting agricultural production and productivity, poverty alleviation, and food security. Some farmers cannot easily adopt improved agricultural technologies due to different factors. There are a lot of scholarly literature reports on constraints to adoption, such as the nature and awareness about the technologies, risk aversion, institutional constraints, lack of human and financial capital and lack of infrastructure (Rogers, 2003). Adoption studies can be beneficial for a variety of reasons, including providing useful feedback from farmers and helping in the refinement of technology generation and dissemination efforts, assessing the effectiveness of a technology transfer strategy and improving the flow of information between research and extension and policymakers, and documenting the impact of technology generation or extension (Assefa and Gezahegn, 2010). The farmers, however, demand for new technologies governed by factors related to household characteristics and socio-economic circumstances.

Therefore, the main aim of this study was to analyze the seed system actors' roles, responsibilities, and linkages; assess the seed supply system, access to certified seeds and its effect on improving food security of farm households; determine the factors influencing the adoption of improved varieties; and examine the impact of adoption of certified seeds of improved wheat, teff, and maize varieties on household food security in central Ethiopia.

1.2. Statement of the Problem

The Ethiopian seed system has been confronted with several constraints such as a lack of a clear seed policy/strategy (Mohammed, 2017; Addis, 2015); inefficient extension service (Getachew *et al.,* 2020; Dawit *et al.,* 2019); inadequate certified seed supply (Kassa and Merkine, 2020; Yehuala, 2019); weak coordination and linkage between different actors, lack of information as to what are the possible factors hindering effective linkage, and lacks functionality in the seed systems (Tesfaye, 2017; Bayissa, 2015); low private sector involvement in the formal system; inefficient seed promotion, distribution, and marketing mechanisms (Kumulachew, 2015; Dawit *et al.,* 2019); weak variety release and seed quality assurance system (Joshi and Braun, 2022; Tefera *et al.,* 2020; Karta and Dey, 2022). The Ethiopian seed policy has not been revised for a long time and this had negative consequences for plant genetic resources conservation, plant breeding research & development, as well as seed production and distribution system (Mohammed, 2017). The latest national seed policy and strategy is drafted in 2020.

Most farmers in Ethiopia have very limited access to high-quality seeds of improved varieties, and many released varieties of different crops with higher traits have not still been widely disseminated. Some of the specific challenges associated with seed include the limited capacity and lack of role clarity of the different actors, the seed system focuses on very few crops and varieties, weak seed demand assessment, and a mismatch between supply and demand in the formal system (Dawit *et al.,* 2019; Stellmacher and Kelboro, 2019). There are also several factors related to farmers that hinder the use of certified seed varieties, such as new varieties developed by agricultural research institutions do not have the attributes required by farmers; distribution channels for certified seed with suitable varieties fail to reach small-scale farmers on time, at an affordable price, and accessible locations; and extension services or agricultural credit institutions fail to provide the necessary input to farmers (Kasa and Merkine, 2020). The unavailability of certified seeds at the right place and time coupled with poor promotion due to the inefficiency of the seed systems are the key factors accounting for the limited use of certified seeds, which contributes to low agricultural productivity in Ethiopia (Temesgen, 2019).

The adoption of enhanced agricultural technologies is a technique for boosting productivity in the agricultural sector, alleviating poverty, and ensuring food security. However, farmers cannot easily adopt improved agricultural technology due to various factors, and many adoptions are not well understood if they are late (Shiferaw et al., 2014). Solomon (2020) indicated some studies have reported multiple barriers to adoption including technology awareness, risk aversion, institutional restrictions, and lack of human and financial capital and infrastructure.

Since the 1970s, Ethiopia has introduced and released about 1489 crop varieties. Among cereal crops, 99 varieties of wheat, 54 enhanced teff varieties, and 77 improved maize varieties were released, and avail farming methods to farming communities and many recommended technical packages have been developed by national and regional research centers (MoA, 2021). But still, the smallholder farmers in the study area face a shortfall of certified seeds.

Hence, it is important to take into account assessing the seed system with institutional frameworks for the development of the seed sector and improving production, productivity, and food security, identifying the constraints and opportunities of the seed sector, dissemination of seed of improved varieties, and assessment of the prevailing knowledge gap. As a result, this study attempts to contribute to the body of literature on a gap in the limited availability of early generation seed, pricing mechanism, lack of clear communication, role and responsibility among various seed actors, limited adoption of improved varieties, and food availability and access by analyzing the seed system, actors' roles and responsibilities, and linkages; assessing the access to quality seed of improved varieties; factors affecting the adoption of improved varieties; and examining the impact of improved varieties on household food security in the study areas.

1.3. Objectives of the Research

The overall objective of the study was to examine the seed system, adoption, and impact of improved crop varieties on household food security in central Ethiopia.

Specifically,

- To analyze the seed system actors' roles, responsibilities, and linkages.

- To assess the seed supply system, access to certified seed and its effect on improving the food security of farm households
- To identify the determinants of the adoption of improved varieties of wheat (*Triticum aestivum*), teff (*Eragrostis teff*), and maize (*Zea mays L.*).
- To examine the impact of the adoption of improved crop varieties on household food security in Central Ethiopia.

1.4. Research Questions

The study explored how the seed system and adoption of improved varieties oversee the food security of farm households in central Ethiopia. It is underpinned on the fundamental theory that the seed supply system, access, and adoption are key to enhancing farm household food security. This study responds to the following research questions in the farming households' context:

1) What are the gaps among the seed actors' roles, responsibilities, and linkages? How the existing seed system is functioning in the study area? (Chapter II)
2) What are the factors that influence seed access and supply system? (Chapter III)
3) What are the determinants affecting the adoption of improved wheat, teff, and maize varieties? (Chapter IV)
4) To what extent does the adoption of improved crop varieties contribute to food availability, consumption, yield, and household food security? (Chapter V)

1.5. Significance of the Study

This study emphasized on the seed systems, adoption, and impact of improved crop varieties on household food security. Food insecurity and poverty are serious issues in Ethiopia, particularly among the rural population that relies primarily on subsistence farming with low productivity. To alleviate poverty and achieve food security, there should be a clear mechanism for improving the productivity of smallholder farmers by providing new technologies. One of these technologies is certified seeds. The study is significant with its findings, lessons and recommendations on how the seed system, adoption behavior and its impact on household food security can be improved for sustainable agriculture sector development. Therefore, the findings from this study will be benefiting for the public and private seed sectors, which assist government policy-makers in designing future policies and strategies to make relevant decisions to intervene in the seed sector. Furthermore, it adds a useful reference for researchers and others for further studies in the study areas.

1.6. Scope and Limitation of the Study

The scope of this study was confined to the exploration of the impact of seed systems and adoption of improved crop varieties on the food security of farm households. Specifically, it addresses the seed system actors' roles, responsibilities, and linkages; the seed access and supply system to farm households, and factors affecting the adoption of improved crop varieties. The study focused on three districts- Ada'a and Bora from the Oromia region and Moretena Jiru from the Amhara region who participated in the main cereal crops (wheat, teff, and maize) production. The study used cross-sectional data and applied a mixed approach method gathered from sample households, key informants and secondary sources.

The limitations of this study include that the study only considered three major crops. The study was undertaken in only three districts due to time, financial, and current situation constraints and was unable to include other major maize-growing districts in the country in order to increase the sample size. One of the limitations of this study is that adoption and impact were analyzed using smaller numbers of farming households who adopted improved varieties. This could limit the generalizability of the results from quantitative models across the population. Moreover, as the study was conducted in the time of national political instability, the production system may also be affected and the system description may deviate from the times of stable political circumstance, even though there is a general agreement that the effect is not significant in the study areas.

1.7. Literature Review

1.7.1. Conceptual and theoretical foundations

Basic concepts:

Seed systems is a set of activities contributing to variety development, seed production, and delivery to farmers. De Boef and Edeme (2013) classified the seed systems as farm-saved seed, community-based, public companies, commercial companies, and closed value chains.

Agricultural Transformation Agency (ATA, 2017) has recognized the three seed systems in the Ethiopian seed sector: formal, informal, and intermediary. According to Dejen (2021), the seed systems characterizes informal with low quality, formal with low quantity, and an intermediate system contribution to seed production.

A formal seed system - represents certified/commercial seed production and marketing, usually by seed companies and governments, and includes the importation of seed under the supervision of a national seed service.

The informal seed system - represents farming households and communities producing, saving, selling or exchanging uncertified seeds of improved varieties and local landraces.

The intermediate seed system - is the line between the formal and informal seed sectors that can become somewhat blurred, as seeds of improved varieties can be saved by farmers and eventually considered as “local variety” or “local seed” after some years of usage.

Food security is a dynamic concept, which has continuously integrated new dimensions and levels of analysis over the years. It is a concept that has evolved considerably over time and its definitions developed and diversified by different researchers, scholars, and organizations (Clay, 2002). The food security concept originated in the mid-1970s during the international discussion on the global food crisis. The initial focus of food security attention was primarily on food supply problems of assuring the availability and to some degree the price stability of basic foodstuffs at the international and national levels (FAO, 2005). World Food Conference in 1974 was held to solve the problem of world food crises and major famines around the world. Food security and insecurity are terms used to describe whether or not households have access to sufficient quality and quantity of food. With progress in time and the severity of the problem, food security issues gained prominence and great attention at the global, national, household, and individual levels. Without much change in the basic concepts, different institutions and organizations define food security in different ways. With regard to this, there are approximately 200 definitions and 450 indicators of food security. However, the most comprehensive definition comes from FAO (2002) stated that “when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets dietary needs and food preferences for an active and healthy life”. FAO (2004) stated, “Food that is available to everyone at all times, that they have means of access to it, that it is nutritionally adequate in terms of quantity, quality and variety, and is acceptable within the given culture". In recent studies, food security defined as "adequate availability of and access to food for households to meet the minimum energy requirements as recommended for an active and healthy life" (Hussien and Janekarnkij, 2013). The absence of any of these conditions at household, regional and national levels causes food insecurity.

Food insecurity is a concept for the situation that occurs at the individual, household, or national level that has neither physical nor economical access to the nourishment they need. A household is said to be food insecure when its consumption falls to less than 80 per cent of the daily minimum recommended allowance of caloric intake for an individual to be active and healthy. In particular, food insecurity includes low food intake, variable access to food, and vulnerability, a livelihood strategy that generates adequate food in good times but is not resilient against shocks.

The **seed security** concept can potentially help bring forth seed system analyses that inform policymakers and development actors of such potentially harmful side effects of formal seed system development, as well as effective policy measures within both formal and informal seed systems that contribute to strengthening farmers' livelihoods (Sarah and Ola, 2020). Frameworks based on the seed security concept unpack the complexity of seed systems by separating key dimensions such as availability, accessibility, quality, varietal suitability, and diversity. In this regard, seed security is an extremely relevant concept for the development sector (Sarah and Ola, 2020). A household is a seed secure when it has sufficient access to adequate quantities of good quality seed and planting materials of preferred crop varieties at all times following both good and bad cropping seasons (FAO, 2016). Therefore, seed insecurity exists when any of the above aspects is significantly constrained. An effective seed intervention can only be designed upon the understanding of a seed system concerning the aforementioned (Sperling and McGuire, 2010).

Adoption is the integration of a new technology into existing practice and is usually proceeded by a period of "trying" and some degree of adaptation (Loevinsohn *et al.,* 2013). Challa (2013) describes adoption as a mental process an individual pass from first hearing about an innovation to final utilization of it. It has two categories: rate of adoption and intensity of adoption. Rate of adoption is the relative speed with which farmers adopt an innovation, and has as one of its pillars, the element of time. While the intensity of adoption refers to the level of use of a given technology in any time period. Technology adoption is a complicated task since it varies with the technology being adopted. Adoption can be classified as an *individual (farm level) adoption* and *aggregate adoption*. Adoption at the individual farmers‟ level is defined as the degree of use of new technology in long-run equilibrium when the farmer has full information about the new technology and its potential. In the context of aggregate adoption behaviour, they defined the diffusion process as the spread of new technology within a region. This implies that aggregate adoption is measured by the aggregate level of specific new technology within a given geographical area or within a given population (Gishu *et al.*, 2018).

Theoretical underpinning/ foundations:

The theoretical foundations for seed systems can be analyzed from different perspectives. The market perspective often used to analyze seed systems, places much emphasis on farmers' uptake of new varieties (Tripp, 1997). Seed system analysis from a regulatory framework's perspective cares more about formal arrangements and processes leading to seed release (Muhhuku, 2002). Another way of analyzing seed systems is to focus on characteristics that differentiate between informal and formal seed supply systems, public and private actors' involvement and achievements and more attention is often given to perceptions of end-users of seeds (Etwire *et al.*, 2013).

There are also theoretical underpinning for food security situation analysis which have progressively developed and expanded over time. Accordingly, Hussein (2006) also revealed that it is impossible to employ a single theory to best analyze the whole aspect of food security as each theory has its weakness in light of the multi-disciplinary nature of food security. With this view in mind, the study employed the two most commonly used theoretical approaches, in the context of subsistent farm households. The first approach is the *General Explanation*, in this regard, some environmental and socioeconomic attributes are concerned. The principal ones include ecological degradation, climatic elements, government mismanagement, and unequal access to resources, unequal exchange, socio-economic factors, and political unrest. The argument here is that one or a combination of these can disrupt food production. The second approach is through food security models of which only *Food Availability Decline (FAD)* and *Food Entitlement Decline (FED)* are considered. This study is generally framed by the complementary point of the above approaches. However, some interconnected biophysical and socioeconomic factors influence household food availability and accessibility, determining whether households are food secure or food insecure.

The emergence of the concept of food security very much relates to the political concerns towards fighting an increasing malnutrition and famine at global level. The early years of the 1970s was when the proportion of the malnourished world population was higher than ever before. At that time the UN/FAO took the initiative to call upon the world nations to take part in the first world food conference in 1974, which adopted the universal declaration on the eradication of hunger and malnutrition. The declaration states that "Every man, women and child has the unchallengeable right to be free from hunger and malnutrition in order to develop fully and maintain their physical and mental faculties" (UN, 1975). Hence, the main emphasis was how to enable the world able to feed every individual, at global level, and what should every nation do to become food self-sufficient.

Thus, the issue of food security has therefore become central to academic research. To this effect, many studies have been conducted with the aim of identifying explanations for food insecurity, particularly in various regions of the world where food insecurity has been a prevalent problem. Research efforts were directed towards understanding the main constraints to increasing agricultural production, thereby resulting in sufficient food availability at the national level. The outcome of these efforts was the emergence of the theory of the *Food Availability Decline (FAD).* According to this theory, a decline in food availability may be attributed to various factors, specifically demographic (such as rapid population growth, diminishing of per capita livelihood resources, land fragmentation and competition over resources) and natural hazards, including drought, flood, pest and, crop and livestock diseases.

There are two economic approaches to explaining food insecurity: *Food Entitlement Decline (FED)* and *'market failure'*. The FED model is pioneered by Amartya Sen (1981) as an alternative method to FAD. His theory has brought about a shift in famine analysis, from seeking explanations for the short supply to the identification of symptoms of the failure in demand. It suggests that food availability in the economy or in the market does not entitle a person to consume, and famine can occur without aggregate availability decline. Sen presents a range of evidence for his argument: the Bengal famine of 1943, the Ethiopian famines of 1973 and 1984 and the Bangladesh famine of 1974. Maxwell and Smith (1992) reported in their study that one of the strong points of the FED approach, which distinguishes it from the FAD counterpart, is the potential capacity to identify which group of people will be affected by various threats of availability or access to food. However, the model has certain weaknesses to be addressed before directly applying it as a framework for a study of food security.

The main limitations of the FED model include failure to take into consideration the intra-household distribution of food; exclusion of relief entitlement (aid food); concentration on proximate causes of famine; heavy focus on food deprivation; omitting all non-legal transfers of resources, failure to give attention to the significance of cultural preferences and tastes; no temporal dimension; and cannot account for changing vulnerability to entitle failure. Devereux (2006) revealed a possible economic explanation for food insecurity related to market failure, which is demand (pull) failure and supply (response) failure. Pull failure refers to people's lack of purchasing power which is caused by poverty and can therefore be explained in terms of lack of exchange entitlements to food. While response failure happens when markets fail effectively to meet people's demands. This is a critical contribution since it resolves one of the major disagreements between FAD and FED supporters.

Therefore, food security is defined as the continual availability of sufficient world supplies of fundamental foodstuffs to support steady rise in food consumption while compensating for changes in production and cost (UN, 1975). This concept makes it obvious that a country must have enough food accessible for consumption, either from domestic production or from outside imports, in order to be food-safe. The study sought to ascertain why agricultural productivity is low and how to increase food output to ensure national food security. In general, the Food Availability Decline (FAD) theory is guided this research, which concentrated on one aspect of the problem based on their area of concern and interest. The FAD theory prioritizes seed supply, but this does not ensure accessibility. Seed supply, on the other hand, is a necessary and a vital aspect in ensuring food security.

1.7.2. Related literature review

Seed systems in Ethiopia

Fischer and Edmeades (2010) and Abebe *et al.* (2017) clarify that the seed system in Ethiopia signifies the whole complex structure, institutional, and individual operations related to the development, multiplication, processing, storage, distribution, and promotion of seeds. De Boef *et al.* (2010) describe a seed system as a collection of dynamic interactions between seed supply and demand that lead to the use of seeds. FAO (2020) enlighten it is the economic and social mechanism by which farmers' demand for seed and other desirable seed traits is met by various sources of supply. Teshome (2021) simplify as physical, organizational, and institutional components, their actions, and interactions that determine seed supply, and use. Several scholars classified seed systems into distinct types: According to Dawit (2010) and Abebe (2010), seed systems organize into formal and informal, Louwaars *et al.* (2013) categorized as farm-saved, community-based, public companies, commercial companies, and closed value chains, World Bank (2018) sort as local and formal. Recently, an intermediate seed system has appeared in the Ethiopian seed sector and combines both the formal and the informal seed systems. Dejen (2021), and Teshome *et al.* (2021) noted that the seed system is divided into informal, formal, and intermediate seed systems with low quality and quantity. ATA (2017) has recognized the three seed systems in the Ethiopian seed sector and states as a "formal" or "commercial" seed sector that the seed of improved varieties is sold to farmers through farmer cooperatives, input suppliers, and other channels; the "informal" or "traditional" seed sector that farmers save seed from their harvest or exchange through social networks for the next planting seasons, gift, borrow, and buy informally; and "intermediate seed systems" imply coordinated actions between the formal and informal seed sectors.

Currently, the share of the formal seed system is estimated to be about 10-20% of the actual demand of the country and less than 5% of the cultivated area is covered by certified seed (Dejen, 2021). ATA (2017) mentions the informal seed system accounts for 90% of the seed used by smallholder farmers while the share of certified seed is less than 10%, there are good reasons which is a low-cost option for farmers to access seed, it is relatively cheaper, and readily available in the farmer's villages simply at the time of seed is required. The informal seed system includes farmers to farmer's exchange, farmers save seed, seed aid, NGOs support, community-based seed production, pre-scaling up and farmer's demonstration (Girma and Amanuel, 2017). According to ATA (2017), the intermediate sector is to focus on activities that identify and effectively address systemic challenges that hamper the growth of market-oriented yet limitedly regulated community-based seed enterprises and to strengthen a more decentralized seed production and dissemination system that complements the currently centralized formal seed system. The intermediate sector is specifically defined as business-oriented community-based groups (cooperatives and unions) that are engaged in the multiplication and distribution of noncertified seeds of either improved or local varieties.

The role, responsibilities, and linkages of the seed system actors

In Ethiopia, there are different actors in the seed sector, the national agricultural research system (NARS) supports the EIAR and RARIs, along with their research centers, and Higher Learning Institutions/ universities (HLIs) in producing improved varieties and materials required to produce and multiply certified seed for sale to farmers. Varietal release, seed certification, and quality control are performed by regulatory authorities such as MoA, RBoA, and district BoA. The Ethiopian Agricultural Business Corporation (EABC) former Ethiopian seed Enterprise (ESE) and regional seed enterprises (RSEs) produce and multiply seed of improved varieties on their farms, and to a limited extent bulk up a seed that is delivered to the local extension and supply system for inputs. The role of public seed enterprises is significant in Ethiopia. They are multiplying and distributing certified seeds for major crops of cereals, pulses, fruits, vegetables, and forages (Dawit *et al.* 2018). Before 1991, the ESE sold most of its seed directly to state farms, to farmers through NGOs, and to the Agricultural Inputs Supply Corporation (AISCO). The RSEs include Amhara Seed Enterprise (ASE), Oromia Seed Enterprise (OSE), and South Seed Enterprise (SSE) are started gradually replacing ESE as the sole public seed enterprise (Dawit, 2011). These public seed enterprises concentrate on a few crops (hybrid maize, bread wheat, teff, and barley) and have little interest or capacity (technical, facility, and finance) in investing in crops/varieties required by niche markets. Regional bureaus of agriculture, district offices, and extension agents working at the kebele level comprise the regional system. In seed production, distribution, and marketing, these organizations work closely with private seed companies, seed producer cooperative unions, NGOs, and seed agents & agro-dealers (ATA, 2017).

Seed supply system and access in Ethiopia

Various actors and stakeholders are involved in seed producing activities in Ethiopia. All of these contribute to the production, promotion, supply, and marketing of certified seeds in the country in one way or another. CSA (2021) reported in Ethiopia, less than 5% of the farmers using certified seed. Studies also show that only a small area of land is covered by certified seed. However, the total amount of certified seed used and the area of farmland covered by certified seed have increased during recent years. However, the supply of seeds of improved crop varieties is in shortage for such programs (Dawit, 2010). Seed multiplication by EABC and RSEs focused mainly on two cereal crops (wheat and maize) and the annual supply of certified seed by the enterprise doesn't exceed 20,000 tons.

A seed supply system is a collection of components, processes, and their organization, as well as the continuing interactions and support required in seed production and marketing. Breeding, multiplication, processing, quality control, certification, storage, and distribution are all distinct processes in the overall chain (Shimelis *et al.,* 2018). The formal seed supply system is not well developed in many developing countries, including Ethiopia. The informal seed supply system offers many opportunities for improving the seed security of small-scale farmers built on farmers' knowledge and capacities. Farmers' variety proven to be the best alternative in many situations, given the local climate, soils, limited resources, and various household demands. Hence, the majority of the seed demand in Ethiopia is filled by the informal sector. Certified seed supply is essential for the improvement of food security and farm household livelihood (McGuire and Sperling, 2011). In that aspect, a formal seed system that functions adequately feeds the informal seed system, and they are noted to be complementary (Almekinders *et al.*, 2007). Furthermore, the seed supply system benefits small-scale farmers by raising productivity, increasing small farmers' income, reducing poverty and enhancing food security, and facilitating the transition to a viable commercial agricultural sector. (Giusti, 2004).

Access to certified seed is the ability to acquire seed through social network trade, loan, barter, or use of power. Farmers can access seeds from a different source, including the district bureau of agriculture, unions, cooperatives, seed enterprises, local markets, and research centers. Bassa *et al.* (2018) stated that even though the formal seed sector takes a larger share of certified seed dissemination, still most of the farmers used seed from informal seed systems, including own-saved seed, and exchange farmer-to-farmer. Dawit *et al.* (2019) indicated the farmers do not have access to certified seeds and they widely use the local varieties since the certified seeds are very expensive. Accessibility to certified seed is a critical component in enhancing agricultural production and stimulating technology adoption in smallholder agriculture. Farmers in the study area have frequently mentioned seed scarcity as a major limitation. A number of initiatives that have addressed this issue through sustainable local seed production have resulted in increased access to adequate, economical, and timely seeds. However, initiatives are being made to encourage the private sector to contribute to the efficient production and distribution of seed.

Adoption of certified seeds of improved varieties

Farmers cannot easily adopt certifies seeds of improved varieties due to different factors and incase the adoption level is going slowly, and many aspects of adoption is not well understood. There are a lot of scholarly literature reports on constraints to adoption, such as the nature of the technology, awareness about the technologies, risk aversion, institutional constraints, lack of human and financial capital and lack of infrastructure (Rogers, 2003). According to Solomon (2020), adoption and diffusion theory have been widely used to identify the determining constraints that influence the decision of the user whether to adopt or not. The process of adopting new technology has been studied by different scholars, Mishra *et al.* (2015) indicated it is quite known that adoption decision is not permanent rather it could change at any time due to a number of reasons. Rogers' (2003) revealed the innovation-diffusion model, and an individual passes through five stages from hearing about an innovation to adoption, and these are knowledge, persuasion, decision, implementation and evaluation stages. He identifies five characteristics of innovations that impact the speed of adoption, these include relative advantage, compatibility, complexity, divisibility, and observable. Similarly, Hall (2003) highlighted two other factors that influence the rate of adoption: variances in the cost of adoption and the technology's group action needs. He argued that the adoption of improved technology is determined by profitability, riskiness, divisibility, complexity, and availability. Feder *et al.* (1985) stated that the adoption decision and intensity of adoption are made simultaneously in the process of adoption. Farmers have always chosen whether to adopt individual or aggregate adoption; singular or package technology; and divisible or non-divisible technology.

1.7.3. Empirical literature

The empirical literature review for this study is organized into three components. The first section includes evidence from seed system functioning, the second on determinants of adoption of certified seeds of improved varieties, and the third on findings from earlier studies on the food security situation and factors of food insecurity.

Empirical review on seed system in Ethiopia

The seed system is composed of organizations, individuals, and institutions involved in different seed-related functions. Abebe (2010) reported these seed-related functions to involve research and development, seed multiplication, seed processing, seed storage, seed marketing, and seed distribution. Scoones and Thompson (2011) explain seed system denotes a physical, organizational, and institutional components, their actions and interactions that determine seed conservation, improvement, supply, and use. Teshome *et al.* (2021) mentioned the system includes formal, informal, and intermediate seed systems. Loch and Boyce (2003) indicated the system must use an appropriate combination of formal, informal, market, and non-market channels to efficiently meet farmers' demand for quality seeds. Sthapit *et al.* (2008) and Almekinders and Louwaars (2007) in their study revealed that farmers' seed systems involve in farmers' seed selection, production, storage, and dissemination. Dawit (2011) and Ertiro et al. (2019) describe the formal system plays a crucial role in delivering certified seeds of improved varieties of certain crops, including maize, teff, and wheat. Louwaars *et al.* (2013) specified the formal seed system in the Ethiopian context is a system that involves a chain of activities leading to the certified seed of released varieties. Bishaw *et al.* (2010) indicated in their study both traditional varieties and improved varieties that have been released by the formal system in the past and integrated into the local seed system, which is obsolete improved varieties. Dawit (2010) pointed out that regulatory agencies, along with all actors involved in the seed chain, supervise the production and distribution of certified seed. However, Ariga *et al.* (2019) and Bishaw *et al.* (2010) state that the formal system is still at an early stage of growth and is dominated by public institutions. The formal seed system could not satisfy the seed demand of the vast majority of the nation's farmers, who are smallholders and subsistence farmers, particularly in remote areas.

Coomes *et al.* (2015), Fikre *et al.* (2012), and McGuire and Sperling (2016) shows farmers in some countries involve in the informal seed system for the selection of seed, multiplication, storage use, and distribution through social seed networks and local markets. It dominates in terms of delivering large quantities of seeds of a diversity of crop varieties. Vernooy *et al.* (2020) found globally about 60–90% of the seed is produced and distributed through the informal system. McGuire (2005) shows also up to 90% of the seed demand is fulfilled by the informal seed system.

Ayana *et al.* (2013), Kansiime and Mastenbroek (2016), Sisay *et al.* (2017), and Fadda and Van Etten (2019) pointed out the intermediate seed system has recently emerged from market-oriented community based seed producer groups that produce and market non-certified seeds of improved varieties and farmer-preferred local varieties. ATA (2017) and Hirpa *et al.* (2010) explained that the intermediary seed system also includes the production and marketing of seed by local farmers under financial and technical support from NGOs and breeding centers. In addition, the intermediate seed system includes non-profit community-based seed producers such as community seed bank (CSB) groups, who produce higher quality seed than typically produced by the informal system, even if it is not certified nor fully regulated under existing regulations.

Empirical studies on determinants of adoption of certified seeds of improved varieties

Empirical studies by Kinuthia and Mabaya (2017) and Ahsanuzzaman (2014) suggest that factors such as household characteristics, farm characteristics, and socioeconomic and institutional characteristics influence the adoption rate of improved crop varieties among farmers and impact the adoption decision. According to Gishu (2018) and Degefu (2017), the ***Sex*** of the household head has been found negatively influence the adoption of technology. In contrast to this finding, Asfaw *et al.* (2012) discovered that the sex of the household head negatively influences the adoption of the technology. The findings of several studies, ***Age*** has a positive link with the adoption decision (Ahsanuzzaman, 2014; Kinyanjui and Kinuthia, 2017). This means that as farmers get older, they gain knowledge and resource that allow them to experiment with new technologies. In contrast, Djido *et al.* (2013) found that age had a negative and substantial relationship with technology adoption. He claims, younger farmers are more willing to adopt new technologies since they are more educated than the older group. Mekonnen (2017) found that age has no effect on the adoption decision. The study conducted by Menale *et al.* (2015) studied whether there is a positive association between ***Education*** level and technological adoption. The year of education increases the likelihood of adopting certified seeds. In contrast, Ahsanuzzaman's (2014) study found no significant relationship between years of schooling and adoption decisions. The association between technology adoption decisions and ***Family size***, according to Menale *et al.* (2015), varies depending on the type of technology. Family size is beneficial to labor-intensive technologies. However, it has a negative influence for capital-intensive technologies. In contrast, Ahsanuzzaman (2014) found an insignificant but positive relationship between the two.

The impact of ***Farm size*** on technology adoption is determined by the characteristics of the new technology. In a study conducted by Menale *et al.* (2015) and Woldemariam and Gecho (2017), the size of farmland is expected to positively influence the adoption of agricultural technology because those operating larger farms have more financial resources, incentives, and land to allocate to improved varieties. Farmers with more ***Farming experience*** may have better abilities and access to information about improved technologies. More agricultural experience suggests more acquired farming knowledge and skill, which might aid in adoption. Chanido and Jiang (2018) and Sisay (2016) confirmed this theory and found a positive and significant relationship between farming experience and adoption. On the other hand, it has a negative link with adoption. Nevertheless, Jaleta *et al.* (2018) showed that there is no statistically significant association between farming experience and adoption. Yu and Nin-pratt (2014) and Hailu *et al.* (2013) stated that ***Farm income*** had a positive and significant effect on technology adoption. The income obtained from farm selling crops and livestock helps farmers to purchase farm inputs. Tura *et al.* (2010), Legese *et al.* (2010), and Diiro (2013) in their studies reported as ***off-farm*** income has a positive impact on technology adoption. Hailu *et al.* (2013) and Abadi *et al.* (2017) confirmed livestock holding (***TLU)*** by farmers has a positive impact on the farm's status, intensity, and speed of technology adoption, as well as the decision to implement recommended agronomic measures.

Extension service is one method of providing farmers with knowledge about new technologies. The majority of empirical studies suggest that ***frequent contact with extension*** has a positive and significant relationship with farmer adoption decisions (Menale *et al.,* 2015; Birhanu *et al.,* 2014). Most of empirical studies suggest that ***market distance*** has a negative and considerable impact on the decision to adopt technology. This view was confirmed by Hagos and Zemedu (2015), who highlighted that market distance is substantial and has a detrimental impact on the adoption of improved varieties. A study by Govind *et al.* (2015) and Obayelu *et al.* (2018) mentioned ***access to credit*** is positively and significantly linked to adopting improved crop varieties. It can make it easier for farm households to purchase necessary agricultural inputs and increase their ability to make long-term investments in their farms.

Empirical evidences on the food security situation and factors of food insecurity

Different studies were carried out in rural as well as urban part of the country and these studies concluded that the food security status of the households is different from region to region and from district to district. Empirical evidences argued that the majority of households in the central Ethiopia are food insecure. For instance, Beyene and Muche (2010) pointed out that about 64% of the households were food insecure and the rest 36% were food secure. It also revealed that the average value of the energy available for food-insecure and secure households was 1,822 Kcal/AE/day and 2,908 Kcal/AE/day, respectively. Girma (2012) showed the minimum and maximum energy available for food-insecure households was 1,043 Kcal and 2,098 Kcal, respectively. Whereas the minimum and maximum energy intakes of food-secure households were 2,203 Kcal and 3,492 Kcal, respectively.

In general, many of the natural and human-induced factors that made Ethiopia a food-insecure country at the national level over the last few decades are mentioned in a paper by Degefa (2002). Asenso-Okyere *et al.* (2013) investigated the determinants of food security in Ethiopia and discovered that the educational level of the household head, farm size, and livestock holding are the most significant factors influencing household food security. According to Nigatu (2004), livestock rearing, growing cash crops, and trading are important variables in achieving household food security. Feleke *et al.* (2003) indicated that farming system, farm size, family size, off-farm income, and wealth are considered to be determinants of food security. Birhanu et al. (2004) and Hailu (2012) suggested that the depth and intensity of food insecurity are high, influenced by poor functioning of marketing systems and other household and socioeconomic factors. Chalachew (2018) explains that in the household food security situation in central Ethiopia, 50% of the household were food insecure, 31% percent were moderately food secured and the remaining 19% were food secured. Furthermore, According to Degefa (2002) and Hussein (2006), the reasons of household food insecurity vary from one another. In general, environmental, demographic, economic, social, infrastructural, and political issues are all linked to food insecurity in Ethiopia.

1.8. Methodological Approach

1.8.1. Pragmatism as a Philosophical Underpinning of the Research

The worldview's philosophical ideas and elements are *post-positivism* (determination, reductionism, empirical observation and measurement, and theory verification), *constructivism* (understanding, multiple participant meanings, social and historical construction, and theory generation), *transformative* (political, power and justice-oriented, collaborative, and change-oriented), and *pragmatism* (consequences of actions, problem-centred, pluralistic, and real-world practice-oriented) (Neesham, 2018). These philosophical ideas in research still influence the practice of research and the nature of research that a researcher brings to a study. Cohen (2007) explained the philosophical foundation of any research is the reflection of the researcher's worldview, understanding, and method used to measure the social reality or social world. The philosophical assumptions or positions are a basic component of any research and, as such, need to be clearly set out at the beginning of the methodology section. According to Ormston *et al.* (2014), these assumptions are ontology, epistemology, methodology, and methods of investigating social reality, knowledge, and voluntarism.

There are various ontological and epistemological perspectives on the universe and knowledge, such as objectivism/constructivism and positivism/interpretivism. In positivism, facts and values are very distinct, thus making it possible to conduct an objective and value-free inquiry (Snape & Spencer, 2003). Objectivism derives from the acceptance of natural science as a paradigm to study human knowledge, methods for data collection and data interpretations similar to those used in natural science including hypothesis testing, causal explanations and modelling (Bryman, 2012; Ormston et al, 2014). Mayer (2015) states interpretivism and constructionism approaches argue that knowledge is produced by exploring and understanding (not discovering) the social world of the people being studied, focusing on their meaning and interpretations, i.e., meanings are socially constructed by the social actors in a particular context.

As a philosophical underpinning for mixed methods research, pragmatism philosophical assumption is applying the consequences of actions, attention to the research problem, and then using pluralistic approaches to derive knowledge about the problem (Morgan, 2007). Creswell (2014) asserted that pragmatism gives a philosophical view for research. Maxcy (2003) found that pragmatism in the historical contributions of philosophy embraces a plurality of methods. Lohse (2017) elaborated pragmatic philosophy has the discretion to choose and use both qualitative and quantitative research designs, methods, techniques, and procedures that best meet their research objectives. Pragmatism reconciles positivism and social constructivism by allowing the researcher to use mixed methodologies. Mitchell (2018) explained pragmatism as an appropriate philosophical foundation for social science research and stressed the need to apply and endeavor to use mixed methods thereby responding to research questions instead of choosing either a positivist or subjectivist view with implications to depend on either quantitative or qualitative research method only.

Therefore, pragmatism provides a philosophical basis for this study to use both quantitative and qualitative data to deliver the best understanding of a research problem and research questions; to look at many approaches for collecting and analyzing data rather than subscribing to only one way; and to establish a purpose for their mixing, a rationale for the reasons why quantitative and qualitative data need to be mixed in the first place employed in this dissertation.

1.8.2. Methodology

1.8.2.1. The study woredas settings

The study was conducted in three *woredas* Ada'a and Bora (East Shewa zone, Oromia region), and Moretina Jiru (North Shewa zone, Amhara region). According to USAID and MoARD (2016), the name of the *woredas* with their corresponding dominant livelihood zone are Ada'a (Ada'a Teff and Chickpea), Bora (Rift valley Maize and Horse bean), and Moretina Jiru (North Shewa highland Wheat and Teff).

Ada'a is one of the 14 *woredas* in the East Shewa Zone, Oromia National Regional State (ONRS) of Ethiopia, and has 27 *kebeles* (the smallest administrative unit). It is adjacent to Dugda Bora to the South, Akaki to the Northwest, Gimbichu to the Northeast, and the Lume district to the East. The administrative center is Bishoftu, about 45 km from Addis Ababa. Astronomically the district lies between latitude 8° 37' 30" to 8° 46' 30" N and longitude 39° 0' 00" to 39° 9' 00" E (Fig. 1.1). According to CSA (2017), national census projection, this district had a total population of 165,729, of whom 3% were in urban areas and 97.3% were rural residents. Altitude ranges between 1500 to 2000 meters above sea level and the mean annual rainfall was 839 mm. The minimum and maximum temperatures were between 7.9^{0}C to 28^{0}C. It covers an area of 1,750 Km^2 (IPMS, 2007). The farming systems are mixed in terms of crops and livestock. Major crop components are cereals (teff, wheat, maize, and sorghum) and pulses (chickpeas, field peas, faba beans, and lentils) grown at medium and high altitudes. Irrigated horticultural crops are emerging as a new opportunity in the district. Cattle, sheep, goats, and poultry are all produced as part of an existing market-oriented production system. In some locations within the district, farmers also produce honey.

Bora is located in the great rift valley of Ethiopia. It consists of 18 rural *kebeles* and is bordered by Lake Ziway to the southeast, Adami Tulu to the south, Southwest Shewa to the northwest, Awash River to the north, Lake Koka to the northeast, and Arsi to the east. The administrative center is Bote (Alem Tena) and it is about 238 km from Addis Ababa. Astronomically the district is located between latitude 8° 10' 30" to 8° 30' 00" N and longitude 38° 50' 00" to 39° 3' 00" E (Figure 1.1). The total population was estimated as 78,610, of whom 77% were in rural areas and 23% were urban residents (CSA, 2017). The altitude of the *woreda* ranges from 1650 to 2020 meters above sea level. The lowest and highest temperatures are 22^{0}C and 28^{0}C, respectively, and the annual mean rainfall is bimodally distributed and ranges from 750 to 805 mm. The total area of the district is estimated at 484.7Km^2(Wikipedia, 2020). The farming system is mixed, with major crops such as wheat, maize, teff, barley, chickpea, haricot beans, fruits, and vegetables.

Moretina Jiru is one of the 23 *woredas* in the North Shewa zone, Amhara National Regional State (ANRS) of Ethiopia, and has 15 rural *kebeles*. It is adjacent to the Siyadebrina Wayu to the south, Ensaro to the southwest, Merhabiete to the northwest, Menz Keya Gabriel to the northeast, and Basona Werana to the east. The administrative center is Enewari, about 175km from Addis Ababa. Astronomically the district lies between latitude 9° 52' 30" to 10° 1' 00" N and longitude 39° 1' 00" to 39° 18' 00" E (Figure 1.1). The district had 112,650 people, of whom 86% were in rural areas and 14% were urban residents (CSA, 2017). The altitude varies from 1350 to 1850 meters above sea level, and annual rainfall ranges from 450 mm to 761 mm. It covers an area of 706.2 Km^2 (Wikipedia, 2020). The district is characterized by a crop-livestock mixed farming system. In the rain-fed agriculture, farmers produce long-matured crops of wheat, teff, lentil, chickpea, faba bean, sorghum, and mung bean. The oil crops sesame and linseed are also produced. By using irrigation, the most common horticultural crops-vegetables and fruits are produced. The livestock reared in the district includes cattle, shoat, equine, and poultry. In most parts of the area, cattle fattening is used for income sources (DBoA, 2021).

These *woredas* were selected on cereal-based farming systems. Crop production and productivity have been showing a declining trend in the areas with limited use of certified seeds and weak seed supply systems. Moreover, the study sites are identified following justifications on the literature gap and the researcher's personal observations of the research problems.

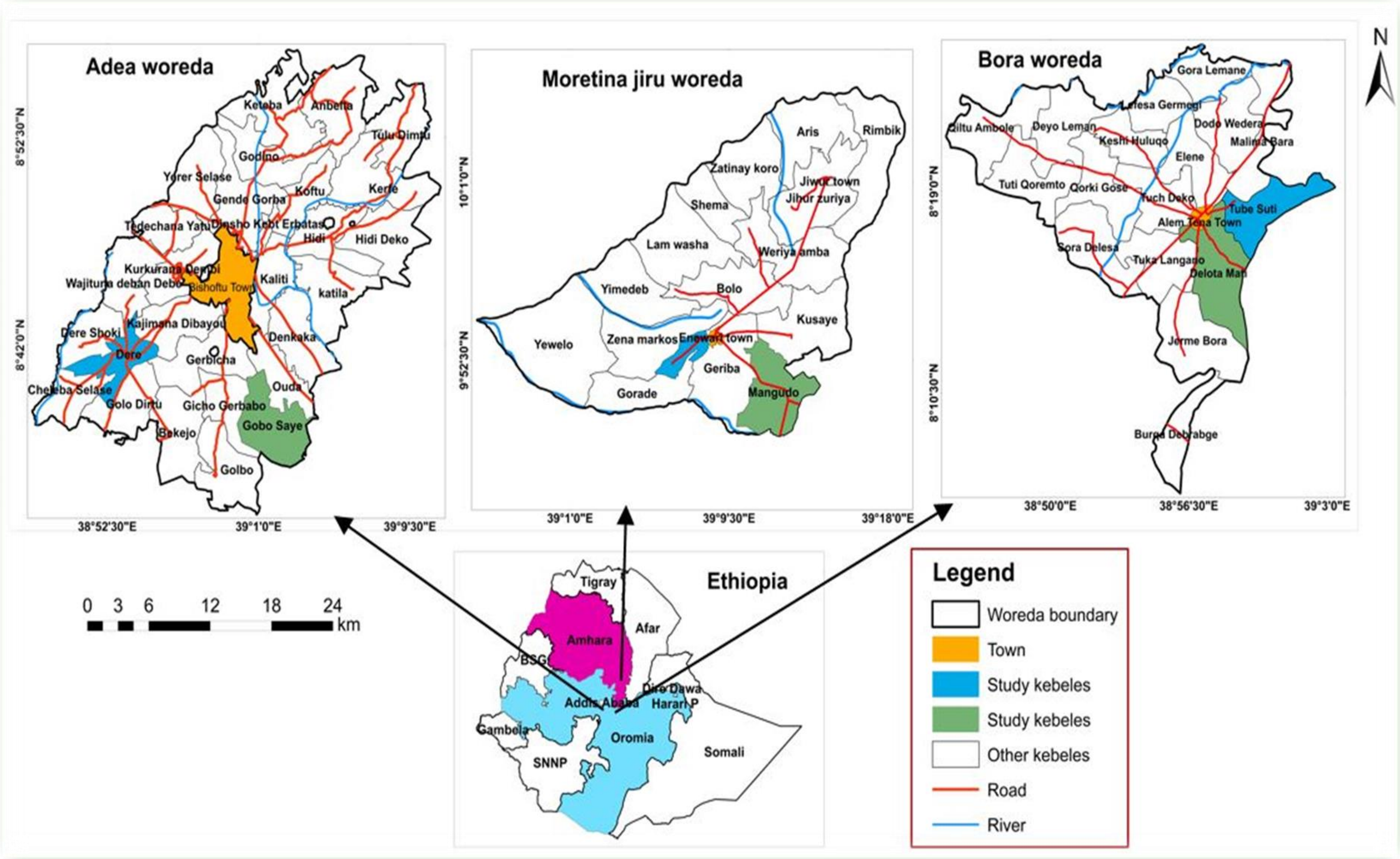

Figure 1.1: Map of the study area in its national and regional settings (*Source: EIAR - GIS)*

1.8.2.2. Sampling techniques and sample size determination

The sampled households were chosen using a multistage sampling technique. Two regions and three districts were purposely chosen at the initial stage based on their accessibility and agroecological suitability for wheat, teff, and maize production. The second step involved a random selection of six representative *kebeles*, the smallest administrative unit in a district. Step three, within targeted *kebeles,* farmers who adopted or did not adopt the technology were identified by stratified sampling techniques. Finally, the respondent households were selected by using a random sampling technique within the two strata. The sample sizes were determined using a simple formula provided by Kothari (2004), which is known to predict population prevalence with high precision for the target population. Assumed a 95% confidence interval, 30% projected population proportion, and 5% desired level of precision. The total sampling frame was 4,026 in six kebeles, and the researcher used the following formula to calculate a total of 299 interviewed samples (108, 68, and 123 samples from the Ada'a, Bora, and Moretena Jiru districts, respectively).

$$n = \frac{Z^2 p\, q\, N}{e^2 (N-1) + Z^2 p\, q}$$ -- Kothari (2004)

Where,

n = the desired sample size,

N = targeted population size,

Z = standard normal variable at the required level of confidence (Z=1.96),

P = expected proportion in the target population (P=30%),

e = desired level of Precision (5%),

q = (1-p)

In Table 1.1, the total sample size has been distributed to each sample *kebele* based on the proportion of the total number of households in each selected *kebele*.

Table 1.1: Sampling distribution by *kebele* probability proportional to the size

Districts	Sample Kebeles	Number of farm Households			Sample Size
		M	F	Total	
Ada'a	Dire Arerti	586	75	661	49
	Gobosaye	717	80	797	59
Bora	Dalota mati	426	60	486	36
	Tube suti	317	107	424	32
Moretena Jiru	Gerba-segenet	418	252	670	50
	Mangudo	843	145	988	73
	Total	3307	719	4026	299

Source: obtained from districts Administrative BoA, 2021

1.8.2.3. Method of data collection and data sources

A cross-sectional and narrative research design was used to conduct this study during the 2020/21 cropping season. Primary data sources were used to collect this information through the cross-sectional survey. Quantitative data were gathered from a sample of respondents using a structured questionnaire developed with digital data capturing tools, i.e., Computer Assisted Personal Interviews (CAPI) and standard household food security measurements. Qualitative data from KIIs and FGDs were collected to triangulate and substantiate the quantitative data by using a checklist. Secondary data were also used to supplement the primary data. A mixed methods research approach is utilized for an inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks. The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone. The mixed-method approach is pragmatic knowledge claims, sequential, concurrent, and transformative. This study begins with a broad survey to generalize results to a population and then, in a second phase, focuses on qualitative, open-ended interviews to collect detailed views from participants to triangulate the quantitative data.

Quantitative data collection methods

A Household survey questionnaire has several sections to collect different kinds of data required for this study. It has separate components for the demographic, socioeconomic, and institutional factors information, crop production and seed systems, adoption, and household food security measurements. Both closed and open-ended semi-structured questionnaires were prepared to generate the required information. Before the formal data collection, orientation was given for enumerators to have a common understanding of the questionnaire and the data collection instrument. Enumerators who can speak the local language and who have knowledge about the culture of the society were also employed to collect the data. After training, the questionnaire was pretested in one village outside the sample kebeles for further fine-tuning and revised according to the feedback obtained.

Qualitative data collection methods

Key informant interviews (KIIs): A semi-structured interview is conducted in a face-to-face conversation between two individuals with the sole purpose of collecting relevant information about the issues related to the description of the study area and objectives of the study. The KIIs are selected based on their knowledge and expertise and facilitate information from different perspectives, especially having a deep understanding of the seed system and food security situation. It is useful for exploring an individual's beliefs, values, understanding, feelings, experiences, and perspectives on an issue. Key informants were the subject of structured interviews conducted as part of the study utilizing an interview guide. Twenty-five key informants were chosen by using the key informant sampling technique and comprised six development agents, three crop & livestock production experts, three extension agents, one bureau of agriculture heads, two MoA agricultural input & production marketing experts, one from Ethiopian agricultural broadcasting corporation (EABC) experts, two experts from regional seed enterprises (RSEs), two NGO officials (ISSD and GIZ), one from ATA, one from seed association, and three seed producers. All the key informants had an extensive understanding of the seed system and farm experience.

Focus group discussions (FGD): help to generate data on group dynamics, and allows a small group of respondents to be guided by a skilled moderator or facilitator, to focus on the key issue of the research topic. FGDs are intended to generate qualitative information through an organized discussion with a selected group of individuals on a particular topic. Six FGDs were also organized and held in each sampled *kebeles*. Each group was composed of 5-7 members and selected using a random sampling technique based on being socially respected within the society, comprising a mix of participants such as DAs, community elders, women-headed households, and farmers in the study area. The selected participants had similar backgrounds and experiences to discuss the research questions. The FGDs provided further understanding of community members' experiences and perceptions of the seed system, adoption of improved varieties, and food security.

Field Observation: is a data collection method by which information on a phenomenon is gathered through observation. It involved the active acquisition of information from a primary source. It can also involve the perception and recording of data via the use of scientific instruments. The best tools for observation are *checklists* and *direct observation* (an observational study method of collecting evaluative information). The method is crucial to comprehend the topic's points. In order to gain a deeper knowledge of the issues and to see people interacting in their natural settings, the study used both participant and direct observation techniques. During the research period, informal observation and contact with community members allowed researchers to build trust with research participants, facilitating greater access to knowledge and boosting the reliability of the findings. The field observation was carried out to validate the information provided through primary and secondary data collection tools. Primary information like the means of livelihoods, culture, attitude, marketing mechanism, infrastructural activities, and social services like human health, veterinary, schools, and water supply was obtained by visiting the study area and then by talking informally with people in their sites.

1.8.3. Data analysis

The data were analyzed using econometric modelling and descriptive statistics. The quantitative data were analyzed using STATA version 14.2. The descriptive analysis includes frequency, percentage, mean, standard deviation, and cross-tabulation distribution used to describe the respondents' socio-economics, institutional, and demographic characteristics. Inferential statistics were used to analyze and compare the mean or to see the presence of statistically significant differences (t-test) for continuous variables and show interdependency between adoption categories (Chi-square test) for dummy variables. The logit model, multinomial logit model, and binary probit regression model were among the econometric models that were employed to assess the quantitative data. The detailed econometric model specifications for various types of analyses are given in the relevant chapters. Before executing the model the hypothesized predictor variables were tested for possible multicollinearity problems. Variance Inflation Factor (VIF) was used for association among the explanatory variables to test multicollinearity problems for continuous and dummy variables. The VIF was found to be below 10 for continuous regressor variables and the Contingency Coefficient (CC) below 0.5 for dummy variables indicating that no severe problems of multicollinearity in the model. As a rule of thumb, if the VIF of a variable exceeds 10 that variable is said to be highly collinear and it can be concluded that multicollinearity is a problem, if the values are around

1, we are in good shape and can proceed with regression (Gujarati, 1995). This study also employed Propensity Score Matching (PSM) method to estimate the impact of improved crop variety adoption on household food security that selects, matches and compares certified seed adopters and non-adopters observations on the estimated probability of being treated (propensity score). Data from key informant interviews, focused group discussions, observations, and secondary data analysis were used to examine the qualitative data reported. These data also served as the basis for narrative and conceptual reasoning. Furthermore, the stakeholder analysis method was applied to examine the linkages between the seed system actors.

Techniques of food security analysis

The food security data were collected using the standard questions. To investigate the status of household food security, there are several measurement tools available for households and it differs based on the scope and purpose of the assessment. The study utilized the Household Food Balance Model (HFBM) to quantify the net available food, the Household Food Insecurity Scale (HFIAS) to quantify the food access, and the Food Consumption Score (FCS) to measure the calorie sufficiency of food at the household level.

The **HFBM** was used to determine the food security/insecurity status of the sampled households in terms of food availability at each household level. The researcher preferred and utilized this model because it is more applicable in investigating and determining the food security status of households. The HFBM was adapted from FAO Regional Food Balance Model and widely used by different researchers (Degefa, 1996; Degefa, 2002; Meskerem and Degefa, 2015; Demeku *et al*., 2015; Beneberu and Biazin, 2020; Hiwot and Degefa, 2022). The model was employed to quantify the net available food grain owned by each of the sampled households in the study area (Appendix 1.9). All variables needed for the HFBM model were transformed from local grain measurement units to kilogram grain equivalents (EHNRI, 2000). To compare supply with demand for grain food, 2,100 kilocalories per person per day was used as a measure of calories required to allow an adult to appreciate a healthy, moderately active life (EHNRI, 2000). A comparison of calories available and needed by a household was used to estimate a household's food security status.

The **FCS** is one of the alternative tools for measuring food security developed by WFP and is commonly used as a proxy indicator for access to food (Appendix 1.10).. A seven-day recall period is used to make the FCS as precise as possible and reduce recall bias (WFP, 2019). In this approach, different food items are categorized into ***nine main food groups*** and the given corresponding ***weights***. These include main staples: cereals, starchy tubers, and roots (2); Pulses: legumes and nuts (3); Meat and fish: beef, goat, poultry, pork, eggs, and fish (4); Vegetables (1); Fruits (1); Oil: oils, fats and butter (0.5); Milk: milk, yoghurt, cheese and other (4); Sugar: sugar, sweets, honey, and other (0.5); and Condiments: spices, salt, coffee, tea, and alcoholic (0) (Appendix-7). The FCS of a household was calculated by multiplying the frequency of foods consumed in the last seven days with the weighting of each food group. The WFP has assigned a weight to each food group based on its nutritional density. According to WFP (2019), the maximum FCS has a value of 112 which would be achieved if a household ate each food group every day during the last 7 days. The total FCS is then calculated using the sum of the scores and then compared to pre-established thresholds: Poor food consumption 0 to 21; Borderline food consumption 21.5 to 35; and Accepted food consumption > 35.

The **HFIAS** module produces information on food insecurity (access) at the household level. Food access concerns a household's ability to acquire adequate amounts of food through one or a combination of its own home production and stocks, purchases, barter, gifts, borrowing, and food aid. According to Coates et al. (2007), the household food security status is measured by using HFIAS. Deitchler et al. (2011) describe the HFIAS as a set of nine generic questions related to *three different domains of food insecurity access*: ***anxiety and uncertainty*** about the household food supply, ***insufficient quality*** in terms of variety and preferences of the type of food, and ***insufficient food intake*** in terms of reducing the quantity of food. These indicators provide summary information on the prevalence of households experiencing. The HFIAS score indicates each frequency-of-occurrence question from three frequency categories ***rarely*** (1 to 2 times), ***sometimes*** (3 to 10 times), and ***often*** (>10 times) (Appendix 1.11). HFIAS scores range from 0 to 27, with a higher score showing the more food insecurity (access), while a lower score indicates the less food insecurity (access) the household experienced. The HFIAS prevalence will be determined in terms of the four categories: *Food Secure, Mildly Food Insecure, Moderately Food Insecure, and Severely Food Insecure* (Coates et al., 2007). The

HFIAS indicators provide an overview of the determinants, domains, scale scores, and prevalence of access in households experiencing food insecurity (Coates *et al.,* 2007).

1.9. Analytical Framework

The seed system can be conceptualized in three intersecting components: *agricultural research* as the source of improved crop varieties and produce EGS (breeder and pre-basic seed). The *commercially-oriented seed supply (formal)* for the production of basic and certified seed by the public seed enterprises and the *community-based seed supply (informal)* where farmers and communities produce uncertified seed and exchange seed through social networks. *Formal seed system:* represents the plant breeders in the public research institutes developing new crop varieties with desired characteristics, such as high yield, and tolerance to pests and diseases. The early generations of released varieties are multiplied by public seed sectors or the private sector with appropriate quality control. *Informal seed system:* farmers use traditional methods to produce, process, store and exchange seed through social networks and save their seeds for the next planting season. *Intermediate seed system*: also includes the production and marketing of seeds by local farmers under financial and technical support from NGOs and breeding centers. The major actors in this system are NGOs and farmers engaged in community-based seed production & marketing.

The analytical framework of this study is discussed based on the seed systems, adoption, and their impact on household food security and there is a horizontal and vertical relationship between them (Figure 1.2). This study was assessed the functions of the existing seed systems, and analyze the linkage between different actors involved in the system, the gaps between different actors and constraints that participate in the system, and how the institutional arrangement of the system benefits and moves in the study area. The seed systems are influenced by commercially oriented seed supply, farming households, and institutional factors. These have different elements, in the commercially oriented seed supply (local seed business, certified seed production, and commercial seed marketing), in farm households factor (seed varietal selection, farmer based seed production, non-certified seed distribution, and renew seed stocks), similarly in the institutional support factor (developing new variety, EGS and CBS production, variety testing and release, and seed quality control).

This framework presents the adoption of certified seeds of improved crop varieties that are influenced by a number of household, socio-economic, and institutional characteristics. There are different variables in each characteristic. Consequently, in analyzing the seed system farmers' availability and accessibility to the high-quality seed of well-adapted improved varieties is central to boosting seed production and productivity, improving rural livelihoods, farmers' income, and ensuring food security.

The analytical framework has also described the impact of the adoption of improved crop varieties on household food security with different components (HFBM, FCS, and HFIAS) and variables in line with the seed system and the adoption. Finally, the outcome of the study will be an understanding of whether the households benefited from the supply and access to quality seeds of improved varieties at the right time and affordable price, the households ensuring food security in the study areas.

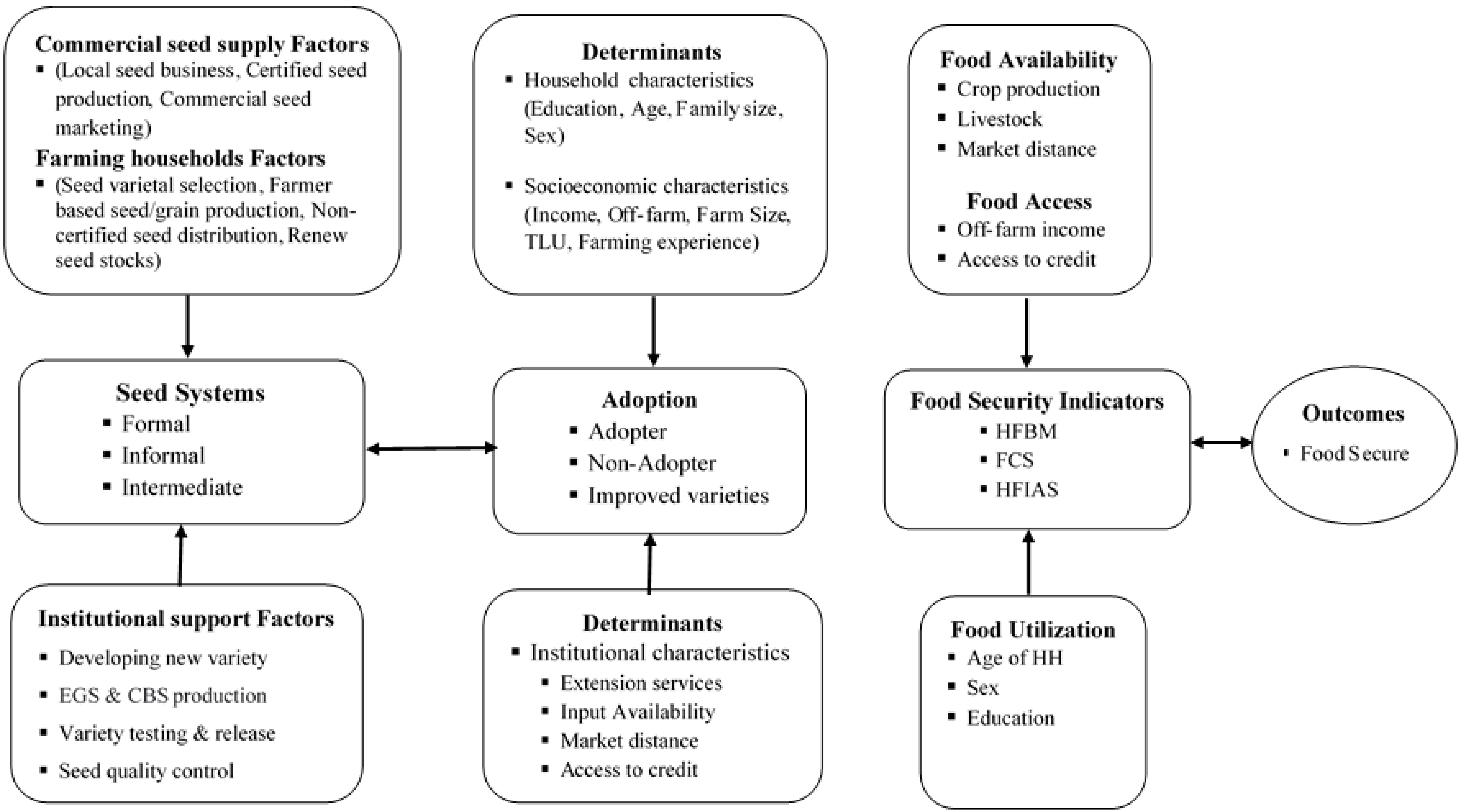

Figure 1.2: Analytical framework of the study
Source: Own construction based on the literature

1.10. Structure of the dissertation

This dissertation answers the specific research questions and is organized into six chapters. The current chapter presented the general introduction consisting of the background of the study, statement of the problem, objectives of the study, research questions, significance of the study, scope and limitation of the study, methodological approach, literature review, and analytical framework. The remaining chapters are organized as follows: Chapter two deals with analyzing the seed system actors' roles, responsibilities, and linkages. This section identified the constraints of the seed systems and the gap among the seed actors' linkage. Chapter three described the determinant factors of the adoption of certified seeds of improved wheat, tef, and maize varieties. In chapter four the seed supply system and access to improving food security of farm households were assessed. Chapter five examines the impact of the adoption of improved crop varieties on household food security. This analysis estimated by propensity score matching includes the adoption of improved crop varieties impacted on yield, food availability per capita, and food consumption score. Finally, Chapter six explained in terms of synthesis of the main findings, conclusion, recommendations, policy implications, and suggestions for future research to manage the constraints of the seed systems, agricultural technology adoption, and food security in central Ethiopia.

Chapter 2: Analysis of Seed System Actors' Roles, Responsibilities, and Linkages in Central Ethiopia

Abstract

In Ethiopia, a seed system refers to all of the complicated organizational, institutional, and human procedures involved in the creation, multiplication, processing, storage, distribution, and sale of seeds. It covers formal, informal, and intermediary seed sectors. The objective for this study is to show how the interests and interactions of seed actors are connected to the functioning of the seed system in the formal and informal seed sectors. The study aims to analyze the seed systems actors' roles, responsibilities, linkage, and implications of the gap. The study used qualitative data collected from 25 key informants, and six separate focus group discussants in Ada'a and Bora districts (Oromia region), and Moretena jiru district (Amhara region). Moreover, secondary data sources were used. The data were analyzed using stakeholder analysis to describe, categorize, narrate, and discuss the seed system actors. The result of the study identified the constraints and gaps of the roles, responsibilities, and linkages of seed system actors related to limited collaboration among the seed actors; limited engagement of the private sector and seed associations during the development of regulatory measures; considerable mismatch in the supply and demand of certified seed of available crop varieties; inefficient seed distribution and marketing mechanisms; weak variety release, seed quality assurance system, and lack of a clear seed policy. The major findings were also that the linkage among seed system actors was very weak due to weak management capacity; lack of coordination between production, processing, and delivery of certified seeds of improved varieties; poor marketing systems; and inappropriate planning & evaluation. This study summarizes the seed system should need further investigation to minimize the constraints and gaps. Coordination and linkages among all actors need strengthening to stand in rapid, orderly, and effective growth. Inter-organizational linkages should be assessed to maintain better aspects negotiate improvements in existing linkage mechanisms and build new relationships among actors.

Keywords: Seed system; Actors; Roles; Linkages; Stakeholder analysis

2.1. Introduction

The government of Ethiopia places a high focus on agricultural development to promote overall economic growth, combat poverty, and achieve food security. Agriculture in Ethiopia contributes about 39% of the GDP, generates 90% of the total exports, and provides employment for 80% of the population (CSA, 2013). Seed is the most vital input for crop production and productivity

(Fekadu, 2010). An increase in seed quality can increase the yield potential of the crop by significant folds and thus, it is one of the most economical and efficient inputs to agricultural development. Seed is the most important determinant of crop success or failure, alongside soil fertility and water (Hussien *et al.,* 2013). According to Kassa and Merkine (2020) seed is an essential component and valuable commodity in agriculture, sustained increase in crop production and productivity, and the pillars of farmer’s livelihood and food security. One of the important elements of the country's agricultural reform goal has been recognized as the creation of the national seed system. (Abebe *et al.,* 2017). Given the significant current and future role of the agriculture sector, a vibrant seed system that provides quality seed to meet the demands of farmers is an essential facilitator to the continued economic and social development of Ethiopia.

In Ethiopia, the seed system represents the whole complicated structure, institutional, and individual operations related to the development, multiplication, processing, storage, distribution, and promotion of seeds (Fischer and Edmeades, 2010; Abebe and Lijalem, 2011). De Boef et al., (2010) describe a seed system as a collection of dynamic interactions between seed supply and demand that lead to the use of seeds and subsequently plant genetic resources at the farm level. According to FAO (2020), the seed system is the economic and social mechanism by which farmers’ demand for seed and other desirable seed traits is met by various sources of supply. A seed system refers to physical, organizational, and institutional components, their actions, and interactions that determine seed conservation, improvement, supply, and use (Teshome, 2021). Different authors classify seed systems into different types: Dawit (2010), and Abebe (2010) explain seed systems classify into formal and informal, while others classify them as local and formal (World Bank, 2015). Louwaars *et al.* (2013) categorized them as farm-saved, community-based, public companies, commercial companies, and closed value chains. In recent years, the idea of an intermediate seed system has appeared in the Ethiopian seed sector and combines both the formal and the informal seed systems (Mohammed and Lemma, 2011). Dejen (2021) noted that the seed system is divided into informal, formal, and alternative seed systems with low quality, quantity, and an intermediate contribution to crop production. A seed system in Ethiopia classifies as a formal, informal, and intermediate seed system (Teshome *et al.,* 2021). Ethiopian Agricultural Transformation Agency (ATA) has recognized the three seed systems in the Ethiopian seed sector: In the “formal” or “commercial” seed sector that the seed of improved varieties is sold to farmers through farmer cooperatives, input suppliers, and other channels; the "traditional" or "informal" seed sector that farmers save seed from their harvest or exchange through social networks for the next planting seasons, gift, borrow, and buy informally; and "intermediate seed systems" imply coordinated actions between the formal and informal seed sectors (ATA, 2015).

2.1.1. Formal seed system

ATA (2015) describes the formal seed system as a mainly government-supported system and several public institutions are also involved in it. The formal seed system was established with the aim of a dynamic, efficient, well-regulated formal sector that provides farmers with sufficient, affordable, timely, and high-quality certified seeds of improved varieties for key crops through multiple production and distribution channels while maintaining the genetic biodiversity of the country. It is guided by scientific methodologies for plant breeding, multiplication is controlled & operated by public or private sector experts, and significant investments have been made throughout the process (Louwaars and De Boef, 2012). The formal seed system involves public and private sector institutions and a linear series of activities along the seed value chain, including, plant variety development, variety release and registration, quality seed production, and distribution (Louwaars *et al.*, 2013). This system aims to supply adequate amounts of seeds of high quality, at the right time and place, and reasonable prices. According to Abebe *et al.* (2017), the formal seed systems have been limited by data-based decision making which is demonstrated by the variation and mismatch between seed demand and supplies. Currently, the share of the formal seed system is estimated to be about 10-20 percent of the actual demand of the country and less than 5% of the cultivated area is covered by certified seed (Dejen, 2021). The major actors involved in the formal seed system are the Ministry of Agriculture (MoA), Ethiopian Institute of Agricultural Research (EIAR), Regional Agricultural Research Institutes (RARIs), Higher Learning Institutions (HLIs), Ethiopian Agricultural Business Corporation (EABC), Regional Seed Enterprises (RSEs), Regional Bureau of Agriculture (RBoA), Private Seed Companies (PSCs), Cooperative Unions, and Seed regulatory authorities at federal & regional level.

2.1.2. Informal seed system

The informal seed system involves farmers choosing their seeds, multiplying, storing, using, and distributing them through social seed networks and neighborhood marketplaces. It dominates in terms of delivering large quantities of seeds of a diversity of crop varieties (Coomes *et al.*, 2015; McGuire and Sperling, 2016). The system establishes millions of individual small-scale farmers, who save or exchange seed at the local level and includes development agencies and projects supporting community seed production with no regulatory oversight (Dawit and Zewdie, 2015). Informal seed systems include farmer-saved and exchanged seeds of important food crops, comprising both local and improved varieties that have been accessed through the formal distribution system (Yohannes *et al.*, 2012). Zewdie (2016) noted it includes both traditional and improved varieties that have been released by the formal system in the past and intermediate into the local seed system. In Ethiopia, the informal system is crucial for the security of seed supply. About 60-70 percent of seed used by smallholder farmers is saved on-farm and exchanged among farmers, and the remaining 20-30 percent is borrowed or purchased locally. ATA (2015) explains the informal seed system accounts for 90 percent of the seed used by smallholder farmers while the share of certified seed is less than 10 percent. The majority of Ethiopian farmers have a predisposition to rely on the informal system because it is currently more affordable and readily accessible in the farmer's villages just at the time seed is needed; allows the use of seeds after testing on primary adopter farmers; and is more reliable and its sustainability is more guaranteed than the formal system (Abebe, 2010). In the informal seed system mainly the Non-Government Organizations (NGOs), farmer organizations, individual smallholder farmers, seed agents, and agro-dealers are the main actors.

2.1.3. Intermediate seed system

The distinction between the formal and informal seed sectors may become somewhat blurred, as farmers may save seeds of better kinds and later regard them to be "local varieties" or “local seed” after some years of usage. In Ethiopia, both the formal and informal seed systems operate simultaneously and sometimes overlap. In addition, there have been attempts made by the government and NGOs to promote quality seed production and distribution through market channels for landrace varieties, although until now the volume they represent is quite small. The newly recognized intermediate seed system has overlapping features with both the formal and informal seed systems. According to Adane *et al.* (2010), the intermediate seed system also includes the production and marketing of seeds by local farmers under financial and technical support from NGOs and breeding centers. The major actors in this system are NGOs and farmers engaged in community-based seed production & marketing.

A sustainable seed system will make sure that high-quality seeds are produced, completely accessible on time, and reasonably priced for farmers and other stakeholders. Extensive research conducted on Ethiopia's seed system, but farmers have not yet been able to fully benefit from the advantages of using quality seed due to inefficient seed production, distribution, and quality assurance systems, as well as bottlenecks caused by a lack of good seed policy on key issues such as access to credit for inputs (Kumulachew, 2015). Seed supply remains limited especially for small-scale farmers; the number of varieties that are suitable for different agro-ecological conditions and farming systems remains limited, shortage of foundation seed for certified seed production, and the varieties are usually low yielding and therefore negatively affect food security (Gebremedhin, 2015). The weak linkage between actors working in agriculture and rural development is one of the challenges of extension services. In addition, the farmers wouldn't tolerate gaining benefits from the new agricultural information that could increase their productivity and output (Teka *et al.*, 2019).

Therefore, due to this limitation, this research attempts to examine these issues more closely. The objective of this study was to analyze the seed systems actors concerning seed policies; to assess the gap in actors' roles and responsibilities, and to identify the factors hindering effective linkage between the actors related to seed production and dissemination in Ethiopia that influence the seed systems by answering the specific question "How the existing seed system and actors are functioning in the study area"?.

2.2. Materials and Methods

2.2.1. Study area

The study was conducted in three districts (locally known as *Woreda*). These were *Ada'a* and *Bora* districts from the East *Shewa* zone, *Oromia* region, and *Moretena Jiru* district from North *Shewa* zone, *Amhara* region, Ethiopia. Major crop components of the districts are cereals (tef, wheat, maize, and barley) and pulses (chickpeas, field peas, faba beans, and lentils) grown under rain-fed agriculture. Irrigated horticultural crops are emerging as a new opportunity in the districts.

2.2.2. Sampling techniques

Multi-stage and purposive sampling technique was used to select two regions, three districts, and two targeted *kebeles* from each district intentionally based on their major crop production and involvement in the seed system. Twenty-five key informants were identified by using the purposive sampling technique and selected from development agents (6), crop & livestock production experts (3), extension agents (3) and Bureau of agriculture heads (1), MoA agricultural input & production marketing experts (1), EABC (1), RSEs (2), ISSD (1), GIZ (1), ATA (1), Seed Association (1), Seed producers (3). All the key informants were having a deep understanding of the seed system and farm experience. Six focus group discussants were organized and selected randomly based on being socially respected within the society, each group was comprised of 5-7 members with a mix of participants such as DAs, community elders, women-headed households, and farmers in the study area.

2.2.3. Method of data collection

In conducting this study a cross-sectional and narrative research design was used. Each primary and secondary sources were accustomed compile the information. Qualitative data were collected from KIIs and FGDs and secondary data sources were used from relevant sources that are, intensive reviews of published and unpublished documents such as peer-reviewed articles, books, dissertations, thesis, and research reports.

2.2.4. Data analysis

The data were generated from KIIs and FGDs and all interviews were transcribed and uploaded into stakeholder analysis software, then categorized, summarized, narrated, and discussed. We employed the stakeholder analysis that is used to understand a system through key actors or stakeholders. It involves two separate steps, identifying actors and their respective roles; and assessing actors' influence and linkages in the system. A systematic policy evaluation was also made on information generated from secondary data sources. A systematic literature review was conducted to gather information on seed policy frameworks as well as evidence on the past and current impacts of seed policies on the quality of seeds used by seed system actors in the country. This study reviewed the documents such as a national seed policy, strategy, proclamations, regulations, and directives with substantial implications for seed systems in Ethiopia.

2.3. Results and Discussion

The findings of this study were presented and discussed in the subsequent order first, the evolution of the seed system actors and review of policies concerning seed system actors; followed by analyzing the roles and responsibilities gap concerning seed actors; then analyzing the gap of seed actors linkage. Finally presents the conclusions and recommendations.

2.3.1. Evolution of the seed system actors

In Ethiopia, the formal seed system actors started five decades ago as an ad-hoc extension activity by academic and research institutions. In 1942, Jimma Agricultural School was the first to start certified seed production and distribution. As early as 1954, the Alemaya College of Agriculture used to distribute seeds to farmers, and the Institute of Agricultural Research (IAR) followed when it was established in 1966. Later on, the *Chillalo* Agricultural Development Unit (CADU) began to produce and supply seeds to serve farmers in the Arsi region and its surroundings. Meanwhile, in the late sixties and early seventies, many private large-scale commercial farms grew, which were eventually nationalized by the government. The government established new state farms in some parts of the country and farmers' producers' cooperatives were also organized. These developments led to increased demand for modern agricultural inputs, particularly seeds of improved varieties. Certified seed supply was lacking as there was no organized system in the country until the government established the Ethiopian Seed Enterprise (ESE) in 1979. The ESE was initially tasked with providing seeds to the entire farming community through domestic production or imports from other countries. Although its activities were largely skewed to the state farms and cooperatives at the expense of small farmers, then, it has remained the main seed producer and supplier in the formal seed sector.

Moreover, major seed actors or stakeholders were also reconstituted and established into new legal entities through various proclamations and regulations including Ethiopian Seed Enterprise (ESE, proclamation No. 266/1982); National Seed Industry Agency (NSIA, proclamation No. 56/1993); Ethiopian Institute of Agricultural Research, EIAR (proclamation No. 79/1997); Institute of Biodiversity Conservation and Research, IBCR (proclamation No. 120/1998); Ministry of Agriculture and Rural Development, MoARD (proclamation No. 380/2004); Oromia Agricultural Research Institute, OARI (proclamation No. 44/2001); Amhara Regional Agricultural

Research Institute, ARARI (proclamation No. 48/2000); South Agricultural Research Institute, SARI (proclamation No. 37/2001); Tigray Agricultural Research Institute, TARI (proclamation No. /2000); Somali Pastoral Agricultural Research Institute, SoPARI (proclamation No. 31/2002); Afar Pastoral Agro-pastoral Research Institute, APARI (proclamation No. /2007); Oromia Seed Enterprise, OSE (regulation No. 108/2008); Amhara Seed Enterprise, ASE (regulation No. 66/2009); South Seed Enterprise, SSE (regulation No. /2010); and Somali Seed Enterprise, SoSE (regulation No. 108/2011). This shows the commitment and interest of the government to strengthening the seed system in the country and all organs dealing with seed regulation, seed production, and seed distribution.

With the gradual move of the country toward a market economy, private seed companies are getting more and more involved in the seed sector. Pioneer Hi-bred Ethiopia, a multinational private company, is the first private seed company that started its operation in the 1990s, following economic reforms. Other private seed producers entered the Ethiopian seed market gradually. Seed-producer cooperatives in Ethiopia were recognized as legal institutions in the 1960s during Emperor Haile Selassie's regime (Dawit *et al.*, 2017). During the era of a state-owned economic system (1974–1991), cooperatives were formed and reorganized to facilitate the implementation of collective ownership of properties, which was the government policy, and engaged mainly in the production of industrial crops, such as tea and spices (Bezabih, 2012).

Review of previous and current policies concerning seed system actors

Policies play a major role in shaping the seed sector, particularly as part of the transition to a more market-oriented economy. To guide this process it can be advantageous for countries to have a national seed policy as a declaration determined for their management of the seed sector actors and to provide a stable basis for decision making. The Ethiopian seed industry policy was first formulated in 1992 and serves as the basis for different laws and regulations. The main objectives of this policy were to ensure the plant genetic resources collection, conservation, and evaluation; enhance variety development, release, registration, and maintenance; develop an effective system for producing and supplying high- quality seeds to satisfy the national seed requirements; encourage the participation of farmers in germplasm conservation as well as in seed production and supply systems; create a functional and efficient organizational setup to facilitate collaborative linkage and coordination in the seed industry; regulate seed quality standards, import and export, seed trade, quarantine, and other seed-related issues. Several proclamations were issued to legally enforce the implementation of the seed industry policy. It included Plant Protection Decree (No. 56/1971); Plant Quarantine Regulation (No. 4/1992); Seed Regulation (No. 16/1997); Seed law Proclamation (No. 206/2000); Plant Breeders' Rights Proclamation (No. 481/2006); and Access to Genetic Resources, Community Knowledge, and Community Rights Proclamation (No. 482/2006) which aimed at creating a legal framework for the protection of the interests and control of the seed actors; designating government agencies which support, advise and control individuals or organizations engaged in the production, processing, import, export, sale, and distribution of quality seeds through the effective and quick supply system.

Several countries have formal seed policies, with the majority of them based on the seed system development pathway. This path highlights the steps of seed system evolution from traditional farmer-production of seed to a commercially operating seed industry (Louwaars *et.al,* 2013). In Ethiopia, only a few studies have looked at policy aspects of the seed industry, and existing policy has limited a full understanding of the Ethiopian seed sector's difficulties (Mohammed, 2017). Yohannes *et al.* (2012) indicated in their research that seed policy and regulatory frameworks in Ethiopia have been harmonized with rural development policies and strategies. Despite the presence of a seed policy, seed law, and seed standards, its implementation is primarily at the infant stage due to insufficient capacities within regulatory authorities. Kumulachew (2015) noted that in most cases, the policy remains on paper, and several proclamations are being updated ahead of their implementation, seed actors' understanding of these laws and regulations is still quite limited. As indicated by Dawit (2012), Ethiopian seed policymakers are currently striving to modernize and enhance the formal seed system, encouraging the adoption of new seed varieties. Gloria *et al.* (2017) indicated in their study the Ethiopian seed policy provisions have a much larger positive impact on the formal seed sector than on the informal sector. In his findings, 16 percent of coded provisions appear to have negative implications for the formal seed sector, while 25 percent of provisions appear to have negative impacts on the informal seed sector. The current seed policy strongly promotes agricultural cooperatives to provide smallholders access to the market through collective actions (Dawit *et al.,* 2017).

This study shows that there were net positive effects of policies on both the formal and informal seed sector actors, but the positive effects for the informal sector were dominated by the overpowering positive impacts of seed policies enlarging to the formal sector. This imbalance implies the neglect of informal seed systems during the lack of policy and proclamations implementation. In general, in this study the identified seed policy bottlenecks were the poor implementation of legislation due to lack of awareness among actors; limited engagement of the private sector, seed associations, and other civic societies during the development of regulatory measures; lack of independent and aligned national and regional seed authorities. The results obtained from key informants and focus group discussants indicate that the policies and strategies of the government towards relation were perceived as positive. But the policies and strategies were not usually put into practice as expected. The results also revealed that the constraints of the seed system were lack of a clear seed policy/strategy; inadequate seed marketing information and infrastructure; inefficient extension service; limited collaboration within the seed sector; private companies tend to concentrate on profitable crops; inadequate improved and basic seed supply; lack of effective large scale seed enterprises.

The current seed policy describes how important parties and seed actors contribute to the coordination, organization, operation, and development of the seed system. This policy ensures that the government’s vision is adequately reflected in day-to-day operations within the seed sector, and it is under revision since 2020. The Seed law Proclamation No. 206/2000 was updated by proclamation No. 782/2013 (It is also under revision in 2021) and covers variety release and registration; seed production and distribution; quality control and assurance, import & export of seed, supply of emergency seed; certificate of competence; seed inspection; and other related issues. It protects farmers through a variety of registration and seed quality controls; to create a level playing field for seed producers by keeping poor-quality seeds from the market. However, it is constrained by insufficient implementation mechanisms and capacity to accommodate the rapidly expanding seed sector development while maintaining the necessary national and international regulatory frameworks. The recent Biosafety proclamation No. 896/2015 and Plant Breeders Right (PBR) proclamation No. 1068/2017 encourage the generation of high-yielding and quality cultivars, a buildup of competitive and innovative breeders, recognizes the rights of farmers to save, use, exchange, and sell both farm-saved seed and protected varieties, encourage foreign investment, and then provides recognition and economic rewards for those who contribute to the development of high-quality improved varieties. Nonetheless, this proclamation is not operational yet. The absence of regulations, responsible bodies, and guidelines for application and registration mainly hinder the implementation of the PBR proclamation. The seed standards, procedures, and variety of release and registration guidelines are important for seed system actors. There are about 111 items that are currently in use by the Ethiopian standard and these criteria are excessively high as compared to international standards. Producers have not also adhered to the stated requirements in a consistent manner, and there is no agency to enforce implementation. However, these policies, proclamations, and regulations still need to be put into practice, through the establishment of regulatory frameworks.

Therefore, a healthy seed industry is an important component of agricultural development. The Ethiopian seed policy has not been revised for a long time to guide its development and has negative consequences for plant genetic resources conservation, plant breeding research & development, and seed production and distribution system. The seed policy and proclamations are exclusively targeting the formal seed system actors, which ignores the informal seed system actors. As a result, it should be changed and approved to accommodate and encourage the development of both the formal and informal seed sectors, including the establishment of community-based and small-scale seed enterprises.

2.3.2. Gap analysis of the roles and responsibilities of the seed system actors

Structure of the seed system actors

The seed sector in Ethiopia comprises a range of both public and private sectors (Figure 2.1). The national research system regulated by the Ethiopian Institute of Agriculture Research (EIAR) and embraced by a range of federal research centers, RARIs with regional research centers, EABC, RSEs, and Higher Learning Institutions/ universities (HLIs) is charged with developing improved varieties and materials needed to produce and multiply certified seed advancing sale to farmers. Varietal release, seed certification, and quality control are performed by regulatory authorities such as MoA, RBoA, and district BoA. Seed of improved varieties production and multiplication is carried out by the EABC and RSEs which rely on their farm and to a limited extent bulk up a seed that is given to the local extension and supply system for inputs. The regional system is made up of regional bureaus of agriculture, their district offices, and extension agents working at the *kebele* (the smallest administrative unit of Ethiopia) level. These organizations collaborate closely with private seed companies, seed producer cooperative unions, NGOs, and seed agents & agro-dealers in seed production, distribution, and marketing (ATA, 2015).

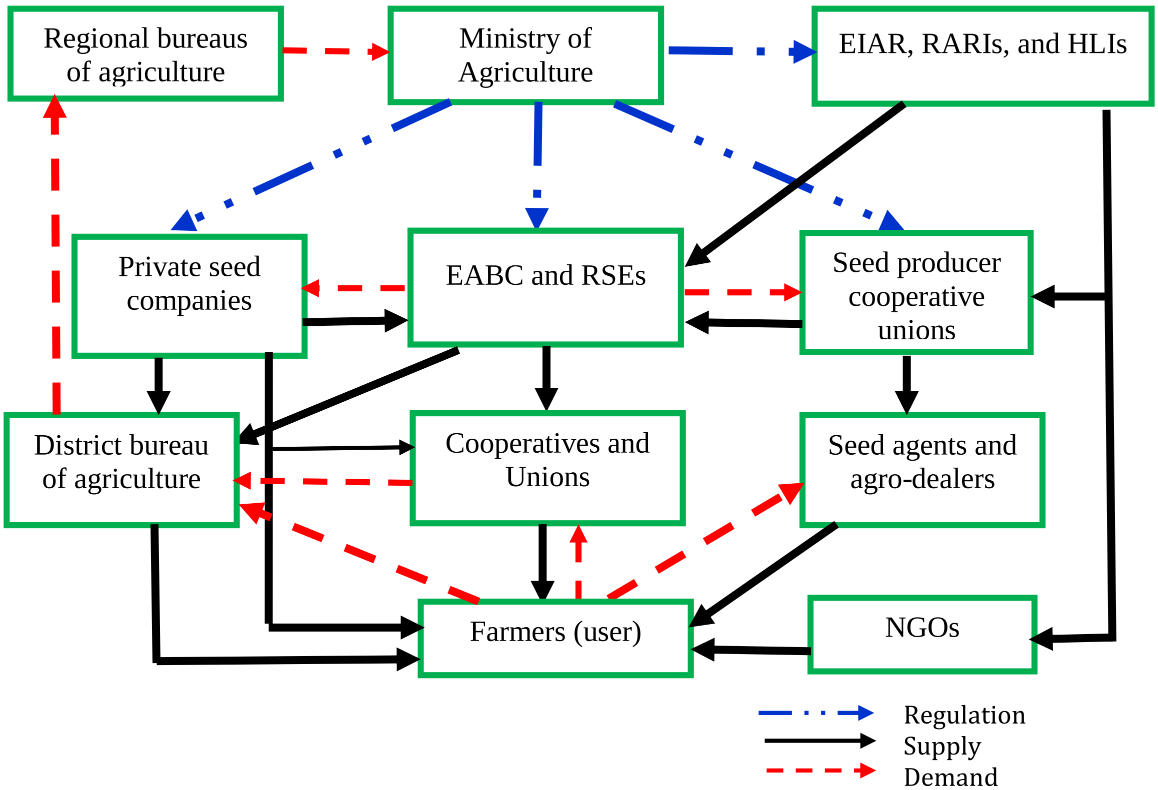

Figure 2.1: Structure of the Ethiopian seed system actors. *Source: Author's construction*

Several seed actors are involved in promoting sustainable seed businesses in Ethiopia. These actors range from non-market actors to market actors including the Ethiopian Institute for Agricultural Research (EIAR), Regional Agricultural Research Institutes (RARIs), Institute of Biodiversity Conservation (IBC), Higher Learning Institutions (HLIs), Ethiopian Agricultural Business Corporation (EABC), Regional Seed Enterprises (RSEs), Private seed companies (Pioneer Hybrid Seed Ethiopia), Ministry of Agriculture (MoA), Regional Bureaus of Agriculture (RBoA), district bureau of agriculture, regulatory agencies, Seed Producer Cooperatives Unions (SPCUs), seed agents & agro-dealers, NGOs, and farmers. The roles and responsibilities of these partners vary and sometimes overlap. The review of the document shows that the current rule and regulation has no specific roles and responsibilities mentioned for each actor involved in the linkage either by grouping them in terms of their expected role or as an individual actors. The study identified the major challenges of the seed actors such as lack of proper linkage between different actors involved in seed systems; inadequate supply of quality seed at affordable prices; focus on few crops in the formal system; low private sector involvement in the formal system; inefficient seed promotion, distribution, and marketing mechanisms; weak variety release and seed quality assurance system.

Comparison of the roles and responsibilities of the seed system actors:

Research Institutes: the roles and responsibilities of research institutes given by policy and regulation are variety development; early generation seeds (EGS) planning; breeder and pre-basic seed production; demonstration & popularization; researching agricultural issues; provision of information on agricultural technologies; and capacity building & training. EIAR is responsible for the coordination of the national agricultural research system. It undertakes research to generate agricultural technologies relevant to the country as a whole and coordinates different research centers which maintain their autonomous status, and develops extension packages with MoA. RARIs have gradually been appointed to develop varieties suitable for their regions, and conduct targeted research within various geographical identities. IBC is responsible for the conservation of the country's biological resources and plays an important role in the conservation of local germplasm and also in the enhancement of the pool of the existing crop germplasm through the introduction of germplasm from international sources. They maintain a gene bank for the preservation of indigenous varieties, a close partner of the research system in the identification, collection, characterization, and maintenance of improved varieties by providing new genetic material for breeding initiatives. They are also a key collaborator in the identification and management of risks related to biodiversity reduction that is associated with the widespread adoption of improved varieties. HLIs participate in a variety of development, capacity building & training, and conducting quality, relevant and impact-oriented research. Currently, the research systems actors are doing variety development and evaluation, variety release and verification, demand assessments, early generation seed multiplication, breeder and pre-basic seed production for specific crops, processing, marketing, dissemination, capacity building & training, and conducting research.

Seed regulatory authorities: the role of these actors are variety testing, registration, and release; seed demand planning; emergency seed procurement & supply; seed certification, quarantine, and seed extension; regulatory activities during seed production and marketing; national seed policy & regulatory framework document preparation; input distribution; evaluation & verifications of seed quality inspection laboratory (SQIL); quality declared seed assurance; experience sharing to other farmers, demonstration & popularization. The responsibilities of MoA are developing the national agricultural policies & strategies, coordinating policy implementation across regions, and overseeing the distribution of inputs. The ministry focused on variety registration and release, seed import/export, seed quality control, seed distribution and certification, quarantine, and extension. The regulatory directorate under MoA is expected to provide technical support to the regions on seed quality assurance. They are also in charge of mediating disputes between local state regulatory agencies and seed producers. At the federal level, regulatory services are provided by two directorates. The role of the plant variety release, protection & seed quality control directorate is to provide seed laboratory services under its support and to serve as a reference laboratory and arbitrator for disputes between seed producers and laboratories in the regional states. While the plant health & quality control directorate focuses on the quarantine of seeds moving across the national border. At the regional level, seed regulatory services are provided by semi-autonomous authorities operating under the technical supervision of the BoAs. They are not only responsible for seeds, but also other agricultural inputs. Currently, the seed regulatory authorities acted on variety release and registration, providing and protecting plant breeder rights, phytosanitary services, assuring seed quality, and issuing certificates of competence to seed businesses. Actors are engaged in the assurance of the release of superior improved varieties with distinct characteristics, in the provision of the certificate of competence for seed production and agro-dealers, in EGS seed quality control and assurance, and quality assurance of certified seed production. These also follow both internal and external quality control systems (Mandefro *et al.*, 2020).

Public seed enterprises: these actors focus on the production, distribution & marketing of certified seeds of improved varieties; farmer-based seed production, distribution, and sales; farm area selection & clustering; contract seed multiplication; demonstration & follow up on seed production; determine the prices of all seed classes; and demand assessment. The role of EABC (former ESE) has been multiplying and distributing certified seeds of improved varieties for major crops of cereals and pulses and dominating the formal seed system market. RSEs are the sole public seed enterprise and the main tasks are to multiply and distribute certified seeds of improved varieties of major crops to satisfy the regional seed demand. Currently, they are doing on producing and supplying large volumes of certified seeds to the country. But, they focus only on a few crops (hybrid maize, bread wheat, tef, and barley) and do not have much attention and technical, facility and finance capacity in investing in crops/varieties demanded by markets.

Private seed companies: the roles and responsibilities of these actors are demand planning; variety testing; production, processing, and marketing of hybrid maize seed; engaging in certified & basic seed production; contractual seed multiplication; involvement in research and development activities; agricultural input provision and demonstration. The government policy encourages the involvement of the private sector in agricultural intensification in areas of variety development, seed production, and marketing. Currently, their role is in the multiplication and distribution of seeds. Some produce seeds on their farms and others under a contractual framework with individuals or groups of farmers.

Seed producer cooperatives & unions (SPCUs): the given tasks are multiplying seeds, distributing agricultural inputs, providing marketing services, emergency seed procurement, engaging in basic seed production, and demonstrating pre-scaling up. Currently, the roles of SPCUs are to produce and market quality seed to local markets and beyond, to make seed a commercial product, and thus to generate income and improve the livelihood of their members. These multipurpose cooperatives are to help members to get the required inputs (seeds and fertilizers), negotiate seed prices with contracting parties (seed companies), and to access training and technical support in seed production and marketing.

Seed agents and agro-dealers: the role of these actors are to sell seed to farmers on behalf of seed producers the seeds are sold at a fixed producer price and the commission is based on the amount sold. To supply agricultural input in rural areas at a retail price including seed, and related information on input performance across different contexts. They have the potential in supporting farmers' decisions on input purchases and have described the constraints they face to expand and consolidate their businesses. At present, they offer a strategic entry point for interventions to accelerate varietal turnover in the seed sector and interactions between seed companies, seed retailers, and farmers. Sell seed and provide technical assistance to farmers on seed selection.

Non-governmental organizations (NGOs): involved in emergency seed supply; participation in joint research trials; organizing farmers' groups and seed producer cooperatives by coordinating with the cooperative promotion offices of the government. Improve the capacities of farmers' groups for producing and marketing seed, by organizing training and donating post-harvest technologies, such as seed cleaning machines, funding linkage platforms where farmers and other actors raise development problems; capacity development & training; farmer-based seed production. Currently, they focus on intermediary seed systems with a community-based and local seed business approach. It supports the establishment of primary cooperatives and unions for achieving local seed security and consequently attaining food security. Others support establishing community seed banks and providing emergency or relief seeds.

Farmers: participating in the process of problem identification, and rural development; engaged in certified and farmers-based seed production; provision of clustering fields for seed multiplication; participating in demonstration & pre-scaling up; sharing information/knowledge with different stakeholders concerning agricultural technology development and extension service; demanding certified seeds of improved varieties. Currently, farmers depend on locally selected and saved seeds alongside farmer-to-farmer seed exchanges. Participate in seed production, procure, save, exchange, and sell seeds as farmer-led seed systems and adoption of improved varieties and other agro-inputs.

Gaps the roles and responsibilities of seed system actors

Research system (EIAR, RARIs, HLIs): the gap in the research institutes was a limited variety of development and adaptation specific to the district agro-ecology; lack of providing extension and training for DAs and lead farmers to increase awareness on varietal information and agronomic practices; variety replacement rate is low due to slow release of new varieties and low seed multiplication of released varieties; limited availability of EGS in quantity; the disparity between the amount of breeder seed delivered to the formal seed system and the amount of certified seed;

lack of clear institutional arrangements and system setting; inconsistent demand for EGS; lack of commercial concept into seed units of the research system and limited capacity.

Seed regulatory authorities (MoA, RBoA, District BoA, and RQCAA): lack of demand assessment system; lack of an independent body for variety release and registration; limited involvement of public and private seed producers, farmers, and agro-processers in NVRC; inadequate human resources to conduct field inspection at all seed production stages; limited laboratory facilities and testing protocols to conduct quality tests of all seeds from producers' plots contributing to ineffective seed certification; lack of training provided on seed production and infrastructure support for individual households and cooperatives to increase the capacity seeds that they obtain from public seed companies should be stored correctly.

Public seed enterprises (EABC, RSEs): focus on limited crops and varieties; absence of internal quality control system and limited facilities; sometimes, wrong varieties are distributed in wrong agro-ecological areas; lack of early generation seeds production due to limitations in crop adaptation; limited price incentives for certified seed producers, weak seed demand for non-commercial food security crops, and lack of seed promotion in non-commercial crops.

Private seed companies: limited to the production of hybrid maize seed and sale; lack of opportunity to participate in the development of varieties; lack of expertise and appropriate varietal release mechanism, and low linkage of the informal sector to the variety release activities.

Seed producer cooperatives & unions: distribute untraceable poor-quality seeds due to lack of accountability and transparency in the conventional seed distribution system; distributes seeds of improved varieties to areas for which there is no demand or to the wrong agro-ecologies; do not participate in seed demand assessment and depend on unrealistic data collected by extension agents and wrong quota allocation.

Non-governmental organizations (NGOs): lack of training provided on crop diversification often promotes traditional varieties as better varieties than improved varieties.

Seed agents and agro-dealers: seed sold at local markets is generally rated by farmers as poor in terms of germination and purity; lack of good storage facilities for temporary stocking until they sell seeds or return leftover seeds, which sometimes affects quality.

Farmers: lack of sources of new disease-resistant varieties; difficulty in assessing the physical or genetic qualities of seeds before they are planted; they do not save their seeds to meet their needs mostly depend on the local exchange or purchase of recycled seeds of improved varieties; lack of good storage facility cause damages in household seed stocks.

Implications of the gap analysis roles and responsibilities

Research Institutions (EIAR, RARIs, and HLIs): ensure all EGS producers have internal quality control systems and enforce all producers to have certification by external seed certification agency and capacitating knowledge on maintenance breeding modernization of national capacity to ensure testing of varietal genetic purity using advanced methods like DNA fingerprinting techniques. The need for the clarity of mandate and responsibility for the production of EGS among actors and to manage the issue of demand creation with a clear role and responsibility for EGS and certified seed producers. Semi-commercialize the EGS multiplication and delivery system in the public research institutes could be established. The government needs to recognize the private sectors as key role players in a variety of development, so it should provide support to strengthen its capacity. Reconsider and redesign the EGS production scheme including decentralization and variety licensing.

Seed regulatory authorities (MoA, RBoA, District BoA, and RQCAA): the need to reconsider the role of the public sector in the demand assessment and shift more to the regulatory aspect, and ensuring the demand assessment is the responsibility of the seed producers themselves along with the risk of marketing. It is imperative to have an independent national body to handle variety release and registration, with full capacity and authority, and a need to broaden members of the variety release committee by including the stakeholders. Established a system for creating independent certifying authorities that could support increasing the availability of quality seeds. Laboratories should be accredited based on ISTA standards that would facilitate seed harmonization largely among the neighboring countries to export and import seeds.

Public seed enterprises (EABC, RSEs): establishing internal quality laboratories would minimize the delivery of poor quality seed and the expected internal check and balance services for the certified seed produced by the seed producer organization itself. This implies the need to ensure traceability, accountability, and transparency as well as competitiveness in terms of price, quality, and brand support for seed producers. Need to revisit the extension system that can deliver the full package of seed promotion and capacitate the farmers in terms of skill and knowledge which creates a huge demand for certified seeds. Establish incentive mechanisms to increase participation of cooperative unions, seed producer cooperatives, agents/agro-dealers, and local private sectors in the seed industry.

Private seed companies: a need to support participation in research and crop improvement, variety development, and variety release activities.

Seed producer cooperatives & unions: need to assess their seed demands directly from the farmers and recruit professional cooperative managers and considered agronomists. The necessity to develop a system of traceability and accountability.

Non-governmental organizations (NGOs): develop guidelines that can support cooperatives and unions through capacity building. Needs enhancing crop diversification, and strengthening the rural infrastructural development.

Seed agents and agro-dealers: a need to incentivize retailers working in seed marketing, especially in remote areas, capacitate the dealers that would improve access to inputs to farmers, and need to standardize the seed store.

Farmers: the need to involve in farmers' research and extension groups in participatory variety evaluation, on-farm demonstration, and promotion of the newly released variety that would help to avail preferred varieties by farmers. The need to establish a seed reserve system with standard storage facilities across the country.

2.3.3. Gap analysis of the seed actors' linkage

The analysis of linkage interactions among actors and institutions is based on the roles & responsibilities in the seed system that allow the exchange or transfer of information, resources, and power, mechanisms that can be structural or functional by the social network approach. Coordination and linkage among actors in the seed value chain play a very crucial role to enhance the efficiency of seed production and marketing. To play various roles in the chain, multistakeholders should take part as operators, supporters, and enablers (Habtamu *et al.,* 2019). Linkages between the seed actors are widely recognized as essential for an effective flow of technology and information. The types and nature of the linkage between actors are directly influencing the production and productivity of smallholder farmers. It is commonly recognized by stakeholders that poor performance of the seed system is often related to linkage problems (Shimelis, 2012).

Technical linkage within the seed system actors'

The research institutions conduct adaptation trials in collaboration with the district bureau of agriculture on farmers' plots to ensure suitability to farmers' environmental and socioeconomic conditions; produce EGS and make these available for public seed enterprises, unions, and SPCs; conduct internal quality control of its EGS before distribution to other actors for adaptation trial and multiplication; supports field demonstration and extension to increase awareness of farmers and development agents on varietal information and good agronomic practices, and provides training in the post and pre-harvest technologies. According to Karta *et al.* (2021), the existence of strong early generation seed schemes at research centers and with other actors is essential for sustaining crop productivity. Provide technical expertise to seed companies for the production of quality inputs & research on agricultural issues.

The seed regulatory authorities provide technical training on quality seed production, processing, and storage for internal seed quality control for seed producer cooperatives and farmers. The district bureau of agriculture brings pre-basic/basic seeds or early generation seeds (EGS) of improved varieties from research institutes located in similar agro-ecology and conducts participatory variety trials together with farmers under different input packages and agronomic practices; assesses farmers' seed demand and determine the number of certified seeds required; provide external support for formally organized farmers for seed production and distribution in collaboration with cooperative unions promotion office; support market-led seed supply to increase the availability of certified seeds and locally produced quality declared seeds (QDS) in collaboration with the regional bureau of agriculture.

The public seed enterprises produce certified seeds & EGS and supply through MoA distribution channels. They train contract cluster groups and members of SPCs in quality seed production and management as well as agronomic practices; produce certified seed through contract arrangement on public and private commercial farms and on farmers' fields along with the production on their farms; provide training to participating farmers along with area selection and clustering. The regional seed enterprises and private seed growers are using seed laboratories of their respective regions, neighboring regions, or EABC laboratories for quality assurance, cleaning, and labeling of their seeds.

The private seed companies produce seeds on their farms and under a contractual framework with individuals or groups of farmers and combine their efforts to produce and supply seed to the growers, share information on their activities and learn from other actors.

The seed producer cooperatives & unions (SPCUs) support farmers in the provision of basic and certified seeds, training, and supervision through linking farmers with research institutions and input service providers; procures certified seeds from public seed enterprises and private seed companies to deliver to farmers; engaged in seed production of open pollinating varieties with technical support from district BoA.

The non-governmental organizations (NGOs) link between researcher and beneficiaries, partner for need-based research program; provides financial, technical, and administrative support to increase the number and capacity of SPCs and seed agents for the production and distribution of large quantities of crop varieties; disseminating knowledge, advisory services, and provide training to farmers and SPC members on clustering, isolation, and field management.

The seed agents and agro-dealers share knowledge of the quality and quantity required for input generation; supply of inputs, marketing, and sale of agricultural inputs in collaboration with farmers and SPCUs. Farmers' linkage is to verify the varietal suitability of seed accessed through social networks and seed agents; share information/knowledge and experience with other farmers; identification of field problems with other actors; participate in the preparation of action plan with extension agents and district bureau of agriculture.

The identified seed system actors at the national level linked to one another strongly MoA with EIAR, EABC, RBoA, and RQCAA; EIAR with MoA, RARIs, HLIs, EABC, DBoA, and RQCAA; RARIs and EABC with RSEs and RQCAA; RSEs with RBoA, RQCAA, and DBOA; PSCs &

cooperative unions with Farmers; PSCs with DBoA; SPCUs with cooperative unions & Farmers; DBoA with Farmers, SPCUs, Cooperative unions, NGOs, Seed agents & agro-dealers; RBoA with RQCAA, DBoA, and cooperative unions; seed agents & agro-dealers with Farmers, SPCUs, and cooperative unions. There is a medium linkage between MoA with DBoA, PSCs, SPCUs, & cooperative unions; EIAR with RSEs, RBoA, PSCs, farmers, and NGOs; EABC with Farmers, Seed agents & agro-dealers, DBoA, SPCUs; RSEs with cooperative unions & seed agents & agro-dealers; PSCs with RBoA; NGOs with Farmers; SPCUs with NGOs; RQCAA with cooperative unions and DBoA; RARIs with RBoA and DBoA; RBoA with SPCUs and Farmers. The weak linkage between MoA with RARIs, HLIs, RSEs, NGOs, and Farmers; EIAR with cooperative unions and SPCUs; RARIs with EABC, PSCs, cooperative unions, NGOs, Farmers, and SPCUs; EABC with RBoA; RSEs with PSCs, SPCUs, and Farmers; PSCs with RBoA, cooperative unions, Farmers, SPCUs, and seed agents & agro-dealers; HLIs with RBoA, cooperative unions, and SPCUs; EIAR with SPCUs; RQCAA with NGOs, SPCUs, and Farmers. The result also indicates no linkage between HLIs with EABC, RSEs, DBoA, PSCs, seed agents & agro-dealers, and Farmers; EABC with PSCs, cooperative unions, and NGOs; RSEs with NGOs and Farmers; PSCs with NGOs and RQCAA; MoA, EIAR, RBoA, RQCAA, and NGOs with seed agents & agro-dealers.

The result showed that 34 percent of the linkages among actors were weak, 29 percent were strong, 20 percent medium, and 17 percent had no linkage. The reasons for weak linkage were poor management capacity; inappropriate organizational structure; unfavorable reward systems; time and money constraints; inappropriate planning, monitoring, and evaluation of the process of interaction; different organizational cultures, expectations, and operating procedures; lack of integration among actors; poor marketing system; and poor seed multiplication schemes. All of the identified actors have roles and responsibilities that are interrelated. The inefficiency of one actor has an automatic detrimental impact on the performances of the other performers. The key informants also stated that there is a lack of commitment, coordinated planning, poor communication between linkage partners, and implementation in the linkage of different actors. Therefore, inter-organizational linkages should be assessed to maintain better aspects negotiate improvements in existing linkages, and linkage mechanisms, and build new relationships among actors.

Seed actors' linkage gaps

The identified seed system actors' linkage gaps were a lack of coordination between production, processing, and delivery of certified seeds of improved varieties; limited EGS of improved varieties provide to the district bureau of agriculture for use in participatory trials, but most of them failed to adapt to the local environment; insufficient quantities of certified seeds and EGS supply by the public seed enterprises and distribution is often delayed; distribute varieties that are not recommended for the specific agro-ecology (e.g., hybrid maize for highland is sold to midland areas). Actors did not establish seed reserves for seed system resilience in cases of disaster; inconsistent and inaccurate demand planning; productivity gaps and financial constraints in their contract grower schemes; lack of diverse and good quality varieties as well as limited quality assurance mechanisms.

Implications of the gap analysis of seed actors' linkage

Collaborative institutional linkages need to be promoted among all actors to strengthen the seed system of the country. Create dialogue-based relations with farmers to enable them to express what desirable technologies are for them in their particular context. Improve the operational effectiveness of public seed enterprises, such as through improved assessments of farmer demand and revised seed production strategies. A favorable policy environment needs to be established to encourage and enable innovations by seed actors. Thus, system perspectives with transparent and agreed-upon linkage policies based on the consent of the seed actors should be a prerequisite for vibrant and integrated seed sector development. Joint visions and regular multi-stakeholder discussions are needed between the range of actors and interest groups that result in joint analysis, planning, and hence collective action. Improving the performance of seed producers' interaction between seed sector actors, and the factors that affect the individual performance of the different actors themselves.

2.4. Conclusion and Recommendations

The Ethiopian seed system has been confronted with several constraints. Some of the identified constraints of the seed system were lack of a clear seed policy/strategy; inadequate seed marketing information and infrastructure; inefficient extension service; inadequate certified seed supply; lack of proper linkage between different actors involved in seed systems; focus on few crops in the formal system; low private sector involvement in the formal system; inefficient seed promotion, distribution, and marketing mechanisms; weak variety release and seed quality assurance system. In Ethiopia, the formal seed sector, which includes both public and private companies' supplies about 10-20% of the actual demand of the country, while certified seed covers less than 10% of the cultivated area. The informal seed system accounted for about 80-90% of the local seed used by smallholder farmers.

The seed system requires more investigation with full utilization, collaboration, and dedicated responsibilities and should be given attention to effective seed demand assessment mechanisms and seed system planning. Seed system strategy should be properly prepared in terms of quality, time and place of supply, and fair pricing; fill the huge gap between seed demand and supply; establish clear and simple institutional and functional linkages between research and seed-producing institutions.

The Ethiopian seed policy has not been revised for a long time to guide its development. This has negative consequences for plant genetic resources conservation, plant breeding research & development, as well as seed production and distribution system. The existing national seed policy, seed law proclamation, and seed regulation articles and provisions should be reviewed and updated to support and encourage the development of formal and informal seed systems, as well as small-scale farmers and cooperatives.

To simplify the roles and responsibilities gap among existing seed actors in the sector, and resolve any issues that arise, a joint vision and development program should be developed between the research institutes, public sector producers, private seed companies, cooperatives, and farmers along with a regular discussion forum to highlight and mitigate any issues.

Weak coordination and linkages were observed among seed actors for seed production, distribution, and marketing due to weak management capacity; inappropriate organizational structure; inappropriate planning; lack of accountability and responsibility were the main challenges observed to enhance the efficiency of the seed sector. So, coordination and linkages among seed actors should need to strengthen to stand in rapid, orderly, and effective growth; create a mechanism to strengthen their linkage in the seed system.

References

Abebe Atilaw. 2010. A baseline survey on the Ethiopian seed sector. The African seed trade association. Addis Ababa, Ethiopia.

Abebe Atilaw and Lijalem Korbu. 2011. Recent development in seed systems of Ethiopia. Improving farmers' access to seeds empowers farmers' innovation. Series No. 1, edited by Alemu D, Kiyoshi S, and Kirub A, 13–30. Addis Ababa, Ethiopia: JICA

Abebe Atilaw, Dawit Alemu, Zewdie Bishaw, Tekeste Kifle, and Karta Kaske. 2017. Early Generation Seed Production and Supply in Ethiopia: Status, Challenges, and Opportunities. Ethiopian Journal of Agricultural Science. 27(1): 99-119.

Adane Hirpa, Meuwissen M, Agajie Tesfaye, Lommen W, Oude A, Admasu Tsegaye, and Struik P. 2010. Analysis of seed potato systems in Ethiopia. American Journal of Potato Research. 87:537–52. Doi: 10.1007

ATA. 2015. Seed system development strategy: Vision, systemic challenges, and prioritized interventions. Agricultural Transformation Agency. Working strategy document, Addis Ababa, Ethiopia.

Bezabih Emana. 2012. The cooperative movement in Ethiopia. Paper presented in a workshop on perspectives for cooperatives in Eastern Africa, 2–3, October 2012, Uganda

Coomes O, McGuire S, Garine E, Caillon S, McKey D, and Demeulenaere E. 2015. Do farmer seed networks make a limited contribution to agriculture? Four common fallacies. Food Policy. 56:41–50.

CSA. 2013. Living standards measurement study intermediate surveys of agriculture. Ethiopia socio-economic survey. Federal Democratic Republic of Ethiopia, Central Statistical Agency, Addis Ababa, Ethiopia.

Dawit Alemu. 2010. Seed system potential in Ethiopia: Constraints and opportunities for enhancing the seed sector. International Food Policy Research Institute.

Dawit Alemu. 2012. The Political Economy of Ethiopian Cereal Seed Systems: State Control, Market Liberalization, and Decentralization. Future Agricultures Consortium. Policy Brief. 048.

Dawit Alemu, and Zewdie Bishaw. 2015. Commercial behaviors of smallholder farmers in wheat seed use and its implication for demand assessment in Ethiopia. Development in Practice. 25(6):798–814. doi:10.1080/09614524.2015.1062469

Dawit Tsegaye, Frans JHMV, and Hans CMT. 2017. Seed producer cooperatives in the Ethiopian seed sector and their role in seed supply improvement: A review. Journal of Crop Improvement. 31(3): 323-355. DOI: 10.1080/15427528.2017.1303800

De Boef W, Dempewolf H, Byakweli J, and Engels J. 2010. Integrating genetic resource conservation and sustainable development into strategies to increase the robustness of seed systems. Journal of

Sustainable Agriculture. 34:504–531. DOI: 10.1080/10440046.2010.484689

Dejen Bekis. 2021. Status of Seed System in Ethiopia. Journal of Advances Crop Science and Technology. 9:4. ISSN: 2329-6879.

Demekech Gera, Fisseha Moges, Getnet Zeleke, Kindie Tesfaye, and Melkamu Ayalew. 2010. Multi-stakeholder linkages in rural innovation processes in Amhara region, Ethiopia. Amhara National Regional State, BoARD. Working Document Series 137.

FAO. 2020. National Community Seed Bank Platform for Strengthening Informal Seed System in Ethiopia. Benefit Sharing Fund Project – 4th Cycle. Food and Agriculture Organization of the United Nations.

Fekadu Beyene. 2010. The role of NGO in informal seed production and dissemination: The case of eastern Ethiopia. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 111(2): 79-88.

Fischer R, and Edmeades G. 2010. Breeding and Cereal Yield Progress. Journal of Crop Science Society of America. 50:85-98. DOI: 10.2135. | 677 S. Segoe Rd., Madison, WI 53711 USA.

Gebremedhin Welu. 2015. Challenges and Opportunities of Seed Multiplication in Eastern Tigray Ethiopia. Journal of Biology, Agriculture and Healthcare. 5(3):42. ISSN 2224-3208.

Gloria A, Travis W, Altinay K, and Isabel L. 2017. Implications of Seed Policies for On-Farm Agro Biodiversity in Ethiopia and Uganda. Journal of Sustainable Agricultural Research. 6(4): ISSN 1927-050X E-ISSN 1927-0518

Habtamu Diriba, Dandena Gelmesa, Kemal Kasim. 2019. Prospects and Challenges in Seed Sector Development: Lessons from Eastern Ethiopia. European Business & Management. 5(4):51-63.

Hussien Mohammed, Tadesse Dessalegn, Fetien Abay, and Thijssen MH. 2013. Participatory varietal selection for enhancing farmers' access to quality seed in Ethiopia. In Community Biodiversity Management-promoting resilience and the conservation of plant genetic resources, 279–84. New York, USA.

Karta Kaske, Astawus Esatu, and Abebe Atilaw. 2021. The interface of demands for certified seed and supplies of early generation seed in major food crops in Ethiopia: Challenges and ways forward. In: Karta Kaske, Taye Tadesse, Sofiya Kasa, and Driba Geleti. (Eds), Early Generation Seed Production in Ethiopia: Trends and Way Forward. Proceedings of a 1st consultative workshop, August 3-4, EIAR.

Kassa Tarekegn and Merkine Mogiso. 2020. Assessment of improved crop seed utilization status in selected districts of Southwestern Ethiopia. Journal of Cogent Food and Agriculture. 6:1. DOI: 10.1080/23311932.2020.1816252

Kumlachew Alemu. 2015. Seed Production and Dissemination Systems Analysis: The Case of Ethiopia. Journal of Food Science and Quality Management. IISTE. ISSN 2224-6088. Vol.35.

Louwaars N, and De Boef W. 2012. Intermediate seed sector development in Africa: A conceptual framework for creating coherence between practices, programs, and policies. Journal of Crop Improvement. 26:39-59. doi:10.1080/15427528.2011.611277.

Louwaars N, De Boef W, and Edeme J. 2013. Intermediate seed sector development in Africa: A basis for seed policy and law. Journal of Crop Improvement. 27:186–214.

Mandefro Nigussie, Karta Kaske, Amsalu Ayana, Dawit Alemu, Mohammed Hassena, Tefera Zeray, Abeneazer Adam, and Amsale Mengistu. 2020. Status of Seed Quality Control and Assurance in Ethiopia: Required Measures for Improved Performance. EIAR. ISBN: 978-99944-66-52-8.

McGuire S, and Sperling L. 2016. Seed systems smallholder farmers use. Food Security. 8:179–195. DOI: 10.1007/s12571-015-0528-8

Mohammed Hassena. 2017. The seed for change: the making and implementation of seed policies in Ethiopia. Ph.D. thesis, Wageningen University, the Netherlands. ISBN: 978-94-6343-668-7 DOI: 10.18174/421204

Mohammed Hassena, and Lemma Dessalegn. 2011. Assessment of the Ethiopian Seed Sector. Paper presented at the African Seed and Biotechnology Program Workshop, May 2011, Addis Ababa.

Shimelis Atalay. 2012. Analysis of research-extension-farmer linkage in finger millet technology development and delivery in Mecha district of Amhara Region, Ethiopia. Journal of Agricultural Economics and Development. 1(6):121-129.

Teka Debele, Mulugeta Gebeyehu, and Alemayehu Abebe. 2019. Contributions and Challenges in Research and Extension Linkage for Agricultural Transformation in Ethiopia. International Journal of Agricultural Extension. 7(2):187-195. DOI: 10.33687/ijae.007.02.2971

Teshome Hunduma. 2021. Politics of Seed in Ethiopia's Agricultural Transformation: Pathways to Seed System Development. Journal of Frontiers in Sustainable Food System. 5:742001. DOI: 10.3389.

Teshome Hunduma, Dalle SP, Makate C, Haug R, and Westengen O. 2021. Pluralistic Seed System Development: A Path to Seed Security? Agronomy. 11: 372. https://doi.org/10.3390/

World Bank. 2015. Enabling the Business of Agriculture: Progress Report. Strengthening the Seed System. The World Bank.

Yohannes Tesfaye, Amsalu Ayana, and Gareth B. 2012. Ethiopia Seed Sector Assessment. ISSD Briefing Note September 2012**.** Wageningen University and Research center, Wageningen, the Netherlands.

Zewdie Bishaw. 2016. Rapid deployment of rust-resistant wheat varieties: ICARDA's experience and lessons learned. In Containing the Menace of Wheat Rusts: Institutional Interventions and Impacts; Zewdie Bishaw, Dawit Alemu, Abebe Atilaw, Abebe Kirub Eds.; Ethiopian Institute of Agricultural Research: Addis Ababa, Ethiopia, pp. 1–40

Chapter 3: Seed Supply System, Access to Certified Seeds, and Its Effect on Improving Food Security of Farm Households in Central Ethiopia

Abstract

Availability and access to adequate and quality seed at the right time are critical factors to improve agricultural productivity, increase agricultural production and enhance food security. This study aims to assess the seed supply system, access to certified seeds of improved varieties, and estimate their effect on household food security status. The study is based on primary data generated from 299 sample households selected using systematic random sampling techniques and from key informant interviews and focus group discussions. The data were analyzed using descriptive statistics, a multinomial logistic regression model, and HFIAS food security measurement. The finding shows that the seed supply system is largely informal, consisting of seed access from their own saved seeds, farmers' neighbor exchanges, and the local market, which can supply up to 70% of their demand. The study found that about 18% of the households were food secure, 32% mildly food insecure, 41% moderately food insecure, and 9% severely food insecure. The result of the assessment of the severity of household food insecurity and access-related conditions showed that about 90% faced a shortage of food, about 78% were unable to eat their preferred food, about 77% eat a limited variety of food, and about 12% used to stay hungry. The multinomial regression analysis shows that the sex of the household head, farming experience, access to seeds, and livestock holding positively influenced household food security conditions. On the other hand, the age of the household head, family size, farm size, and distance to the market negatively affected household food security. Therefore, the study suggested the need to improve seed accessibility and the seed supply system in order to address food insecurity and strengthen the resilience of smallholder farmers.

Keywords: Access, Food insecurity, Household, Seed, Supply system

3.1. Introduction

Food security is one of the basic indicators of growth and development. In Ethiopia, approximately 20.5% of households are estimated to be food insecure (WFP, 2019). At an individual level, the proportion of food insecure persons stood at 25.5% which is about 26 million people food insecure (WFP, 2019). Ethiopia is one of the countries strongly associated with a prolonged food security problem and struggling to develop agricultural production and productivity to combat food insecurity. Hiwot and Degefa (2022) explained the growth in agricultural production can minimize food insecurity by increasing the amount of food available for consumption at the household level.

Adugna (2017) studied the agricultural production system in Ethiopia is highly dominated by traditional farming and the application of modern inputs has been extremely limited. As a result, the yields of various crops are very low. Ethiopia is predominantly an agrarian country where agriculture is the dominant economic sector of which the crop sector contributes much to food security and seed plays an important role in increasing crop production.

Seed is a key input for improving crop production and productivity and it is one of the most economical and efficient inputs to agricultural development. Kutoya and Kebede (2019) confirm low agriculture productivity is partly due to the limited use of improved varieties and associated technologies, the access, supply system, and utilization of certified seeds of improved varieties play an important role in this endeavor. Girma and Amanuel (2017) reported the significant role of the certified seed, a sustained increase in crop production and productivity is largely dependent on the development of improved crop varieties and an efficient system for the timely supply of seeds to farmers. Generation and transfer of improved technologies are critical prerequisites for agricultural development, particularly for an agrarian-based economy such as Ethiopia. Kassa and Merkine (2020) mentioned that even though the release of several improved crop varieties, there has been limited use of certified seeds by the majority of farmers in Ethiopia. According to Temesgen (2019), the unavailability of certified seeds at the right place and time coupled with poor promotion systems due to the inefficiency of the seed supply systems accounts for the limited use of certified seeds in Ethiopia.

Seed security can be said to exist when the household has sufficient access to adequate quantities of good quality seed and planting materials of preferred crop variety in both favorable and unfavorable agricultural seasons (McGuire and Sperling, 2016). The pillars are seed availability, access, quality, varietal suitability, and resilience. Achieving seed security is quite different from food security, despite their obvious links. McGuire and Sperling (2016) reported seed security has a direct influence on agricultural production, diversity, and resilience, and contributes to food and livelihood security for households who depend on agricultural production. The aim of household seed security is to help improve and strengthen the household food production capacity thus enabling farmers to retain seeds of their preferred local varieties (Fredenburg, 2015). For poor farmers with no planting material, seed security refers to access to seeds to maintain food production. Sperling *et al.* (2020) argued that the two are linked, but far from the same. Seed security and food security come one after the other in agricultural rehabilitation programs. Thus, seed security, both in normal and disaster years, is a prerequisite for increasing food production, improving farmers' income, alleviating poverty, and ensuring food security (Fredenburg, 2015). Securing the supply of quality seeds and planting materials for the most important food crops is the most effective way to sustain food security. Louwaars and De Jonge (2021) stated that the availability of seeds in a given area is not enough to ensure seed security. But, resources to afford seeds influence the seed security situation of farmers. Access to seed refers to farmers' ability to acquire seed through purchase, exchange, loan, or social networks. According to Bassa *et al.* (2018), seed utilization comprises two broad aspects: seed quality and variety quality. Physical, physiological, and hygienic characteristics make up seed quality. Variety quality consists of genetic attributes, such as plant type, duration of the growth cycle, seed color and shape, and palatability.

Seed supply system has been evolving in an attempt to ensure access to seed in the required quantity at affordable prices and time. The seed supply system in Ethiopia, represents the entire complex organizational, institutional, and individual operations associated with seed development, multiplication, processing, storage, distribution, and marketing. Two different types of seed supply systems, formal and informal, are widely known. The formal seed supply system involves a chain of activities leading to the certified seeds of released varieties. Abebe *et al.* (2017) explained the informal system is extremely important for seed security and the bulk of seed supply is provided through this system, implying its importance in national seed security. Girma and Amanuel (2017) confirm that enhanced seed availability through formal or informal sources will improve smallholder farmers' access to seed and enhance variety adoption. Similarly, a certified seed is crucial in the improvement of food security and farm household livelihood.

A sustainable seed access, supply, and utilization system will ensure that high-quality seeds of a wide range of varieties and crops are produced and fully available in time and affordable to farmers and other stakeholders. Girma and Amanuel (2017) in their study reported many farmers still fail to access the certified seeds from formal seed supplies as many of the released varieties have never been widely distributed and made available in time and at affordable prices due to a combination of factors, including inefficient seed production, distribution, and quality assurance systems, as well as bottlenecks caused by a poor seed policy on crucial issues like input credit access. Even if the supply of seed is through public and private seed producers, the demand for certified seed is still increasing rapidly from time to time. Shimelis *et al.* (2018) argued several cereal crops, particularly hybrid maize and bread wheat, are the main focus of both governmental and private seed companies. Zewdie and Dawit (2017) mentioned that they also do not satisfy the diversified seed demand of farmers. In general, the unavailability of quality seeds at the right place and time, poor promotion system, and lack of awareness for farmers are factors affecting the failure to exploit the potential of improved crop seeds. The seed demand forecasting system is an important function to produce and avail seed for the farmers at the right time and required quantity. The low level of certified seed is attributable to a variety of social, economic, institutional, and environmental factors and agricultural productivity is very low due to a lack of a certified seed supply system and access. Therefore, the aim of this paper is to assess the supply system and access to certified seed varieties in improving household food security. Specifically, assess farm households' access to certified seeds, evaluate the seed supply systems, and measure the household food security status in central Ethiopia.

3.2. Materials and methods

3.2.1. Study area

Three districts namely Ada'a and Bora from the East Shewa zone in the Oromia region, and Moretina Jiru from the North Shewa zone in the Amhara region were selected as study sites. They were considered mainly because of their cereal-based farming systems. The farming system is centered on a crop and livestock production system. The most important crops are cereals (tef, wheat, maize, barley, and sorghum) and legumes (chickpeas, field peas, field beans, haricot beans, and lentils) mainly grown under rain-fed agriculture at medium and high altitudes, followed by irrigated horticultural crops, which are used to generate income beyond consumption.

3.2.2. Sampling techniques and sample size

The sampled households were chosen using a multistage sampling technique. Two regions and three districts were purposely chosen for the initial stage based on their accessibility and agroecological suitability for wheat, *tef*, and maize production. The second step involved a random selection of six representative kebeles, the smallest administrative unit in the district. Step three, within targeted *kebeles*, farmers who adopted or did not adopt the technology were identified by stratified sampling techniques. Twenty-five key informants (KII) were identified by using the key informant sampling technique, and all the key informants had an extensive understanding of the seed system and farm experience. Six focus group discussants (FGD) were also organized and selected using a random sampling technique based on being socially respected within the society, each group was composed of 5-7 members. Based on the simplified formula of Kothari (2004), a total of 299 interviewed samples (108, 68, and 123 samples from the districts of Ada'a, Bora, and Moretena Jiru respectively) were randomly selected.

3.2.3. Method of data collection and data sources

A cross-sectional and narrative research design was used to conduct this study. Primary and secondary data sources were used to collect this information. Quantitative data were gathered from a sample of respondents using a structured questionnaire developed with digital data capturing tools, i.e., Computer Assisted Personal Interviews (CAPI), and qualitative data from KIIs and FGDs to triangulate and substantiate the quantitative data by using a checklist.

3.2.4. Data analysis

Data were analyzed using descriptive statistics including percentages, means, and standard deviations in order to assess the demographic and socio-economic characteristics. The econometric model study was performed using STATA version 14.2 software. A multinomial logit model was employed to analyze the quantitative data, while narrative and conceptual justification were utilized to examine the qualitative data. The study also analyzed the household food security status and adopt one of the food security measurements, the Household Food Insecurity Access Scale (HFIAS) with standard questions in the study area.

The HFIAS model specification

The HFIAS is one of the indicators of food insecurity status that is based on the experience of a household’s access to food over a month. The HFIAS assessed the level of food security in households by calculating, comparing, and scaling replies to nine questions. It also limited the number of meals served and scaled back the quality of the food owing to financial constraints. Using HFIAS assessment tools, including characteristics related to household food insecurity and the prevalence of household food insecurity access, the food security status of the study's households was evaluated. The food security status of the sampled households can be assessed using the HFIAS survey data, which then categorizes households into four phases or status of food insecurity: food secure, mildly, moderately, and severely food insecure.

According to FANTA (2007), the HFIAS reflects the three universal domains: anxiety and uncertainty about the household food supply (Q1); insufficient quality in terms of variety and preferences of the type of food (Q2-4); and insufficient food intake and its physical consequences (Q5-9). Households experience any of the conditions at any level of severity in each domain, percent of households that responded "yes" to any of the conditions in a specific domain. For instance: "Percent of households with inadequate food quality."

$$\frac{Number\ of\ households\ with\ \text{yes}\ response\ to\ Q2\ or\ Q3\ or\ Q4}{Total\ number\ of\ households\ responding\ to\ Q2\ or\ Q3\ or\ Q4} x100 \text{ -- (1)}$$

The HFIAS score indicates each frequency-of-occurrence question from three frequency categories rarely (1 to 2 times), sometimes (3 to 10 times), and often (>10 times). HFIAS scores range from 0 to 27, with a higher score showing that the more food insecurity (access), while a lower score indicates the less food insecurity (access) the household experienced.

The household food insecurity access prevalence of each category was analyzed by the following formula.

$$\frac{Number\ of\ households\ with\ HFIAS\ category}{Total\ number\ of\ households\ with\ a\ HFIAS\ category}\ x\ 100 \text{ -- (2)}$$

The HFIAS is computed as the summation of the frequency of occurrence during the past four weeks for the nine-food insecurity-related conditions:

$HFIAS = Q1a * F1 + Q2a * F2 + Q3a * F3 + Q4a * F4 + Q5a * F5 + Q6a * F6 + Qa7 * F7 + Q8a * F8 + Q9a * F9$ -- (3)

Where, HFIAS = Household Food Insecurity Access Scale; Q1-9 = Questions; F1-9 = Frequencies

Multinomial logit model specification

The study assessed the determinants of household food security status levels using a multinomial logit model. Household food insecurity access prevalence (HFIAP) status is the discrete or categorical variable used to describe the dependent variable. According to Greene (2012), the multinomial is a classification technique that extends logistic regression to problems with more than two discrete possible outcomes. It is used to forecast the probabilities of the various outcomes of a categorically distributed dependent variable given a set of independent variables. The multinomial logit model generally captures how households' socioeconomic and demographic variables affect the probability that a household within the sample exhibits the identified possible levels of food insecurity in reference to the base outcome. The independence of irrelevant alternatives implies the marginal effect of choosing food-secure households as reference households are not affected by the existence of other levels of food insecurity (p=0,1,2,3). In other words, even if households at different levels of food insecurity are used as a benchmark, the results or predicted parameters are anticipated to be the same. As stated below, the multinomial logistic regression model:

$$P(x'\beta_j) = \frac{e^{x'\beta j}}{\sum_{j=1}^{m} e^{x'\beta j}} = 0, \ldots., m \quad \text{------} \quad (4)$$

Where p=0 food secure households; p=1 mildly food insecure households; p=2 moderately food insecure households, and p=3 severely food insecure households; βj is a vector of coefficients on each of the independent variables *X*.

The multinomial logistic coefficients are difficult to interpret, and associating the βj with the j^{th} outcome is tempting and misleading. Thus, in order to interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as:

$$\frac{\partial pj}{\partial xi} = Pj\,[\beta jk - \sum_{k=0}^{j} Ph\beta hk] = Pj\,(\beta jk - \bar{\beta} pk) \quad \text{------} \quad (5)$$

Where P is for probability, X stands for socioeconomic traits and other variables, and β is a vector of coefficients. The marginal effects measure the expected change in the probability of a household falling into a particular household food insecurity level with respect to a unit change in an explanatory variable. The marginal effects and corresponding coefficients' signs may also vary. The variables utilized in the analysis are described in Table 3.1 below.

Table 3.1: Explanatory variables, measurement, and expected sign

Variables	Measurement	Type	Exp. sign
Sex	1 if male and 0 otherwise	Dummy	+/-
Age	household age in years	Continuous	-
Family size	Number	Continuous	+
Education	1) No formal education, 2) Gr. 1-4, 3) Gr. 5-8, 4) Gr. 9-10, 5) Gr. 11-12, 6) College and above	Categorical	+/-
Farm size/ land holding	Actual farm size in hectares	Continuous	+
Farm experience	Farming experience in years	Continuous	+
Livestock holding (TLU)	Number of livestock	Continuous	+
Income source	1) sales of the crop, 2) sales of livestock & products, 3) on-farm daily labor, 4- rented out oxen & land	Categorical	+
Non-farm income	1 if yes and 0 otherwise	Dummy	+
Credit	1 if accessed and 0 otherwise	Dummy	+
Seed access	1 if accessed and 0 otherwise	Dummy	+
Extension contact	Number of Visits by extension agent	Continuous	+
Market distance	Distance to the marketplace in minutes	Continuous	-

3.3. Results and Discussion

3.3.1. Socio-economics and demographic characteristics of respondents

The descriptive statistics for the variables of the sample households examined in the study are presented in Table 3.2. It shows that 67.9% of the respondents have not accessed certified seeds, while only 32.1% have accessed certified seeds in the study area. The results of the study were found statistically significant for family size, land holding, farming experience, and livestock holding at a 1% significance level. This suggests that there was a significant difference in all these factors between those who have access and those who do not have access.

Two-sample t-test with equal variance was used to examine group mean the difference between food-secure and food-insecure farm households. Accordingly, the means of food-secure and insecure households significantly differ only in four of the seven continuous variables. The results of these variables were found to be the family size, land holding, and extension contact was statistically significant at a 1% level of significance, whereas, the age of the household heads was statistically significant at a 10% level of significance. This shows that the mean differences in the variables between the food-secure and food-insecure were found to be statistically significant. On the other hand, the farming experience, livestock holding, and market distance were statistically insignificant in determining the food security of the households. This shows that there is no significant difference between the means of the food-secure and food-insecure farm households of these variables (Table 3.2).

Table 3.2: Household characteristics for continuous explanatory variables

Variable	Access to certified seed Yes=96 Mean (SD)	Access to certified seed No=203 Mean (SD)	Mean Diff.	T-test	Food secure N=137 Mean (SD)	Food insecure N=162 Mean (SD)	Mean Diff.	T-test
Age	44.17 (12.09)	42.63 (12.57)	1.536	-0.998	41.78 (13.39)	44.26 (11.45)	2.478	1.725*
Family size	6.43 (2.27)	5.15 (1.99)	1.274	-4.937***	4.88 (2.02)	6.14 (2.12)	1.253	5.200***
Farm size/ land holding	2.69 (1.87)	1.68 (1.01)	1.009	-6.055***	2.27 (1.59)	1.78 (1.22)	0.487	-2.985***
Farming experience	23.92 (10.18)	18.33 (9.91)	5.587	-4.512***	20.45 (11.10)	19.85 (9.63)	0.607	-0.506
Livestock holding	8.29 (6.31)	5.58 (4.76)	2.719	-4.141***	6.97 (5.24)	6.01 (5.59)	0.959	-1.521
Extension contact	2.28 (1.89)	1.93 (2.17)	0.350	-1.352	2.45 (2.18)	1.70 (1.96)	0.742	-3.095***
Market distance	7.32 (3.73)	7.05 (3.77)	0.274	-0.588	7.14 (3.57)	7.13 (3.91)	0.009	-0.020

Source: Survey, 2021 *** and * Significant at p<0.01and p<0.1*

The findings revealed that the sex of the household head, educational level, and marital status were found to be significant in explaining variations in food security status between food-secure and food-insecure farm households. The chi-square result shows that the educational level of the households was significant at a 1% level of significance, and the sex and marital status of the household head were significant at a 5% level of significance respectively. This means that there is a significant association between the variables and food security status. The statistical analysis result revealed that only 23% of respondents had no formal education, while the majority 77% of the respondents could attend formal school in the study area. Among the formal educational level households, 81 and 74% were found to be food-secure and food-insecure, respectively, while 19 and 26% of the non-formal education level households were food-secure and food-insecure, respectively. This result indicates the significance of education for household food security improvement because educated household heads are usually practiced family planning programs thereby limiting their family size when compared with their counterparts and becoming able to manage the food demands of their households. In addition, they participate in a number of non-farm income-producing activities with their family members.

The result of the sex of the household head shows that the percentage of male household heads was 88%. The chi-square result of this variable indicates that 93.4 and 6.6% of male and female-headed sample households are food-secure, whereas 84 and 16% of male and female-headed households are food insecure respectively. In general, male-headed households are more food-secure than female-headed households. The result revealed that statistically significant association between marital and food security status. The majority 87% of the sample households were married and the result indicated 88 and 85% of households are food-secure and food-insecure respectively. Furthermore, the chi-square results indicated that there is no statistical association between farm income, off-farm, access to credit, farm input variables, and food security status (Table 3.3).

Table 3.3: Socio-economic characteristics of the respondents for dummy variables

Variable	Category	Food secure (N=137)	Food insecure (N=162)	Total value	Chi-square
		N (%)	N (%)	N (%)	
Sex	Female	9 (6.6)	26 (16.0)	35 (11.7)	
	Male	128 (93.4)	136 (84.0)	264 (88.3)	0.011**
Education	No formal education	26 (19.0)	42 (25.9)	68 (22.7)	
	Gr. 1-4	47 (34.3)	70 (43.2)	117 (39.1)	
	Gr. 5-8	40 (29.2)	44 (27.2)	84 (28.1)	
	Gr. 9-10	16 (11.7)	4 (2.5)	20 (6.7)	
	Gr.11-12	3 (2.2)	2 (1.2)	5 (1.7)	
	College & above	5 (3.6)	0 (0.0)	5 (1.7)	0.002***
Income	Sales of crop	82 (59.9)	101 (62.3)	183 (61.2)	
	Sales of LS & products	40 (29.2)	39 (24.1)	79 (26.4)	
	Daily labor	2 (1.5)	2 (1.2)	4 (1.3)	
	Rented out oxen	13 (9.5)	19 (11.7)	32 (10.7)	
	Rented out land	0 (0.0)	1 (0.6)	1 (0.3)	0.729
Non-farm	Sale of charcoal	23 (16.8)	25 (15.4)	48 (16.1)	
	Other (shops)	109 (79.6)	128 (79.0)	237 (79.3)	
	Salary	5 (3.6)	9 (5.6)	14 (4.7)	0.718
Credit	No	75 (54.7)	94 (58.0)	169 (56.5)	
	Yes	62 (45.3)	68 (42.0)	130 (43.5)	0.569
Farm input	No	46 (33.6)	51 (31.5)	97 (32.4)	
	Yes	91 (66.4)	111 (68.5)	202 (67.6)	0.700
Marital status	Single	8 (5.8)	4 (2.5)	12 (4.0)	
	Married	121 (88.3)	138 (85.2)	259 (86.6)	
	Divorced	2 (1.5)	12 (7.4)	14 (4.7)	
	Widowed	6 (4.4)	8 (4.9)	14 (4.7)	0.049**

Source: Survey, 2021 ****and ** Significant at p<0.01and p<0.05 respectively*

3.3.2. Seed supply system and Access for Certified seed

Seed supply systems include all organizations, individuals, legal frameworks, and institutions involved in the collection and conservation of seed varieties, variety development, testing, and release; early-generation seed maintenance (breeder and pre-basic seeds), multiplication of basic and certified seeds; quality control and certification; storage and processing; and distribution and marketing of seeds (Shimelis *et al.,* 2018). The major actors of the formal seed supply system in the study area were the ministry of agriculture (MoA), federal and regional research institutes (EIAR and RARIs), the Ethiopian agricultural business corporation (EABC), regional seed enterprises (RSEs), NGOs, private seed companies, and cooperative unions through extension services in order to enhance certified seed availability, adoption of new varieties, and build capacity at the community level to ensure a sustainable supply of quality seed at an affordable price. According to Tekeste *et al.* (2022), all actors have interdependent roles in the system and the inefficiency of one actor automatically affect negatively the performances of the others.

The seed production-distribution chain in the informal seed supply system is short and simple, without any regulation the smallholder farmers are saved on-farm and exchanged among farmers and borrowed or purchased locally. According to key informants in this study, the major actors playing an important role in the seed supply system and their functions were identified: The early-generation seeds are supplied by federal and regional research institutes to EABC and regional seed enterprises then the basic seed is delivered to private seed companies, unions, and cooperatives. Finally, through unions and cooperatives, the certified seeds of improved varieties reached end users (farmers).

The results also revealed that the demand for the seeds of improved varieties is assessed using a bottom-up approach that starts at the kebele level and moves up to the national level in the study area. Demand estimates at the kebele, woreda, zone, region, and national levels are modified based on trends of certified seed consumption in the previous years and government development plans. This result is in line with the study by Teshome and Dawit (2018). The key informant interviews suggested that the informal system is preferred by the majority of farmers in the study region because it is more dependable and sustainable than the formal system, is relatively less expensive, immediately available when seeds are needed, and allows the use of seeds that have been tested on primary adopter farmers.

A study by John (2016) shows the reasons such as loss of seed due to crop failure, incapability to save seed, need to replace seed, and need to acquire new cultivars may motivate farmers to use off-farm seed; and small-scale seed production is important for seed availability. According to FAO (2020), it is possible to create changes that will improve the standard of living, improve food security, and promote the transformation toward a sustainable commercial agricultural sector. Dalle and Westengen's (2020) study shows how maintaining seed security is a central concern for households and drives a number of practices in the seed supply system. The result shows that smallholder farmers largely rely on their own saved seed and from neighboring farmers in the study area. Girma and Amanuel (2017) explained increasing agricultural production is one of the measures taken to assure food security and livelihood enhancement in rural areas, but this improvement can only be effective and sustainable if subsistence farmers have access to affordable certified seeds through the seed supply system. The specific food security studies by Sani and Kemaw (2019), Adebayo *et al.* (2021), and Jabo *et al.* (2016) suggest that the depth and intensity of food insecurity are high, influenced by poor functioning of seed supply and marketing systems and other household socioeconomic factors.

Access to seed is said to be the ability to acquire seed through the exchange, loan, barter, or use of power in social networks. Agriculture is the dominant economic sector of which the crop sector contributes much to food security and seed plays an important role in increasing crop production in the study area and for its having productive land. Its agriculture is characterized by inadequate production technologies that produce important fluctuations in crop yields, uncertainties, and food insecurity in a variable climate. The farmers do not have access to certified seeds and they widely use the local varieties since the certified seeds are very expensive (Dawit, 2019).

The result indicated that farmers can access seeds from different sources. Table 3.4 shows that the major identified sources of certified seeds were own saved seed (46.2%), farmers-to-farmers seed exchange (19.4%), district bureau of agriculture (10.4%), unions (10.4%), cooperatives (7.7%), seed enterprises (3.3%), local market (1.3%), and research centers (1.3%). This research finding was in line with the finding of Bassa *et al.* (2018) that stated the farmers themselves, unions, and the bureau of agriculture are the major sources of certified seed. Even though the formal seed sector takes a larger share of certified seed dissemination, still most of the farmers used seed from informal seed systems, including own-saved seed, and exchanges with neighbors in the study area.

Table 3.4: Sources of seed access

Seed source	Districts			Total
	Ada'a N (%)	Bora N (%)	Moretina Jiru N (%)	N (%)
Own saved seed	39 (28.3)	21 (15.2)	78 (56.5)	138 (46.2)
Neighboring farmers	28 (48.3)	14 (24.1)	16 (27.6)	58 (19.4)
Local market	3 (75)	1 (25)	0 (0)	4 (1.3)
District BoA	13 (41.9)	4 (12.9)	14 (45.2)	31 (10.4)
Research centers	4 (100)	0 (0)	0 (0)	4 (1.3)
Seed enterprises	6 (60)	1 (10)	3 (30)	10 (3.3)
Unions	7 (22.6)	18 (58.1)	6 (19.4)	31 (10.4)
Cooperatives	8 (34.8)	9 (39.1)	6 (26.1)	23 (7.7)
Total	108 (36.1)	68 (22.7)	123 (41.1)	299(100)

Source: Survey, 2021

3.3.3. Measuring the household food insecurity status

The HFIAS indicators provide an overview of the determinants, access scale, domains, and prevalence of access in households experiencing food insecurity (Coates *et al.*, 2007).

3.3.3.1. The occurrence of household food insecurity access scale conditions

An important aspect of analyzing household food security is how households and communities can physically and financially access food. One of the most accurate ways for examining a household's food security situation is HFIAS-related conditions. As a result, the household food insecurity access connected to conditions revealing specific disaggregated information about the surveyed households' behavior and beliefs.

The result in terms of severity of household food insecurity, and access-related conditions across the surveyed households showed that worry about not having enough food was 89.97%, households replied affirmatively to having been unable to eat their preferred food was 77.59%, and the number of households that had eaten a limited variety of foods 76.59% was the three most severe food insecurity conditions encountered by the questioned households. Moreover, the number of households with an affirmative response to the severe conditions of going to sleep hungry or going a whole day and night without food were 8.36% and 3.68%, respectively. The severity level showed that during the previous 4-week period, about 39.9% of households encountered access problems "rarely", 44.01% "sometimes", and 16.09% "often" (Table 3.5).

Table 3.5: Occurrence of HFIAS household food insecurity access-related conditions.

No.	HFIAS Condition	Yes	No	Rarely	Sometimes	Often
		N (%)	*N (%)*	*N (%)*	*N (%)*	*N (%)*
1	Worry about not having enough food	269(89.97)	30(10.03)	203(67.89)	58(19.40)	8(2.68)
2	Unable to eat preferred foods	232(77.59)	67(22.41)	34(11.37)	136(45.48)	62(20.74)
3	Eat just a few kinds of foods	229(76.59)	70(23.41)	51(17.06)	102(34.11)	76(25.42)
4	Eat foods they do not want	183(61.20)	116(38.80)	52(17.39)	105(35.12)	26(8.70)
5	Eat a smaller meal	120(40.13)	179(59.87)	52(17.39)	54(18.06)	14(4.68)
6	Eat fewer meals in a day	99(33.11)	200(66.89)	39(13.04)	51(17.06)	9(3.01)
7	No food of any kind in the household	50(16.72)	249(83.28)	29(9.70)	20(6.69)	1(0.33)
8	Go to sleep at night hungry	25(8.36)	274(91.64)	16(5.35)	9(3.01)	0(0.00)
9	Go a whole day and night without eating	11(3.68)	288(96.32)	10(3.34)	1(0.33)	0(0.00)

Source: Field survey, 2021; Indications to the severity status: Rarely (once or twice in the past 4 weeks); Sometimes (three to ten times in the past 4 weeks; Often (more than ten times in the past 4 weeks)

3.3.3.2. The occurrence of household food insecurity domain

The result shows that the total percentage for domains anxiety and uncertainty, level of insufficient food quality, and insufficient food intake and its physical consequences were 30.6%, 65.1%, and 24.6% in Ada'a; 61.8%, 91.2%, and 35.6% in Bora; and 22%, 66.9%, and 8.3% in Moretena Jiru districts in the study area respectively as shown below in Figure 3.1.

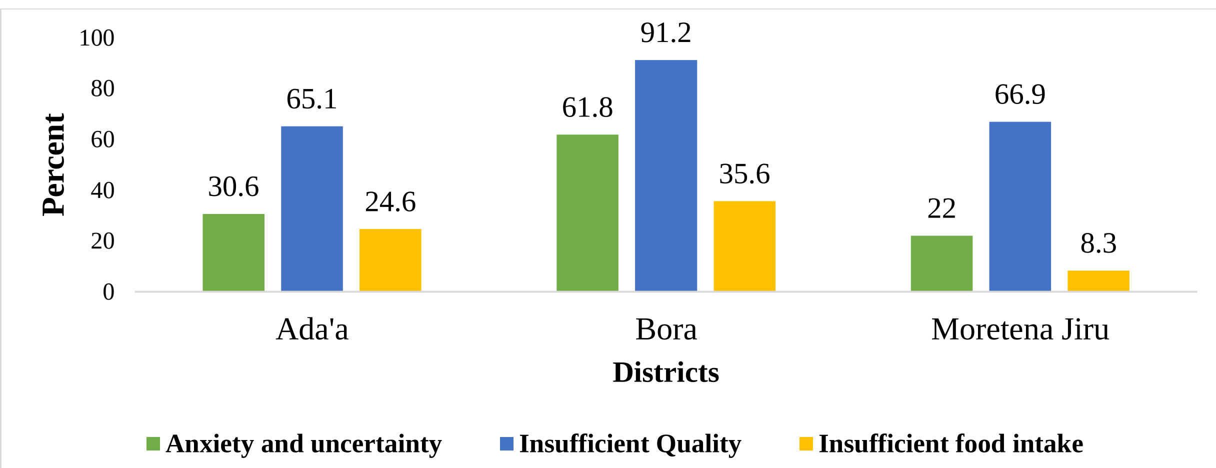

Figure 3.1: HFIAS domain percentage distribution of households in the districts; Source: Field survey, 2021

In general, the study results reveal that the occurrence of household food insecurity, as measured by the HFIAS, is linked to three major domains of food insecurity (access) in the study area, such as 89.97% of study households experiencing anxiety and uncertainty about household food supply, and 71.8% of sampled households insufficient quality in terms of variety and preferences of the type of food. Likewise, the findings show that 20.4% of households in the research area experienced insufficient food intake and associated physical effects (Table 3.6).

As a result, household food insecurity in the domain of access relations shows that almost all families were concerned about a lack of resources to obtain food and that they would not have enough food, especially in terms of quality and the unpredictable nature of gaining food. More than half of the households experienced food insecurity, and many were unable to eat their preferred foods because of a lack of finances. The food insecurity status of the household's access-related domains as a consequence showed that many respondents had food lack in the previous month. According to key informants who are rural farmers and specialists, food insecurity is particularly bad during the summer due to the pre-harvest season of agricultural products and a shortage of suitable supplies in their stores for consumption.

Table 3.6: Occurrence of HFIAS domains among smallholder households

No.	HFIAS domains	HFIAS conditions	Occurrences	
			Yes *N (%)*	No *N (%)*
1	Anxiety and uncertainty	Worry about not having enough food	269(89.97)	30(10.03)
2	Insufficient Quality of food	Unable to eat preferred foods	232 (77.6)	67 (22.4)
3		Eat just a few kinds of foods	229 (76.6)	70 (23.4)
4		Eat foods they really do not want to eat	183 (61.2)	116 (38.8)
			644 (71.8)	253 (28.2)
5	Insufficient food intake and physical consequences	Eat a smaller meal	120 (40.1)	179 (59.9)
6		Eat fewer meals in a day	99 (33.1)	200 (66.9)
7		No food of any kind in the household	50 (16.7)	249 (83.3)
8		Go to sleep at night hungry	25 (8.4)	274 (91.6)
9		Go a whole day and night without eating	11 (3.7)	288 (96.3)
			305 (20.4)	1190 (79.6)

Source: Field survey, 2021

3.3.3.3. Household food insecurity access prevalence

Household food insecurity access prevalence is an essential categorical indicator of the food insecurity status of households, which is divided into four levels: food secure, mildly, moderately, and severely food insecure. The empirical findings also revealed that the HFIAS is better understood when used to measure Household Food Insecurity Access Prevalence (HFIAP) to make geographically targeted decisions (Moroda *et al.*, 2018). The household food security status in the past four weeks of the study area is summarized below in Table 3.7.

Table 3.7: HFIAS Prevalence of the districts

Study Districts	HFIAS Categories			
	Food secure	Mildly food insecure	Moderately food insecure	Severely food insecure
	N (%)	*N (%)*	*N (%)*	*N (%)*
Ada'a	94 (20.80)	128 (28.32)	180 (39.82)	50 (11.06)
Bora	36 (9.6)	115 (30.67)	176 (46.93)	48 (12.80)
Moretena Jiru	103 (24.47)	158 (37.53)	149 (35.39)	11 (2.61)
Total Average (%)	18.7	32.1	40.5	8.7

Source: Field survey, 2021

Based on this, out of the total respondents, the findings of the study showed that 18.7%, of the households, were food secure, 32.1% were mildly food insecure, 40.5% were moderately food insecure, and 8.7% of the respondents were severely food insecure household in the study area. This showed that the food insecurity prevalence trend among the study population was 81.3% (Figure 3.2). According to key informant interviews, the findings showed that food access in the study area was significantly erratic.

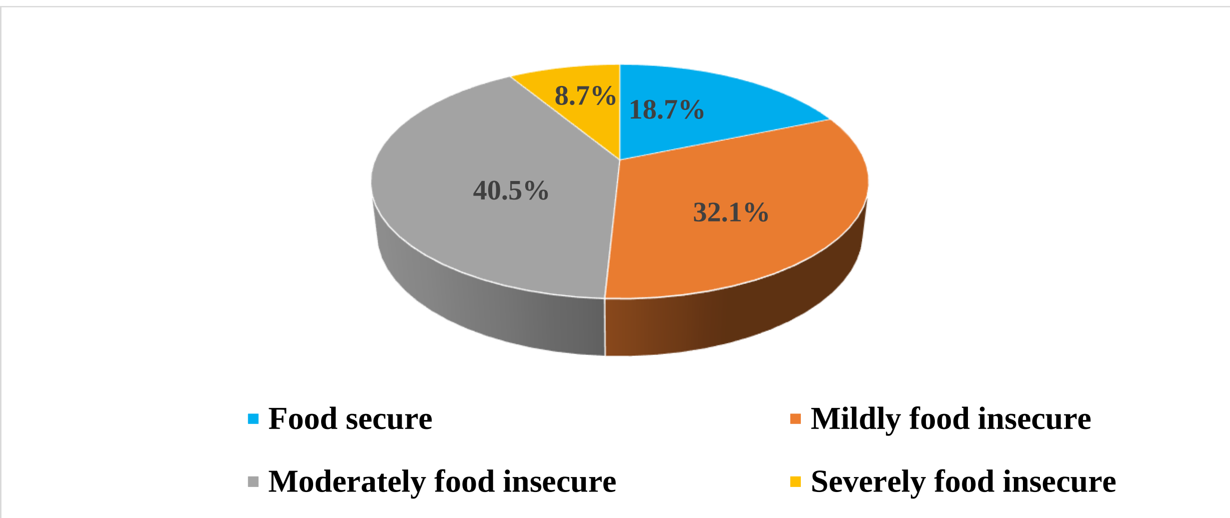

Figure 3.2: Household Prevalence of food insecurity; Source: Field survey, 2021

3.3.4. Effect of seed access and supply system on food security

This study finds that the use of certified seed has positive welfare effects on smallholder households in terms of higher productivity and incomes. Seed supply systems comprise the activities and mean through which farmers obtain seeds of the varieties that have the traits they desire. It can either be formal or informal. A formal seed supply system is regulated and has an organized set of activities, from breeding to delivering certified seeds of known and registered varieties to farmers (Louwaars, 2022). Contrarily, an informal seed supply system entails the exchange of farmer-saved seeds through a variety of channels, such as neighbors, local markets, community seed banks, and local cooperatives, frequently without the involvement of the government (FAO, 2018).

Food security for smallholder farmers requires seed security. It depends on the types of seed supply systems farmers use and the way they function. Smallholder farmers are involved in formal, informal, and community-based seed systems for the production and access to the seeds they need and prefer. However, in the study area, seed systems are still largely informal, consisting of seed sourced from their own saved seed, farmers' neighbor exchanges, and local marketplaces, which can supply up to 60%. These informal seed networks are regularly used by smallholder farmers to obtain desired local varieties that may or may not be available through formal channels within the communal network in the necessary quantity or price, this result is in line with a study by Otieno *et al.* (2018).

Seed access and supply systems can deliver multiple benefits to smallholders such as enhanced food security and income, better nutrition, and greater resilience to climate stresses (FAO, 2018). When the interaction between actors and activities, and environmental and socio-economic drivers work efficiently to provide seed security and ultimately food security. Seed supply systems thus need to offer a ready supply of crop and varietal diversity, adapted to local conditions, of acceptable quality that reaches farmers in time for the planting season (Vernooy, 2020).

The study found that almost the entire seed supply is based on the rain-fed seed production system and this is the key factor contributing to the shortage of certified seed supply in the study area. The public seed enterprise is focusing mainly on two cereal crops wheat and maize, and seeds of other crops are entirely supplied by the informal system (farmer-to-farmer seed exchange). The majority of smallholder farmers are largely dependent on the informal system due to providing cheaper and readily available at the right time and place.

In general, the findings of the study revealed significant impacts on the lives of the beneficiaries when accessing seed. This can be realized through a number of indicators such as improved food access, improved food availability, intake and meal frequency, increased yield, productivity, and income, and enhanced access to livelihood assets like livestock. FGDs, explained communities believed that the livelihood of certified seed users has been increased, the users have been able to feed their families and reduced anxiety and uncertainty, insufficient food quality, and intake rather non-users.

3.3.5. Determinants of household food insecurity

The study employed multinomial logistic regression analysis to determine factors affecting household food security occurrence and hypothesized independent variables were expected to affect household food security. The independent variables were examined for multicollinearity before the econometric model was performed. The calculated VIF values are all less than 10 (the cutoff point) which indicated that no severe problems of multicollinearity in the model. The goodness of fit in multinomial logistic regression analysis was checked and the likelihood ratio test statistics indicated by the Chi-square statistics are highly significant at 0.000 level of significance suggesting the strong explanatory power of the model. The result of the multinomial logit analysis of the hypothesized independent variables which were expected to affect household food security is provided in Table 3.8.

The ***sex*** of the household head positively affected household food security when compared to the base category, i.e., the severely food insecure level. The model predicted that the likelihood of a household being food secure increases by 21.7% when the household head is male. The result suggests that those male-headed households were more technically efficient than their female counterparts, ceteris paribus. This could be attributed to various reasons, which could be the problem of the economic position of female-headed households, including shortage of labor, limited access to information, and required production inputs due to social position.

The result of the model depicted that the ***age*** of the household head was negatively related to household food security as compared to the base category, which is severely food insecure. Keeping other factors constant, food security condition decreases by 14.7% when the age of the household head increases by one year.

Family size positively affects the food secure category and negatively affects moderately food insecure categories in the study area. The marginal effect shows, other things being constant, the likelihood of a household being food secure increases by 2.9% and fall in the moderately food insecure category decreases by 2.8%, as the number of family sizes increases by one unit. This indicates that a large household size is more likely to be food insecure than a small household size.

According to the analysis, the ***land size*** of households was positively associated with food security at a 10% level of significance. This association reveals that households owning large land sizes are more likely to be food secure than households that owned small land sizes. The marginal effect shows other things being constant, the likelihood of a household food security increases by 3.9% as the farm size increases by one hectare. Landholding size is considered a critical production factor that determines the type of crops grown and the size of crop harvests. Therefore, it is anticipated that the size of the land holding will have a substantial impact on how secure the food is for farm households under subsistence agriculture.

The result of this study indicates that the ***farm experience*** of the household head compared with the base category, positively affected household food security at a 5% significant level. The marginal effect reveals that increases the likelihood of household food security by 0.3% and food insecurity by 0.4% as farm experience increases by one year. The implication is that farmers who have more years of farm experience are more likely to have food security than fewer years of farm experience.

Livestock owned in TLU is significant at a 5% level of likelihood and influences positively the mildly food insecure category. Other things remain constant, the marginal effect of the model shows, with a one-unit increase in livestock holding, increases the household's tendency to fall mildly food insecure by 1%.

Access to seed was also one of the determinant factors that affect household food security. Farm input particularly seed access positively determines household food security. The marginal effect shows, other things being constant, the likelihood of households being food secure increased by 10.2% when increasing access to the utility by one unit.

The most significant predictive variable influencing household food security was found to be the ***distance to market***. From the results, we see that compared with the base category, the marginal effect indicates that the likelihood of the household being moderately food insecure. When the distance to the nearest market increases by one-kilometer walking the food security condition decreases by 2.5%.

Table 3.8: Multinomial logit model analysis (Household Food Insecurity Access Prevalence)

Variables	Food Secure			Mildly Food Insecure			Moderately Food Insecure		
	Coef.	Std. Err	dy/dx	Coef.	Std. Err	dy/dx	Coef.	Std. Err	dy/dx
Sex	1.973*	1.034	0.217	0.197	0.626	-0.038	-0.176	0.538	-0.063
Age	-1.360***	0.483	-0.147	-0.243	0.376	0.008	0.182	0.358	0.056
Family size	0.195*	0.104	0.029	0.106	0.094	-0.016	-0.209**	0.101	-0.028
Education	-0.243	0.208	-0.030	0.037	0.171	0.012	0.074	0.177	0.013
Land size	0.249*	0.151	0.039	-0.166	0.169	-0.023	-0.319	0.206	-0.042
Experience	0.051**	0.026	0.003	0.047**	0.022	0.004	0.035*	0.021	0.004
TLU	0.037	0.041	0.002	0.071**	0.036	0.010	-0.010	0.050	-0.004
Income source	0.084	0.000	0.023	0.060	0.000	0.013	-0.789	0.000	-0.097
Non-farm	0.307	0.480	0.008	0.310	0.405	0.004	0.900	0.392	0.107
Credit	0.033	0.395	0.004	-0.148	0.349	-0.034	0.328	0.346	0.049
Seed access	1.033**	0.459	0.102	0.352	0.362	0.013	0.021	0.354	-0.026
Ext. contact	-0.095	0.099	-0.008	-0.074	0.087	-0.007	-0.008	0.080	0.003
Market dist.	0.241	0.052	0.025	0.105	0.046	0.011	-0.125**	0.056	-0.025
_cons	-5.783	2.336		-1.402	1.652		-0.392	1.545	

*Sources: Field survey, 2021 ***, **, and *, Significant at P<0.01, P<0.05, and P<0.1, respectively*

3.4. Conclusion and Recommendations

Early-generation seeds are supplied by federal and regional research institutes to Ethiopian agricultural business corporations (former Ethiopian seed enterprises) and regional seed enterprises then the basic seed is produced and delivered by seed enterprises to private seed companies, unions, and cooperatives. Finally, through unions and cooperatives, the certified seeds of improved varieties reached end users (farmers). Farmers in the study area widely use locally available seeds in markets than certified seeds from formal systems. This is due to the long chain in the supply system, and limited access to needed quantity promptly are the main factors hindering farmers to use formal seed systems from formal suppliers. Since the informal system is generally more affordable, readily accessible when seeds are needed, allows the use of seeds after testing on primary adopter farmers, and is more dependable and sustainable, the majority of farmers in the study area tend to rely on it.

The result indicated that farmers can access seeds from different sources. The identified sources of certified seeds were own-saved seed (46.2%), farmers-to-farmers seed exchange (19.4%), woreda bureau of agriculture and unions (10.4%) each, cooperatives (7.7%), seed enterprises (3.3%), and local market (1.3%), and research centers (1.3%). In the study area, seed systems are still largely informal and can supply up to 60%. The most common reasons farmers quoted for not using improved crop seeds in the study area were no supply of seed at the right time (46%) and the high price of certified seed (37%).

The result in terms of severity of household food insecurity, and access-related conditions across the sampled households showed that 90% worry about not having enough food, 72% insufficient quality variety and preferences of the type of food, and 20% of households experienced insufficient food intake and associated physical effects. The findings of the prevalence of food insecurity indicated that about 18% of the households were food secure, 32% were mildly food insecure, 41% were moderately food insecure, and 9% of the respondents were severely food insecure households in the study area.

The results of multinomial regression model revealed that the sex of the household head, farming experience, access to farm input, and livestock holding positively influenced household food security conditions. On the other hand, the age of the household head, family size, farm size, and distance to the market negatively affected household food security.

Therefore, the study suggested that to improve seed accessibility the seed dissemination system should be strengthened, and access to quality seeds to address food insecurity and poor people at affordable prices. The supply of seeds should be at the right time with the needed quantity and quality. Strengthening the extension system and motivating the extension agents working on kebeles.

Chapter 4: Determinants of Adoption of Certified Seeds for Improved Wheat (*Triticum aestivum),* Teff (*Eragrostis teff*), and Maize (*Zea mays L.*) Varieties in Central Ethiopia

Abstract

Improving agricultural productivity through improved technology is an important way to upsurge productivity and ensure food security. However, several factors limit the use of improved varieties. This study determined what factors led to the use of improved and certified maize, teff, and wheat seeds in central Ethiopia. The primary data were gathered from 299 sample respondents that were selected using systematic random sampling technique, key informant interviews, and focus group discussions. Descriptive statistics and the logit model were used to analyze the data. The result shows that 29% of household respondents adopted certified seeds, while 71% relied on their local landraces. The findings also revealed that farmers' decisions to adopt wheat, teff, and maize varieties were significantly influenced by educational level, farm size, farming experience, income, credit access, extension contact, farm input, and distance to the market. Thus, the study recommends that the government should focus on strengthening extension services, improving access to certified seeds, expanding timely agricultural inputs supply, improving market opportunities, equipping knowledgeable farmers who increase the use of new varieties, and making the land more economical by sharing agronomic practices as areas that need policy attention to enhance the adoption of certified seeds of improved varieties.

Keywords: Adoption, improved varieties, logit model, Ethiopia

4.1. Introduction

The adoption of improved agricultural technologies is necessary for boosting productivity in the agricultural sector, alleviating poverty, and ensuring food security. Farmers cannot easily adopt improved agricultural technology due to various factors. Some studies have proved that there are multiple barriers, including the nature of technology, technology awareness, risk aversion, institutional restrictions, and lack of human and financial capital and infrastructure (Solomon, 2020).

According to the World Fact Book (2020), agriculture is one of Ethiopia's key sectors, accounting for 35% of the country's GDP, providing 75% of employment, and generating 80% of total exports.

The CSA (2020) indicated that *tef*, maize, and wheat are the most important staple foods for crops that make up the majority of Ethiopia's agricultural outputs in terms of cultivated area, yield, and consumption. In 2020/21, out of the total acreage of grains, *tef*, maize, and wheat accounted for 23%, 20%, and 15%, respectively.

Among cereals, wheat is a strategic crop that generates farm revenue and improves food security. According to CSA (2020), wheat yield in Ethiopia was 1.83 tons/ha in 2009 and increased to 3.1 tons/ha in 2020. However, the primary rain-fed wheat yields for smallholder farmers in Ethiopia are still low and lagging behind other countries. During the 2020/21 harvest period, the nation produced 5.78 million tons of wheat from about 1.9 million hectares of land accounting for 19% of all cereal production and 17% of all grain production, and the yield was 3.1 tons/ha (CSA, 2020). Ethiopia is introducing 99 varieties of wheat to suit the population's expanding production needs (MoA, 2021). According to Wordofa et al. (2021) and Karolina & Malgorzata (2020), improved agricultural technology increases yields and farm income, which significantly impacts food security. Bedilu et al. (2021) indicate that farmers are not using better wheat varieties due to a lack of information, access, incentives, and unaffordable input prices.

Regarding *teff*, it is one of the cereal products cultivated in most of Ethiopia's agroecological areas and primarily used for food consumption. *Teff* is gluten-free and rich in iron and fiber, and its demand has been flowing into the international market in recent years. It contributes 16% of the nation's overall grain production and 18% of the total cereal crops (CSA, 2020). Approximately 25 to 30 million people rely directly on tef production, and Ethiopia's productivity is still low. For instance, in the 2020/21 production year, the yield was 1.9 tons/ha, significantly lower than maize and wheat due to low utilization of modern ideas, outdated seed sources, post-harvest damage and absence of high-yielding varieties (Hailu et al., 2022). As a result, numerous better cultivars have been developed and distributed with optimal administration techniques. To date, 54 enhanced *teff* varieties and farming methods have been made available to the farming community, and many recommended technical packages have been developed by national and regional research centers (MoA, 2021). However, various region-specific evidences show low adoption of enhanced *teff* varieties in the nation. This low rate of adoption is associated to several issues, including the high price of seeds, inadequate knowledge about the varieties, and poor agronomic practices, far etc. (Abate et al, 2019).

Maize is the most important commodity that is widely produced and consumed by smallholder farmers, who make up around 80% of the country's population. It is the main crop for food security, leading all other cereals in terms of production and productivity (Dawit et al., 2018). According to CSA (2020), maize is cultivated in a variety of agroecology, from lowlands to highlands of the country. In 2020/21, approximately 10.6 million tons of maize were produced, with yields of 4.2 tons/ha. Since the 1970s, about 77 improved maize technology has been introduced nationally (MoA, 2021). Understanding the factors which affect maize technology adoption is vital in promoting the use of certified seed to enhance its production across the country, especially in the study region.

Certified seed is vital in order to benefit from traceability measures. Farmers receive enhanced features in the certified seed, including higher yield, pest resistance, drought tolerance, and many more. It is thoroughly conditioned to protect the absence of contaminants (Singh, 2016). Even though there is a shortage of certified seeds available in Ethiopia, some smallholder farmers have benefited and have found solutions to their problems by using certified seeds of improved varieties. In general, certified seeds will solve farmers' problems at the farm level by enhancing productivity, reducing risk and increasing net incomes by generating higher yields, more efficient use of available nutrients, more resistance to pests and diseases, and providing higher nutrient content in harvested food (Cevher and Altunkaynak, 2020).

Thus, this study aimed to determine the factors influencing the adoption of the certified seeds of wheat, teff, and maize and to assess the likelihood of adoption decisions. It specifically, analyzes factors affecting the adoption of certified seeds of improved varieties, and assesses the extent of adoption of improved varieties at the household level.

4.2. Materials and methods

4.2.1. Description of the study area

As study sites, three districts were selected: Ada'a and Bora in the East Shewa zone of Oromia region, and Moretina Jiru in the North Shewa zone of Amhara region. They were considered mainly because of their cereal-based farming systems. The farming system is centered on a crop and livestock production system. The most important crops are cereals (teff, wheat, maize, barley, and sorghum) and legumes (chickpeas, field peas, field beans, haricot beans, and lentils) mainly grown under rain-fed agriculture at medium and high altitudes, followed by irrigated horticultural crops, which are used to generate income beyond consumption.

In general, farmers in the study area used two types of seeds: *certified seeds of improved varieties* and *non-certified or traditional seeds*. The characteristics of these seeds revealed that ***certified seeds*** are high-quality seeds that have been produced and handled according to specific standards to ensure their purity, germination rate, and overall health. The first time a farmer is able to evaluate any advertised agronomic benefits on their farm is with certified seeds of recently approved varieties (Muratbek *et al.*, 2020; Abro *et al.*, 2019). New varieties frequently claim increased yields, improved drought tolerance, disease resistance, pest tolerance, shorter days to maturity and improved harvest-ability (reduced straw, resistance to lodging). ***Local seeds*** have not gone through the same amount of testing and quality control as imported seeds. They could be of lower quality and perform inferiorly to certified seeds. It is a farm-saved seed and commercial grain that is cleaned by farmers for replanting (Muratbek *et al.*, 2020; Abro *et al.*, 2019). The saved seed does not require third-party inspections to confirm varietal purity, identity or quality. Germination and vigour tests on local seeds can be performed easily and cheaply to ensure standard levels.

4.2.2. Sampling procedure

The sampled households were chosen using a multistage sampling technique. Two regions and three districts were purposely chosen for the initial stage based on their accessibility and agroecological suitability for wheat, *tef*, and maize production. The second step involved randomly selecting six representative kebeles, the smallest administrative unit in the district. Step three, within targeted *kebeles*, farmers who adopted or did not adopt the technology were identified by stratified sampling techniques. Based on the simplified formula of Kothari (2004), a total of 299 interviewed samples (108, 68, and 123 samples from the districts of *Ada'a, Bora, and Moretena Jiru*) were randomly selected. Twenty-five key informants were identified by using the purposive sampling technique, and all the key informants had an extensive understanding of the seed system and farm experience. Six focus group discussants were also organized and selected using a random sampling technique based on being socially respected within the society, each group was composed of 5-7 members.

4.2.3. Method of data collection

A cross-sectional and narrative research design was used to conduct this study. Primary and secondary sources were used to collect this information. Quantitative data were gathered from a sample of respondents using a structured questionnaire developed with digital data capturing tools, i.e., Computer Assisted Personal Interviews (CAPI), and qualitative data from KIIs and FGDs to triangulate and substantiate the quantitative data. Secondary data were used from intensive reviews of journals, books, dissertations, thesis, and research reports. In order to obtain informed consent for a research project, the researcher and the study participant must be upfront and honest with one another. Thus, before data collection, the study's objective was explained, and written informed consent was obtained from all participants.

4.2.4. Data analysis

We analyzed the data use of both descriptive and econometric models. We use the independent samples of chi-square and t-test to compare means, check for the existence of statistically significant differences in continuous variables (t-test), and showed the interdependence between adoption categories for dummy variables (chi-square test). A logit model is utilized to decide the comparative impact of diverse explanatory variables at the based variable and has the advantage of showing the relative impact on the likelihood of technology adoption. In this scenario, the dependent variable is a dummy variable that accepts values of 1 for adopters and 0 for non-adopters.

The model is specified mathematically by:

$$P_i = E(Y = \frac{1}{Xi}) = \frac{1}{1+ e^{-(\beta o+\beta iXi)}} \text{ -- (1)}$$

Where Pi represents the probability that the respondent performed these activities, Yi = 1, and exp (Zi) is the odds ratio "e to the power Z_i". In the case of explanation, equation (1) is written as; Z

$$P_i = \frac{1}{1+ e^{-Zi}} \text{ -- (2)}$$

Where, $Z_i = \beta_0 + \beta_i X_i$.

The probability of a respondent choosing to perform these activities successfully is given by equation (2), and the probability of a respondent not performing the activity is given by equation (3).

$P_i = \frac{1}{1+e^{Zi}}$ -- (3)

Where, $Z_i = \beta_0 + \beta_i X_i$.

$P_i = \frac{1}{1+e^{-Zi}} = \frac{e^{Z}}{1+e^{Z}}$ --- (4)

If P_i is the probability of an adopter, then the non-adopter is $(1 - P_i)$. So, $1 - P_i = \frac{1}{1+e^{Zi}}$ and

$\frac{Pi}{1-Pi} = \frac{1+e^{Zi}}{1+e^{-Zi}} = e^{Zi}$ --- (5)

$\frac{Pi}{1-Pi}$ is an odds ratio that favors adopters as a result. That is the probability that a particular farmer participates in the seed of improved varieties adoption and does not participate in adoption. Then,

$L_i = \ln\left(\frac{Pi}{1-Pi}\right) = Zi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 ... + \beta_i X_i$ --- (6)

The logit model changes when the error term (Ui) is considered.

$L_i = Zi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 ..... + \beta_i X_i + Ui$ --- (7)

Earlier running the model, we tested the explanatory variables for likely multicollinearity issues. We used STATA version 14 to run a logistic model. The marginal effect (ME), is estimated with a logit model (Greene, 2012). ME = $\frac{\partial Ui}{\partial Xi}$

Based on the study, the subsequent explanatory variables were believed to have an impact on the adoption of wheat, *tef*, and maize technology (Table 4.1).

Table 4.1: Explanatory variables and definition

Variables	Definition
Sex	1 if male and 0 otherwise
Age	household age in years
Family size	Number
Education	1) illiterate, 2) Gr. 1-4, 3) Gr. 5-8, 4) Gr. 9-10, 5) Gr. 11-12, 6) College and above
Farm size/ land holding	Actual farm size in hectares
Farm experience	Farming experience in a number
TLU	Number of livestock
Sources of income	1) sales of the crop, 2) sales of livestock & products, 3) on-farm daily labor, 4-rented out oxen & land
Off-farm income	1 if yes and 0 otherwise
Credit	1 if accessed and 0 otherwise
Farm input	1 if accessed and 0 otherwise
Extension contact	Visiting time by extension agent in a number
Market distance	Distance to the marketplace in minutes

4.3. Results

4.3.1. Socioeconomic and demographic characteristics of respondents

The survey found that 47.5% of sample respondents adopted certified seeds of improved varieties and 52.5% did not. The average number of adopters and non-adopters is indicated in Table 4.2, and there was an average difference between the two hiring categories. Therefore, the results show that as the number of families engaged in agricultural activities increases, the tendency to use improved varieties of seeds increases. Likewise, the result indicates that landholding, farm experience, livestock ownership, and extension contact significantly certified seed adoption at a 1% level of significance. This demonstrates that the mean differences in the variables between the two categories were found to be statistically significant. On the other hand, the household head's age and market distance are statistically insignificant in determining the adoption decision of the households.

Table 4.2: T-test for adoption characteristics

Variable	Adopter (142)		Non-adopter (157)		Mean difference	Min	Max	T-value
	Mean	SD	Mean	SD				
Age	44.22	12.59	42.13	12.23	2.085	20	65	-1.452
Family size	5.92	2.32	5.24	1.96	0.687	1	13	-2.771***
Farm size/ land holding	2.51	1.74	1.54	0.83	0.968	0.3	11	-6.230***
Farming experience	25.05	10.56	15.67	7.78	9.381	0	52	8.802***
Livestock holding	7.47	5.77	5.53	4.97	1.950	0	43	-3.129***
Extension contact	2.51	1.97	1.62	2.12	0.896	0	8	-3.778***
Market distance	6.96	3.73	7.29	3.77	0.329	0.4	15	0.759

Source: Survey, 2021 ****, denotes significance level at 1%*

The findings revealed that there is a statistically significant association between adoption decision and the sex of the household head at a 10% level of significance, and at a 1% level of significance for education, income, credit access, and seed access /farm input (Table 4.3). Furthermore, there is no statistical correlation between adoption decisions and off-farm activity. There is also result that the percentage of male household heads was 88%, whereas 12% were female household heads and only 23% of respondents from both groups were illiterate, while the majority (77%) of the respondents could attend formal school in the study area. Concerning farm income, about 61% of the respondents had income from the sales of crops and crop products. Over 50% of the households lacked credit access, while 68% of the households had farm input access.

Table 4.3: Chi-square test for categorical variables

Variable	Category	Adopter (n=142)	Non-adopter (n=157)	Total value	Chi-square
		% (n)	% (n)	% (n)	
Sex	Female	8.5 (12)	14.7 (23)	11.7 (35)	
	Male	91.5 (130)	85.4 (134)	88.3 (264)	0.096*
Education	No formal education	0.3 (22)	29.3 (46)	22.7 (68)	
	Gr. 1-4	0.4 (47)	44.6 (70)	39.1 (117)	
	Gr. 5-8	0.2 (58)	16.6 (26)	28.1 (84)	
	Gr. 9-10	0.1 (11)	5.7 (9)	6.7 (20)	
	Gr.11-12	0.0 (2)	1.9 (3)	1.7 (5)	
	College & above	0.0 (2)	1.9 (3)	1.7 (5)	0.000***
Income	Sales of crop	44.4 (63)	76.4 (120)	61.2 (183)	
	Sales of LS & products	45.8 (65)	8.9 (14)	26.4 (79)	
	Daily labor	0.7 (1)	1.9 (3)	1.3 (4)	
	Rented out oxen	8.5 (12)	12.7 (20)	10.7 (32)	
	Rented out land	0.7 (1)	0.0 (0)	0.3 (1)	0.000***
Off-farm	Sale of charcoal	13.4 (19)	18.5 (29)	16.1 (48)	
	Other (shops)	83.1 (118)	75.8 (119)	79.3 (237)	
	Salary	3.5 (5)	5.7 (9)	4.7 (14)	0.289
Credit	No	38.7 (55)	72.6 (114)	56.5 (169)	
	Yes	61.3 (87)	27.4 (43)	43.5 (130)	0.000***
Farm input	No	22.5 (32)	41.4 (65)	32.4 (97)	
	Yes	77.5 (110)	58.6 (92)	67.6 (202)	0.001***

*Source: Survey, 2021; Significant levels are indicated by ***, and *, which are 1%, and 10%, respectively.*

4.3.2. Utilization of certified & non-certified seeds

Despite the release of several technologies, certified seeds were of limited use by many Ethiopian farmers. The lack of seeds combined with ineffective promotion schemes is the major factor, further contributing to lower agricultural productivity due to inefficiencies in the country's seed system.

According to CSA (2020), nationally, about 16 million smallholder farmers are engaging in to use of non-certified seeds and six million smallholder farmers are using certified seeds. The area covered by non-certified seeds was 79.7% and 20.3% covered by the certified seed of the total cereal crop area, whereas about 85.7% and 14.3% of the total seed area were covered by non-certified and certified seeds respectively. Regarding inputs, out of the total cereal, certified seeds of maize, wheat, and teff technology were utilized in amounts of 45.8%, 41.7%, and 3.5%, respectively (Table 4.4).

Table 4.4: Certified and Non-certified seeds by Area and Quantity of Inputs used in 2020/21

Crop	Non-certified seed		Certified seed		Total	
	(Ha.)	(T)	(Ha.)	(T)	(Ha.)	(T)
Wheat	1,543,710	310,755	353,695	47,406	1,897,405	358,161
Teff	2,738,114	162,334	190,092	3962	2,928,206	166,296
Maize	1,023,306	63,306	1,502,907	52,000	2,526,213	115,307
Total cereal	8,399,266	806,330	2,139,076	113,612	10,538,342	919,942
Total seed	13,379,273	1,043,516	2,228,604	116,951	15,607,877	1,160,467

Source: CSA, 2020

In the study area in the 2020/21 cropping season, certified seeds were supplied, and accessed to the smallholder farmers through cooperative unions, the bureau of agriculture, and the seed enterprises. The crop types and varieties were wheat (*Kekeba, Ogolcho, kingbird, Hidase, Denda'a, Mangudo, Utuba,* and *Wane*), Tef (*Tsedey*, *Boset*, *Dega Tef,* and *Dagim*), and Maize (*Limu*, *Shone*, *Damot*, and *Kortu*). As shown in (Table 4.5), from the total smallholder farmers engaged in the production of cereal crops in the 2020/21 production season, areas covered by cereals were about 81.2% of the total grain crops. Among cereal crops, the total production of wheat, teff, and maize was 19.1%, 18.2%, and 35% respectively. The productivity of maize, wheat, and Tef were 4.2, 3.1, and 1.9 tons/ha respectively (CSA, 2020).

Table 4.5: Cereal crops in terms of *area and production* in the 2020/21 production season

Crop	Area (Ha.)	grain land (%)	Production (tons)
Wheat	1,897,405	14.62	5,780,131
Tef	2,928,206	22.56	5,509,962
Maize	2,526,212	19.46	10,557,094
Total cereals	10,538,342	81.19	30,205,426
Total grain crops	12,979,460	100	34182869

Source: CSA, 2020

Table 4.6 shows the crops and varieties released and introduced to farmers. The development of improved varieties of seeds should help increase the production and productivity. These varieties have been tested by breeders and rated by experts and the National Variety Release Committee (NVRC) as superior to existing cultivars. It works well in the evaluation and only the varieties approved by NVRC are released or registered in the plant variety registry with the main agronomic and morphological explanations and presented to the user (farmer). According to this, 14 new cereal crop varieties were released during the cropping season of 2020/21, and 487 varieties were registered before 2020/21 (MoA, 2021).

Table 4.6: Cereal crops and varieties released and introduced to farmers in the year 2021/22

Crops	Varieties released in 2021	Released		Released by (Organizations)
		In 2021	Before 2021	
Wheat	Abay, Shaki, and Laku	3	96	Kulumsa ARC/EIAR, Bako ARC/OARI
Tef	Takusa, Jarso, and Boni	3	51	Adet ARC/ARARI, Bako ARC/OARI, and Debere zeit ARC/EIAR
Maize	-	-	77	
Durum wheat	ETCROSS-21	1	41	Debere zeit ARC/EIAR
Triticale	-	-	10	
Emmer wheat	-	-	3	
Buckwheat	-	-	1	
Barley (Food & Malt)	Walashe, Jalqabne, Suba, MBF5P#26(Ras)	4	75	Sinana ARC/OARI, Bako ARC/OARI, Holeta ARC/EIAR, GonderARC/ARARI
Rice (upland, lowland, & irrigated)	-	-	40	
Sorghum	AYINAGE, Erer	2	60	Mechara ARC/OARI, Fedis ARC/OARI
Millet (Finger, Pear, & Foxtail)	Ikhulule	1	29	Mechara ARC/OARI,
Quinoa	-	-	1	
Food oat	-	-	3	
Total		14	487	

Source: MoA, 2021 (Crop variety register)

4.3.3. Adoption of certified seeds of improved varieties

The study shows that the most extensively produced crops in the study area were wheat, tef, and maize with 42%, 33%, and 12% of household respondents adopting certified seeds, respectively, and the majority (71%) of households respondents relying on their local landraces. In terms of input, improved wheat, tef, and maize seed were used in amounts of 31 tons, 7 tons, and 2 tons, respectively (Table 4.7). Therefore, a lack of availability of certified seeds, a lack of awareness about improved cultivars, and a dearth of quality seeds at the appropriate time and place were the main causes of the low adoption rate. There are many reasons, farmers, use certified seeds of improved varieties as an alternative. Such as, the certified seed is a pure seed that has been grown and processed in accordance with rigid production standards, with rigorous restrictions on weeds and other crop types; maximizes the purity of varieties; provides quality assurance; access to new possibilities; allows for capitalization on traceability measures; improves traits such as better yield, pest resistance, and drought and herbicide tolerance; maximize other inputs; access to premium markets.

Table 4.7: Adoption of certified seed of improved varieties & input used in the study area

Crop Type		Districts				Certified seed (t)	Used (%)	Local seed (t)	Used (%)
		Ada'a	Bora	M. Jiru	Total				
		% (N)	% (N)	% (N)	% (N)				
Wheat	No	57 (62)	74 (50)	51 (63)	59 (175)	-	-	7	42
	Yes	43 (46)	27 (18)	49 (60)	42 (124)	31	76	-	-
Tef	No	53 (57)	65 (44)	81 (100)	67 (201)	-	-	6	35
	Yes	47 (51)	35 (24)	19 (23)	33 (98)	7	18	-	-
Maize	No	92 (99)	60 (41)	100 (123)	88 (263)	-	-	0.5	3
	Yes	8 (9)	40 (27)	0 (0)	12 (36)	2	4	-	-

Source: Survey, 2021

The results of the study show that households gave several reasons for not adopting enhanced seeds. According to Table 4.8, the most common reason farmers cited was unable or lacking in timely delivery of seeds 46% and incapable of paying prices 37%. Various studies have found that the main obstacles are the lack of the required amount of seeds at the right time and place and the lack of affordable seed prices, and the poor quality of seeds.

Table 4.8: The main reason for no longer adopting certified seeds

Reasons	Ada'a	Bora	M. jiru	Total
	% (N)	% (N)	% (N)	% (N)
No supply of seed at the right time	52.3 (56)	41.2 (28)	43.9 (54)	46.3 (138)
Unaffordable price	25.9 (28)	44.1 (30)	43.1 (53)	37.1 (111)
Lack of source seed	8.4 (9)	2.9 (2)	2.4 (3)	4.7 (14)
No loan basis provision	5.6 (6)	4.4 (3)	1.6 (2)	3.7 (11)
No difference in productivity from the local one	7.5 (8)	7.4 (5)	8.1 (10)	7.7 (23)
A long way to obtain the seed	0.0 (0)	0.0 (0)	0.8 (1)	0.3 (1)
No exchange-based provision	0.9 (1)	0 (0)	0 (0)	0.3 (1)

Source: Survey, 2021

4.3.4. Factors influencing the adoption decision of improved wheat, teff, and maize varieties

To determine the factors affecting the adoption of improved wheat, teff, and maize varieties were estimated using a logit model. In this study, 13 independent variables were assumed to be factors affecting the household level, of which, the education level, farm size, farming experience, farm income, access to credit, farm input access, extension contacts, age of the household head, livestock holding, and market distance were statistically significant at 1%, 5% and 10% probability levels and prior expectations are revealed in Table 4.9. The effects of statistically significant explanatory variables on adoption are discussed below.

Table 4.9: Likelihood of adoption decisions of improved wheat, teff, and maize varieties

Variables	Wheat			Teff			Maize		
	Odds Ratio	dy/dx	Coef.	Odds Ratio	dy/dx	Coef.	Odds Ratio	dy/dx	Coef.
Sex of the HH	1.4176	0.0405	0.3489	2.7029	0.1308	0.9943	11.8923	0.2435	2.4759
Age of the HH	0.3858	-0.1106	-0.9525	0.5512	-0.0783	-0.5956	0.0685	-0.2636	-2.6803**
Family size	1.1077	0.0119	0.1023	0.8804	-0.0168	-0.1274	1.4723	0.0380	0.3868
Education level	2.4905	0.1059	0.9125***	0.4472	0.1059	0.8049**	1.2499	0.0219	0.2231
Farm size	2.4339	0.1033	0.8895*	2.2788	0.1083	0.8237**	1.9529	0.0658	0.6694
Experience	1.2105	0.0222	0.1910***	1.1402	0.0173	0.1312***	1.1832	0.0165	0.1682**
TLU	0.6929	-0.0426	-0.3668**	1.0609	0.0078	0.0591	1.0156	0.0015	0.0155
Farm income	2.4919	0.1059	0.9131**	0.5735	0.0731	0.5559*	0.1641	-0.1777	-1.8072
Off-farm activities	1.4583	0.0438	0.3773	1.6642	0.0669	0.5093	7.6497	0.2001	2.0347
Access to credit	5.8991	0.2060	1.7748***	4.0649	0.1845	1.4024**	10.2324	0.2287	2.3256**
Access to farm input	1.7510	0.0650	0.5602	4.3524	0.1934	1.4707**	0.2688	-0.1292	-1.3139
Extension contact	1.4121	0.0401	0.3451**	1.0282	0.0037	0.0278	1.5824	0.0451	0.4589*
Market distance	0.9978	-0.0003	-0.0022	1.0011	0.0001	0.0011	1.0241	-0.0023	-0.0238**
_cons	0.0005		-7.5562	0.0396		-3.2293	0.0003		-8.0509

Source: Survey, 2021

*Significant levels are indicated by ***, **, and *, which are 1%, 5%, and 10%, respectively; Sample (N) =299, LR chi^2 (13) = 79.49, Pseudo R^2 = 0.4664, Probability > chi^2= 0.000; Log likelihood = -45.4736*

The results show that the head of the households' ***education level*** was statistically significant at 1% and 5% positively correlated with the likelihood of adoption of wheat and teff varieties. Other factors holding equal, the odds ratio for adopting enhanced wheat varieties upsurges by a factor of 2.491 for farms where the householder is assumed to be literate than for those who are not. This is due to the fact that highly educated farmers have easier access to knowledge and are more aware of new technologies, which may drive technology adoption. The marginal effect shows that after a year of schooling, the head of household is more likely to adopt improved wheat varieties by 10.6%, while others remain constant. This outcome is similar to the conclusion of the study by (Gezahegn, 2021; Aklilu et al, 2022). The odds ratio using the improved teff variety is increased by 0.4472 times and other factors remain constant. This means that well-informed farmers will have better access to information and become more conscious of new technologies, which encourages technology adoption. The marginal effect denotes that the literacy level of household heads increased by one year, and the likelihood of adoption of seeds of improved tef varieties increased by 10.6%, other conditions are constant. Similarly, as confirmed by the finding of (Dawit and Alemayehu, 2020; Chete, 2021).

The ***farm size/ land holding*** positively and significantly influenced farm households' decision to adopt improved wheat and teff varieties at 5% and 10% level of significance. This indicates that the more farmers have large farms, the more they adopt modern technology. Other things being equal, the odds ratio of 2.434 indicates favor of adopting wheat varieties as a land holding increased by one hectare. The marginal effect of farm size is also showing that an increase of farm by one hectare increases the probability of adopters than the non-adopters by 10.3%, other things being held constant. This outcome was reinforced by the result of Aklilu et al. (2022) who obtained positive and significant results on farm size. The odds ratio of the model shows that the farm size increased by a hectare, the adoption of improved teff variety production increased by a factor of 2.2788. The marginal effect is that an increase of one hectare in farm size increases the probability of a farmer making a decision to adopt by 10.8%. The result is in line with (Chanido and Jiang, 2018; Susie and Bosena, 2020).

The ***farming experience*** of the head of household had a positive influence on the adoption of improved wheat, teff, and maize varieties at the 1% and 5% significance level. As the farmer's farm experience increases by one unit, the odds ratio for adopting improved varieties increases by 1.211 times. This indicates that farmers with more agricultural expertise are more likely to adopt improved wheat varieties than farmers with less farming experience. The marginal effect demonstrates that one year of farming experience upsurges the likelihood of adopting enhanced wheat varieties by 2.2%. The results are consistent with (Chanido and Jiang, 2018; Dawit and Alemayehu, 2020). The odds ratio results showed that as the farmer's farming experience increased by a year, the adoption of improved teff varieties increased by a factor of 1.1402, being other variables constant. The marginal effect shows that with an increase in the farming experience by one year, the probability of adoption increased by 1.7%. This result is supported by (Dawit and Alemayehu, 2020). Other things kept constant, as its operating experience increases by a year, the odds ratio increases by a factor of 1.1832. The marginal effect result indicates that, when the head of the household's farm experience increases by one year, the probability of adoption of improved maize varieties upsurges by 1.7%. This result confirms the study done by (Chanido and Jiang, 2018).

The result of ***farm income*** was positively and significantly influenced farm households' decision to adopt improved wheat and teff varieties at 5% and 10% level of significance. The odds ratio increased in favor of using improved wheat varieties by a factor of 2.492, indicating that other variables were held equal as the farmer's income grew by one unit. The marginal effect shows, keeping other variables constant, that the probability of those households who had more income sources was higher than those who had fewer income sources adopting improved wheat varieties by 10.6%. The result of this finding is in line with (Dawit and Alemayehu, 2020; Degefu et al., 2017). The outcome reveals that for every increase in unit income, the odds ratio for the adoption of improved teff varieties increases by a factor of 0.5735. The marginal effects of this model show that an increase of one unit of income increases the likelihood of adopting by 7.3% and keeps the others constant. This result corresponds to the result of a study by (Abatneh, 2020).

Access to credit was also one of the key factors positively influencing the adoption of wheat, teff, and maize varieties, with a significance level of 1% and 5%. The odds ratio showed the decision to the adoption of improved wheat technology enhanced by a factor of 5.899, other things being constant. The finding is analogous to Leake and Adam (2015) and Wondale et al. (2016) households who have credit access. Marginal effects indicate that households with access to credit are 20.6% more likely than those without credit. The odds ratio in favor of households adopting improved teff varieties increases by a factor of 4.0649. Marginal effects indicate that other conditions are constant, and the likelihood of farmers' adoption choice of improved teff increases by 18.5% when a household used credit. This outcome is in line with earlier research by (Gezahegn, 2021; Chanido and Jiang, 2018; Gishu et al., 2018). The findings showed that when farmers receive credit, the odds ratio for choosing an improved maize variety increased by a factor of 10.2324, other things being equal. The marginal effect shows that there was a 22.9% increase in the likelihood that farmers would select better maize varieties. This finding is consistent with those of (Gezahegn, 2021; Chanido and Jiang, 2018).

Model results show that ***access to farm inputs*** positively impacted on the likelihood of adopting improved teff varieties at the 5% significance level. The odds ratio in favor of using the improved teff variety increased by 4.3524 times for each unit's access to the input. The marginal effect shows that increasing access to the utility by one unit increases the chances of adopting by 19.3%. Others are kept constant. This outcome is in line with research by (Wondale et al., 2016; Dinku and Beyene, 2019).

Extension contacts had a positive and significant impact on the adoption of wheat and maize varieties at a 5% and 10% level of significance. This means that farmers who frequently access and expose their advisory services have a higher likelihood of implementing improved varieties than farmers who do not. Other than that, under certain conditions, the odds ratio in favor of using the improved wheat variety increased by 1.412 times concerning the increase in extension services. The marginal effect of this model demonstrates that a household's likelihood of adopting better wheat varieties increases by 4.0% for every additional extension contact that is made. The results are in line with research by (Negussie et al., 2022; Susie and Bosena, 2020). The findings revealed that the odds ratio for choosing an improved maize variety increased by a factor of 1.5824, accompanied by an increase in extension services with additional visits. The marginal effect shows that for every unit of extension contact, the likelihood of adopting maize varieties increases by 4.5%. This finding is in line with a study by (Bedilu et al., 2021; Dinku and Beyene, 2019).

The ***household head's age*** was significant at a 5% level of significance and has a negative impact on the adoption of improved maize technology. The results indicated that younger farmers are more likely to adopt maize technology than older farmers in the study area. The odds ratio implies that a unit increase in the age of a household head will reduce the probability of adopting improved maize technology by 6.9%. The marginal effect shows all other factors remain constant, which with an increase in age of one year, the probability of adopting enhanced maize technology declines by 26.4%. This finding is in line with previous studies by (Aklilu et al., 2022; Luchia and Hadush, 2018).

Livestock holding is positively significant at a 5% level of significance and has a negative impact on the adoption of improved wheat technology. The odds ratio of using the improved wheat variety is reduced by a factor of 0.693 for every unit increase in the livestock holding. Other conditions held constant, the marginal effect shows that with a one-unit increase in livestock holding, the likelihood of households' adoption of improved wheat variety decreased by 4.3%. This result is consistent with the adoption study by (Mengistu et al., 2021).

With a significance level of 5%, it was found that ***market distance*** was a significant and negative relationship with the likelihood of adopting an improved maize varieties. Holding other conditions constant, the odds ratio in distance improves by a factor of 1.0241 for each increase in market distance by one kilometer. Marginal effects indicate that market distance increases by one kilometer and the likelihood of adopting improved maize varieties decreases by 0.2%. This outcome determination is similar to (Gishu et al., 2018; Dinku and Beyene, 2019).

4.4. Discussion

Based on the results obtained from the major determining factors that influence the adoption of improved varieties, this study classified socioeconomic and demographic, farm, institutional, and technological factors. If the technology is very complex and difficult to apply, the farmers cannot voluntarily easily accept it rather they prefer separable technologies like high-yielding varieties and fertilizer (Solomon and Endrias, 2018). The farmers with large farms are more likely to adopt a new technology as they can afford to devote part of their land to try new technology than the farmers who has small land (Solomon and Endrias, 2018). Some independent variables affect the probability of adopting improved varieties more than other factors in specific areas and on specific technologies like age, educational level, farm size, farming experience, TLU, income, credit access, extension contact, farm input, and distance to the market.

The positive experiences of the use of certified seeds of improved varieties in Ethiopia address the problem of the low rate of adoption of improved varieties. It is shown by different studies. Sime and Jens (2018), described farmers who are close to the city using more agricultural inputs and they are more productive and profitable than farmers who are far from the city. Moreover, his study result indicates that transportation has an indirect effect on the yield, utilization, and profitability of improved varieties. Hailu et al. (2015) indicated the adoption of high-yielding varieties increases the productivity of certified seeds of improved varieties. In addition, the level of technical efficiency is positively and significantly related to human capital. Mekonnen (2017) reported that adopters of agricultural technology got better income than non-adopters. Furthermore, the result showed adoption of agricultural technology has a positive and significant impact on the productivity of labor. Therefore, the determinant factors of certified seeds of improved varieties adoption and incorporating farmers' preference criteria and need is very crucial points for policymakers and agricultural technology developer to overcome the low adoption rate problems and in turn for boosting production and productivity, reducing risk and increased net incomes by generating higher yields, efficient use of available nutrients, more resistance to pests and diseases, food self-sufficiency and ensuring food security.

Access to certified seed is an integral factor for stimulating technology uptake and increasing agricultural productivity in smallholder agriculture. In this study, weak seed supply systems have been identified as limiting factors for the extensive adoption of certified seeds of improved varieties. Certified seeds are an enhanced variety of seeds that can be used to produce crops in less time and with higher yields and quality. These seeds require irrigation, fertilizers, and insecticides to grow. They compromise the soil's fertility, though. In contrast, traditional seeds are natural seeds with low yields and quality of crops. These are grown naturally in a particular area, more economical in comparison to certified seeds. Crops with traditional seeds take time to mature, have less tolerance to environmental conditions, and their disease resistance may also be low (Sime and Jens, 2018). Limited availability of good quality seed is a key constraint repeatedly identified by farmers in the study area. A number of initiatives that have addressed this issue through sustainable local seed production have resulted in improved access to appropriate, affordable and timely seeds. Farmers everywhere need easy access to high-quality seeds well-adapted, productive crops to allow them to produce the best possible crops. However, initiatives are being made to persuade the private sector to contribute to the efficient production and distribution of seed. Access to seed is the ability to acquire seed through the exchange, loan, barter, or use of power in social networks.

The result indicated that access to certified seeds from different sources; from the district bureau of agriculture, unions, cooperatives, seed enterprises, local markets, and research centers. Bassa et al. (2018) stated the farmers themselves, unions, and the bureau of agriculture are the major sources of certified seed. Even though the formal seed sector takes a larger share of certified seed dissemination, still most of the farmers used seed from informal seed systems, including own-saved seed, and exchange farmer-to-farmer. Thus, the farmers do not have access to certified seeds and they widely use the local varieties since the certified seeds are very expensive (Dawit et al., 2019).

Even though the certified seed has better productivity, disease, and pest resistance advantage over local ones, some farmers were not willing to use it in the study area. As a result, farmers who do not use improved crop seed were questioned about why they do not use it. The survey results and focus groups revealed that several reasons for not using enhanced crop seeds were raised. The high price of certified seed, limited financial capacity, no supply of seed on needed time, poor quality of seed, inadequate information about the technologies about related costs and benefits, the technologies were not profitable, and also appropriate varieties for farmers' agroecological conditions are not available. Policy environment, which affects the availability of inputs and markets for credit and input prices were the reasons raised by farmers for not using/adopting certified seeds of improved varieties and the key factors affecting the adoption of certified seeds of improved varieties and input utilization in the study area. This result finding is in line with the result of Bassa et al. (2018), and Kutoya and Kebede (2019). Therefore, farmers' decision to adopt or not to adopt is usually based on the profitability and risk associated with the new technology. Before adoption, farmers have to be assured of the expected marginal gains and associated risks.

4.5. Conclusion

The findings revealed that adopters and non-adopters differed significantly on statistically relevant characteristics. The adopted households have a relatively large family size and agricultural experience, own more land and livestock, and have more extension contacts than non-adopted. Low adoption rates were a result of limited availability of certified seeds, absence of awareness about enhanced varieties, a shortage of timely access to good-quality seeds, as well as expensive seed costs. Thus, governments and non-governmental organizations raise awareness, provide capacity-building training, provide agricultural inputs based on credit, promote timely delivery of agricultural inputs, and arrange market opportunities.

A total of thirteen explanatory variables were included in the model of which eight of them had significantly affected the adoption of improved varieties by the household head's educational level, land ownership, farming experience, income, credit, extension contact, farm inputs, and distance from the market. While adoption was significantly in a weak position by livestock ownership and household head age. A range of policies and strategies to increase agricultural production and productivity have been pursued by decision-makers to address problems with the insufficient utilization of production technologies.

The adoption of improved varieties should be increased by raising farmers' knowledge that makes them more rational when using improved technology; making land more economical by encouraging farmers to cultivate their potential land; improving income by promoting market opportunities; providing agricultural inputs based on credit, promoting timely delivery of agricultural inputs, and providing frequent extension visits by increasing the number of agents. Moreover, governments, non-governmental organizations, and advisors should be stimulated to facilitate extension services and knowledge sharing among farmers. In addition, appropriate seed policies need to be established to accelerate seed production and distribution through effective extension systems to facilitate, enhance and maintain the uptake of improved varieties.

Therefore, the results of this study suggested that program interventions can be important for improving and strengthening the agricultural extension service. At the same time, the availability of certified seed proved to be a major constraint for adoption, a fact that calls for improvements in certified seed delivery systems to effectively cope with the demands of small farmers. More focus needs to be paid to delivering more efficient agricultural services by policymakers and other development partners engaged in agricultural development, to overcome the low adoption rate problems and, in turn, for increasing production and productivity, food self-sufficiency, and ensure food security, understanding of the determinant factors of certified seeds of improved varieties adoption and incorporating farmers preference criteria and need is very important.

References

Abate Bekele, Solomon Chanyalew, Tebkew Damte, Nigussu Hussien, Yazachew Genet, Kebebew Asefa, Demeke Nigussie, & Zerihun Tadele (2019). Cost-benefit Analysis of New Tef (Eragrostis tef) Varieties under Lead Farmers' Production Management in Central Ethiopia. *Ethiopian Journal of Agricultural Science, 29(1), 109-123.*

Abatneh Tiruneh (2020). Factors Influencing Adoption of Improved Tef Technology Package: in Yilmana Densa District, Amhara Region.

Abro Zewdu, Bethlehem Debela, & Kassie Menale (2019). The joint impact of improved maize seeds on productivity and efficiency: implications for policy. *Global Food Discussion Paper 128, University of Goettingen.*

Aklilu Atinafu, Meseret, Lejebo, & Abera Alemu (2022). Adoption of improved wheat production technology in Gorche district, Ethiopia. *Agriculture & Food Security, 11(3), 1-8.*

Bassa Zekarias, Erchafo Tessema., Tyohannis Seifu, & Bashe Alemayehu (2018). Status of improved crop seed utilization system across small-scale farmers in southern Ethiopia: The case of Sodo Zuirya in Wolaiyta, Mareka in Dawuro, and Kacha Birra in Kembata Tembaro zones. *Open Access Journal of Science, 2*(6), 331-337.

Bedilu Demissie, Adem Geleto, Hussien Komicha, & Sisay Asefa (2021). Determinants of adopting improved bread wheat varieties in Arsi Highland, Oromia Region, Ethiopia: A Double-Hurdle Approach. *Cogent Economics & Finance, 9(1), 1-23.*

Cevher, C., & Altunkaynak, B. (2020). Investigation of socio-economic characteristics of wheat producers on certified seed use: The case of Ankara province, Yuzuncu Yıl University. *Journal of Agricultural Sciences, 30*(1), 115-123.

Chandio, A., & Jiang, Y. (2018). Factors influencing the adoption of improved wheat varieties by rural households in Sindh, Pakistan. *AIMS Agriculture and Food, 3(3), 216-228.*

Chete, O.B. (2021). Factors influencing adoption of improved maize seed varieties among smallholder farmers in Kaduna State, Nigeria. *Journal of Agricultural Extension and Rural Development, 13(2), 107-114.*

CSA (2017). Federal democratic republic of Ethiopia, central statistical agency. Population Projection of Ethiopia for all regions at the Woreda level from 2014 to 2017, Addis Ababa.

CSA (2020). *Annual Agricultural Sample Survey Area and production of major crops.* The Federal Democratic Republic of Ethiopia, Central Statistical Agency, Addis Ababa, Ethiopia.

Dawit Alemu, Wilfred, M., Mandefro, N., & David, S.J. (2018). The maize seed system in Ethiopia: challenges and opportunities in drought-prone areas. *African Journal of Agricultural Research, 3(4),* *305-314*.

Dawit Alemu, Shahidur R., & Rob, T. (2019). Seed system potential in Ethiopia: Constraints and opportunities for enhancing the seed sector. *International Food Policy Research Institute,* 1-59.

Dawit Milkiyas, & Alemayehu Kaaba (2020). Socioeconomic analysis on determinants of Improved Tef varieties Adoption in Liban Jewi District, Ethiopia. *Academic Research Journal of Agricultural Science, 8(5), 367-376*.

Degefu Kebede, Mengistu Ketema, Nigussie Dechassa, & Feyisa Hundessa (2017). Determinants of adoption of wheat production technology packages by smallholder farmers: Evidence from eastern Ethiopia. *Turkish Journal of Agriculture-Food Science and Technology, 5*(3), 267-274.

Dinku Adunea, & Beyene Fekadu (2019). Adoption determinants of row planting for wheat production in Munesa District of Oromia Region, Ethiopia. *Journal of Agricultural Extension and Rural Development, 11(2), 25-34*.

Gezahegn Kudama (2021). Determinants of Improved Wheat Variety Adoption in Horo District, Oromia Region, Ethiopia. *International Journal of Economics and Business Administration, 7(2), 48-55*.

Gishu Nigatu, Yohannes Mare, & Agidew Abebe (2018). Determinants of adoption of improved (BH-140) maize variety and its management practices in the case of south Ari woreda, south Omo zone, SNNP, Ethiopia. *International Journal of Research Studies in Biosciences, 6(9), 35-43.*

Greene, W.H. (2012). Econometric analysis 7th Eds, New York: Princeton hall.

Hailu Birhanu, Abrha Bihon, & Weldegiorgis Kibrom (2015). Adoption and impact of agricultural technologies on farm income: evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics, 2*(4), 91–106.

Hailu Shiferaw, Getachew Tesfaye, Habtamu Sewnet, & Leulseged Tamene (2022). Crop Yield Estimation of Teff (Eragrostis tef) Using Geospatial Technology and Machine Learning Algorithm in the Central Highlands of Ethiopia. *Sustainable Agriculture Research, 11(1), 34-44*.

Karolina, P., & Malgorzata, K. (2020). The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in the Context of the Problem of Sustainable Food Production. *Journal of sustainability, 12, 1-20*.

Kothari, C.R. (2004). Quantitative Techniques, New Delhi, *Vikas Publishing House Pvt. Ltd.,* 64.

Kutoya Kusse & Kebede Kassu (2019). Access, supply system and utilization of certified seed varieties in Debub Omo Zone, SNNPR, Ethiopia. *Journal of Agricultural Science Food Research. 10,* 258.

Leake Gebresilassie & Adam Bekele (2015). Factors determining the allocation of land for improved wheat variety by smallholder farmers of northern Ethiopia. *Journal of Development and Agricultural Economics, 7*(3), 105-112.

Luchia Tekle & Hadush Hagos (2018). Determinants of the intensity of bread wheat packages adoption in Tigray, Ethiopia. *Turkish Journal of Agriculture, Food Science, and Technology, 6(9), 1101-1107.*

Mekonnen Tigist (2017). Productivity and household welfare impact of technology adoption: Micro-level evidence from rural Ethiopia. *United Nations University Working Paper*, 07.

Mengistu Dereje, Degefa Tolossa, & Abraham Seyoum (2021). Analyzing the contribution of crop diversification in improving household food security among wheat-dominated rural households in Sinana District, Bale Zone, Ethiopia. *Journal of Agriculture and Food Security, 10(1), 1-15.*

MoA (2021). *Crop Variety Register.* Ministry of Agriculture, Plant Variety Release, Protection, and Seed Quality Control Directorate. Addis Ababa, Ethiopia. Issue No. 24.

Muratbek, B., Gershom, E.M., Xue, Z., & Xianhui, G. (2020). Towards cleaner production: certified seed adoption and its effect on technical efficiency. *Journal of Sustainability*, *12*(1344), 2-17.

Negussie Seyoum, Almaz Giziew, & Azanaw Abebe (2022). Factors influencing the adoption of improved bread wheat technologies in Ethiopia: empirical evidence from Meket district. *Heliyon, 8(2), e08876.*

Sime Getachew, & Jens, B.A. (2018). Sustainability of improved crop varieties and agricultural practices: A case study in the central rift valley of Ethiopia. *Agriculture, 8*(11), 177.

Singh, H. (2016). High-yielding variety seeds: Definition, advantages and role in the green revolution of India, Jagranjosh.com.

Solomon Yokamo (2020) Adoption of Improved Agricultural Technologies in Developing Countries: Literature Review. *International Journal of the Science of Food and Agriculture, 4(2), 183-190.*

Solomon Yokamo & Endrias Oyka (2018). Participatory demonstration of maize (Zea Mays L.) variety with its full packages in south Ethiopia, Adv. *Crop Sci. Tech., 6*, 342.

Susie Teshome & Bosena Tegegne (2020). Determinants of Adoption of Improved Teff Varieties by Smallholder Farmers: The Case of Kobo District, North Wollo Zone, and Amhara Region, Ethiopia. *International Journal of Agricultural Economics, 5(4), 114-122.*

Wondale Laduber, Dessalegn Molla., & Daniel Tilahun (2016). Logit analysis of factors affecting the adoption of improved bread wheat (Triticum aestivum L.) variety: The case of Yilmana Densa district, West Gojam, Ethiopia. *Journal of Agricultural Extension and Rural Development, 8*(12), 258-268.

Wordofa Muluken, Jemal Hassen, Getachew Endris, Chanyalew Aweke, Dereje Moges, & Debebe Rorisa (2021). Adoption of improved agricultural technology and its impact on household income: a propensity score matching estimation in eastern Ethiopia. *Journal of Agriculture & Food Security, 10(5), 1-12*.

World Fact Book (2020). *Ethiopia Economy: Contribution of Agriculture to GDP in Ethiopia*. https://theodora.com/wfbcurrent/ethiopia/ethiopia_economy.html

Chapter 5: The Impact of Adoption of Improved Crop Varieties on Household Food Security in Central Ethiopia: A Propensity Score Matching Estimation

Abstract

Agriculture plays a vital role in ensuring food security by increasing food availability at the household level. The study aimed to examine the impact of adopting improved crop varieties on household food security in central Ethiopia. The cross-sectional data was gathered from 299 randomly selected sample households, key informant interviews, and focus group discussions. The data were analyzed using descriptive statistics and a probit model to determine the probability of adoption decisions. A propensity score matching (PSM) method was used to estimate the impact of improved variety adoption on household food security. The household food security was estimated by using the household food balance model (HFBM) and food consumption score (FCS) measurement to quantify the available net food and the calorie sufficiency of food at the household level, respectively. The findings of the study revealed that out of the total sampled households, 54% were food insecure, the mean daily calorie intake was 1533.8 kcal/daily/adult equivalent, which meets 73% of the minimum recommended allowance (MRA), and the daily per capita dietary energy levels ranging from 98 to 12373 kcal. In this study, the age of the household head, educational level, farm size, farming experience, farm income, access to credit, access to farm input, and extension contact were determinant factors of household food security. The PSM analysis result indicated that 157 controlled households were matched with 133 treated families by discarding nine observations out of the standard support region. The kernel bandwidth matching algorithm estimated the average treatment effect on treated (ATT) and the adoption of improved varieties had a significant and positive impact on food availability on average 414 kcal/ day, food consumption score of 5.14, and the yield increased by about 9.87 quintals per hectare than the non-adopters. Thus, government and non-governmental organizations should pay close attention to enhance adoption of improved technologies to reduce food insecurity in the study area.

Keywords: Adoption, Food security, Impact, Improved varieties, Propensity score matching

5.1. Introduction

The prevalence of food insecurity in the world has been increasing with population growth and being more exposed to climate change and putting more people under malnutrition. The prevalence of undernourishment is about 8.9 percent of the world population and 19.1 percent of the population in Africa (WFP, 2020). Recent data show that more than 2 billion people were exposed to the prevalence of food insecurity at a severe level. Both moderate and severe levels of food insecurity were observed at 25.9 percent in the world and 33.75% in Africa (FAO, 2020).

In Sub-Saharan African nations, agricultural production is crucial for alleviating poverty and food insecurity. Most African countries are vulnerable to periodic food shortages and the uncertainties of food aid. Therefore, raising and stabilizing domestic production of staples food is vital for food security (World Bank, 2018). Agriculture in Ethiopia faces significant challenges, due to the nation's demand rising for agricultural production. One of the country's greatest problems is ensuring food security for its population and generations. Agriculture is supposed to significantly impact food security and overall economic growth (Wordofa *et al.*, 2021).

In Ethiopia, the development of improved varieties is helps to increase the production and productivity of crops in the country. To assure this, newly developed varieties are tested by breeders and evaluated for their superiority over existing varieties by professionals and the National Variety Release Committee (NVRC). The released varieties are registered in the plant variety registry book and the Ministry of Agriculture is responsible for providing information on the status of the varieties to breeders, institutions, and beneficiaries. According to MoA (2021), about 1489 improved varieties, including agronomic practices and recommendations were released before the 2020/21 cropping year. Improved varieties that increase yield and food security have been adopted by smallholder farmers. Cereal and pulse crops made up 34% and 19% of the total released crop technology that was made available. This study considered the major crop production (wheat, teff, and maize) in the study area. Since the 1970s, about 141 improved wheat varieties, 54 improved teff varieties, 77 improved maize varieties, and 79 improved barley varieties were released to the farming community in the country to satisfy the growing production demands of the population (MoA, 2021).

The adoption of improved crop varieties plays a key role in increasing production and ensuring food security in developing countries. Growth in agricultural production can minimize food insecurity by increasing the amount of food available for consumption at the household level (Bozsik et al., 2022). Over time, low adoption of improved varieties has been attributed to a range of circumstances that lead to low production and expose an individual, household, community, and country to economic, psychological, and health-related stresses. As a result, food security and the adoption of improved technologies must be assessed simultaneously. By raising yields and farm income, improved varieties adoption greatly contributes to food security. (Shiferaw et al., 2014).

Several studies suggest that improved crop varieties adoption has significantly positive impact on household food security by increasing yields and farm revenue (Jaleta et al., 2018; Manda et al., 2018; Wordofa et al., 2021; Zegeye et al., 2022; Hiwot and Degefa, 2022). According to Jaleta et al. (2018), adoption of improved maize variety has a robust and positive impact on per capita food consumption and significantly increases the probability of smallholder farmers. A study by Wordofa et al. (2021) showed that households using improved varieties increase annual farm income as compared to those households who are not using such technologies. Manda et al. (2018) study showed that largely concentrated on disentangling the positive impacts of improved maize varieties on food security, and education and access to information are important determinants of both improved maize adoption and food security in Zambia. Zegeye et al. (2022) showed that adopting a combined fertilizer and certified seed increases wheat productivity significantly and provides higher productivity than adopting single technologies. The findings of Hiwot and Degefa (2022) confirmed that adoption of improved wheat varieties increased food availability at the household level. Poku et al. (2018) also showed that farmers are unable to adopt improved varieties due to a lack of seed variety knowledge, accessibility, incentives, and expensive input prices. However, different area-specific evidence indicates that the country's adoption rate of improved varieties is low. This low rate of adoption of farmers is determined by the expensiveness and unavailability of seeds, desired varieties, and lack of awareness and the serious sequence of agronomic practices have commonly been mentioned as the constraints (ATA, 2015).

In this study, the impact of adoption of improved crop varieties was analyzed with the estimation of Propensity Score Matching (PSM), which is used to compare adopter with non-adopters' households in terms of their outcome variables- food availability, food consumption, and yield levels. Few studies assessed the impact of adopting crop varieties on household food security with the estimation of PSM (Khonje et al., 2015; Tesfaye and Gutema, 2022; Hiwot and Degefa, 2022; Tadesse and Gebremedhin, 2022; Wordofa et al., 2021). The results of these studies, using propensity score estimation found that farmers who adopted improved crop varieties increased the status of food availability and consumption, yield gain, consumption expenditure, farm income, and enhanced food security at the household level.

Therefore, the main aim of this study was to examine the impact of improved crop varieties adoption on household food security. Specifically, it assesses the level of food security, identifies the determinant factors, and analyzes the impact of crop varieties adoption on farm household food security in the study area. The findings of this study adds to the existing literature by measuring the impact of improved crop varieties adoption on household food security with HFBM and FCS of smallholder farmers in Ethiopia.

5.2. Materials and Methods

5.2.1. Description of the study area

Three districts were chosen as study locations: Ada'a and Bora from East Shewa zone of the Oromia region and Moretina Jiru from the North Shewa zone of the Amhara region, respectively. They were taken into consideration due to their farming practices that relied on cereals. Crop and livestock production systems are at the core of the farming system. Cereals (tef, wheat, maize, barley, and sorghum) and legumes (chickpeas, field peas, field beans, haricot beans, and lentils), which are primarily grown under rain-fed agriculture at medium and high altitudes, are the most significant crops.

5.2.2. Sampling techniques and sample size

The sampled households were chosen using a multistage sampling technique. Two regions and three districts were purposely chosen for the initial stage based on their accessibility and agroecological suitability for wheat, *tef*, and maize production. The second step involved a random selection of six representative kebeles, the smallest administrative unit in the district. Step three, within targeted *kebeles*, 142 farmers who adopted and 157 did not adopt the technology were identified by stratified sampling techniques. Based on the simplified formula of Kothari (2004), a total of 299 interviewed samples (108, 68, and 123 samples from the districts of Ada'a, Bora, and Moretena Jiru respectively) were randomly selected. Moreover, twenty-five KII were identified by using purposive sampling technique, and all the key informants had an extensive understanding of the seed system and farm experience. Six FGD were also organized and selected using a random sampling technique based on being socially respected within the society, each group was composed of 5-7 members.

5.2.3. Method of data collection and Data sources

A cross-sectional and narrative research design was used to conduct this study. Primary and secondary data sources were used to collect this information. Quantitative data were gathered from a sample of respondents using a structured questionnaire developed with digital data capturing tools, i.e., Computer Assisted Personal Interviews (CAPI), and qualitative data from KIIs and FGDs to triangulate and substantiate the quantitative data by using a checklist. Secondary data were used from intensive reviews of journals, books, dissertations, thesis, and research reports.

5.2.4. Data analysis

The data were analyzed using econometric modeling and descriptive statistics. Descriptive statistics such as mean, standard deviation, percentage, and frequency distribution were used to describe the respondents' socioeconomics, institutional, and demographic characteristics. The probit model was used to analyze the quantitative data, while narrative and conceptual justification were utilized to analyze the qualitative data. The study also employed the household food balance model (HFBM) to quantify the net available food and the food consumption score (FCS) to measure the calorie sufficiency of food at the household level. A propensity score matching (PSM) method was also utilized to estimate the impact of improved crop variety adoption on household food security. Moreover, the data were analyzed statistically by using STATA version 14 to run a probit regression model and compute descriptive statistics results.

5.2.4.1. Probit Model Specification

A household-level adoption study considers the decision made by the household head to include new or improved variety in the usual farming practices. Farmers' decision to adopt certified seed varieties is assumed to be the product of a complex preference comparison made by a farm household. To adopt or not to adopt certified seeds of improved varieties is often a discrete choice. The dependent variable is dichotomous, taking the values 1 or 0. In this case, the value 1 represents a farmer who adopts the certified seed varieties while the value 0 represents a farmer who does not adopt them. Therefore, the study utilized the probit model to analyze the likelihood of adoption of farmers because it is an appropriate econometric model for the binary dependent variable and the assumption is that the error term will be distributed normally.

From the economist's perspective, an individual decides to adopt if the utility associated with that adoption choice (V_{1j}) is higher than the utility associated with the decision not to adopt (choice), (V_{0j}). Following Dell (2019), the difference in utilities of the two choices is stated as:

$\mathbf{y_j^* = V_{1j} - V_{0j}}$, the econometric specification of the model is given in its latent as $\mathbf{y_j^* = X_j\beta + e_j}$ Where, $\mathbf{y_j^*}$ is an unobserved (latent) random variable that defines a farmer's binary (adoption) choices, $\mathbf{X_j}$ is a set of explanatory variables associated with individual j. $\boldsymbol{\beta}$ is a vector of coefficients linked to the explanatory variables while ej stands for the random error terms defined as $\mathbf{e \sim N(0, 1)}$. The relationship between the unobserved variable $\mathbf{y_j^*}$ and the observed outcome ($\mathbf{y_j}$) can be specified as $\mathbf{y_j = 1 \text{ if } y_j^* \geq 0 \text{ and } y_j = 0 \text{ if } y_j^* < 0}$ --- (1)

5.2.4.2. Measurement of Food Security

The **Household Food Balance Model (HFBM)** was used to determine the food security/insecurity status of the sampled households in terms of food availability at each household level. The researcher preferred and utilized this model because it is more applicable in investigating and determining the food security status of households. The HFBM was adapted from FAO Regional Food Balance Model and widely used by different researchers (Degefa, 2002; Meskerem and Degefa, 2015; Demeku *et al*., 2015; Beneberu and Biazin, 2020; Hiwot and Degefa, 2022). The model was employed to quantify the net available food grain owned by each of the sampled households in the study area. All variables needed for the HFBM model were transformed from local grain measurement units to kilogram grain equivalents (EHNRI, 2000). To compare supply with demand for grain food, 2,100 kilocalories per person per day was used as a measure of calories required to allow an adult to appreciate a healthy, moderately active life (EHNRI, 2000). A comparison of calories available and needed by a household was used to estimate a household's food security status.

Household food balance model specification

NFGi = (GPi + GBi + GRi + GSi) - (PHLi + GRSi + GMSi + GGi + GNSi) ------------------- (2)

Where, NFGi is net food grain availability (quintal/year/household); GPi is total crop production (quintal/year/household); GBi is total grain bought from the market (quintal/year/household); GRi is total grain obtained from remittance (quintal/year/household); GSi is total grain obtained through stock (previous) (quintal/year/household); PHLi is post-harvest losses (quintal/year household); GRSi is the quantity of grain reserved (utilized) for seed (quintal/year/household); GMSi is total grain marketed (sold out) (quintal/year/household); GGi is grain given to others as a gift (quintal/year/household), and GNSi is grain planned to be left for next season (quintal/year/household).

The analysis of the model was measured in the following steps. First, net food grain available for each household in kilograms was converted into equivalent total kilocalories using conversion factors used for Ethiopia's food composition table (EHNRI, 2000). Second, the food supply at the household level was calculated by dividing the total number of days per year (365) and the calories available per person per day for each sampled household were calculated using the adult equivalent value. Third, based on the EHNRI, 2100 kcal per person per day was used as a measure of minimum calories required (demand) to enable an adult to live a healthy and moderately active life. Then, the required and available grain food was then compared (demand vs. supply). Using 2,100 kcal calories as the cut-off point, a household whose daily per capita calories available (supply) is less than his/her demand was considered food insecure, while a household was food secure if there was no calorie deficit during the study year. The calculated per capita calorie was finally compared against the recommended minimum daily caloric requirement for a moderately active adult to look into the dietary caloric status of the households in the study area.

The **Food Consumption Score (FCS)** is one of the alternative tools for measuring food security developed by WFP and is commonly used as a proxy indicator for access to food. FCS, which tracks a household's consumption of various food types during the course of the seven days preceding the survey. A seven-day recall period is used to make the FCS as precise as possible and reduce recall bias (WFP, 2009). In this approach, different food items are categorized into nine main food groups and the given corresponding weights. These include main staples: cereals, starchy tubers, and roots (2); Pulses: legumes and nuts (3); Meat and fish: beef, goat, poultry, pork, eggs, and fish (4); Vegetables (1); Fruits (1); Oil: oils, fats and butter (0.5); Milk: milk, yogurt, cheese and other (4); Sugar: sugar, sweets, honey, and other (0.5); and Condiments: spices, salt, coffee, tea, and alcoholic (0) refer (Appendix 7).

The FCS of a household was calculated by multiplying the frequency of foods consumed in the last seven days with the weighting of each food group. According to each food group's nutritional density, the WFP has determined its weight to it. In this case, the household food security status was evaluated by collecting household food consumption in the study area. The FCS is then calculated using the sum of the scores.

Food consumption score model specification

$$\mathbf{FCS_i = \sum (w\,X_j)\,(f\,X_{ji})} \text{ --- } (3)$$

Where, FCS_i = Food consumption score for household $w\,X_j$ = Nutrition content-based weight for food group X_j and $f\,X_{ji}$ = Frequency of consumption (number of days a food group consumed) of a food group X_j by household.

According to WFP (2009), the maximum FCS has a value of 112, which would be achieved if a household ate each food group every day during the last 7 days. The total scores are then compared to pre-established thresholds: Poor food consumption 0 to 21; Borderline food consumption 21.5 to 35; and Accepted food consumption > 35.

5.2.4.3. Propensity Score Matching (PSM)

PSM helps in matching sample households that fall into the treatment group with their proper counterfactuals (non-treatment group but with attributes similar to the sample individuals under the treatment group). According to Wordofa et al (2021), PSM constructs a statistical comparison group that was based on a model of the probability of adopting certified seeds of improved varieties, using observed characteristics.

The observable characteristics of adopters and non-adopters are used to predict propensity scores because it is practically challenging to match adopters to non-adopters on each covariate. The average treatment effect of improved crop varieties was calculated as the mean difference in outcomes between these two groups.

Propensity score matching model specification

The propensity score is the conditional (predicted) probability of receiving treatment T given the observed characteristics X (Craycroft et al., 2020). It can be expressed as:

$P(X) = Pr(Ti = 1/X) = E(Ti/X)$ --- (4)

Where, Ti = [0, 1] indicator of exposure to treatment received by unit *i,* and X is the multidimensional vector of pre-determined characteristics or covariates. $Ti = 1$ for treated observations and $Ti = 0$ for control observations. As a result, if the population of units denoted by *i* and the propensity score $P(Xi)$ is identified, the average treatment effect on the treated *(ATT)* can be estimated as follows:

$$ATT = E\{Y^1 i - Y^0 i \mid Ti = 1$$
$$= E\{E\{Y^1 i - Y^0 i \mid Ti = 1, p(Xi)\}$$
$$= E\{E\{Y^1 i \mid Ti = 1, p(Xi)\} - E\{Y^0 i \mid Ti = 0, p(Xi)\} \mid Ti = 1\} \text{ ---------------------------------- (5)}$$

Where, the external expectation is over the distribution of ($p(Xi)\} \mid Ti = 1$), $Y^1 i$ is the potential outcome of the treatment, and $Y^0 i$ is an outcome of the control.

Once the propensity scores are estimated, each adopter is matched to a non-adopter with similar propensity score values, to estimate the average treatment effect for the treated (ATT).

Choosing a matching algorithm

The following main criteria should be taken into account when choosing between different matching algorithms, that is, among various approaches to employing the propensity score to match comparison units with treatment units: whether it involves replacement or not; how to judge the degree of proximity, or the similarity of the matches; whether and how to weight instances in the analysis; and the number of comparison units matched to each treatment unit.

The three commonly used matching algorithms, namely nearest neighbor matching, radius matching, and kernel-based matching, were employed to assess the impact of certified seed varieties adoption on household food security. According to the ***nearest neighbor matching (NNM)*** method, each farmer in the adopter group is paired with the non-adopter group farmer who has the closest propensity score. The replacement of observations is optional while doing the matching. If the nearest neighbor is far away, NNM runs the danger of having poor matches. This risk can be reduced by using a ***radius matching (RM)*** method, which imposes a maximum tolerance on propensity score differences. However, if the neighborhood's size (i.e., the radius) is too narrow to accommodate control units, certain treated units might not be matched. A counterfactual is created by the ***kernel-based matching (KBM)*** technique using a weighted average of all the farmers in the adopter group. The major advantage of the KM method is that it produces ATT estimates with lower variance since it utilizes greater information, and its limitation is that some of the observations used may be poor matches.

The propensity score matching estimator is simply the mean difference in outcomes more than the common support, properly weighted by the propensity score distribution of adopters. The outcome variable for this study was food security and grain yield at the household level. Food security was measured by the food availability in kilocalories per day per adult equivalent and the frequency of consumption of different food groups consumed by a household over the past 7 days. The grain yield was obtained by each household during the cropping season in the study area.

The following variables were hypothesized that influence the adoption of wheat, tef, and maize varieties (Table 5.1).

Table 5.1: Description of variables, measurement, and expected sign

Variables	Measurement	Type	Exp. sign
Dependent variable			
Adoption status	1 if adopter and 0 otherwise	Dummy	
Outcome variables			
HFBM	Kcal intake per day per adult equivalent	Continuous	+
FCS	Frequency of daily caloric intake	Continuous	+
Yield	Production of wheat, teff, and maize in quintal/ hectare	Continuous	+
Independent variables			
Sex	1 if male and 0 otherwise	Dummy	+/-
Age	household age in years	Continuous	-
Family size	Number	Continuous	+
Education	1) No formal education, 2) Gr. 1-4, 3) Gr. 5-8, 4) Gr. 9-10, 5) Gr. 11-12, 6) College and above	Categorical	+/-
Farm size/ land holding	Actual farm size in hectares	Continuous	+
Farm experience	Farming experience in years	Continuous	+
Livestock holding (TLU)	Number of livestock	Continuous	+
Income source	1) sales of the crop, 2) sales of livestock & products, 3) on-farm daily labor, 4- rented out oxen & land	Categorical	+
Off-farm	1 if yes and 0 otherwise	Dummy	+
Credit	1 if accessed and 0 otherwise	Dummy	+
Farm input	1 if accessed and 0 otherwise	Dummy	+
Extension contact	Number of Visits by extension agent	Continuous	+
Market distance	Distance to the marketplace in minutes	Continuous	-

5.3. Results and Discussion

Based on the cross-sectional data, this section discusses the descriptive and econometric analysis of the impact of adopting improved crop varieties on farm household food security. The appropriate diagnostic measures were made for continuous and dummy variables before the estimation of independent variables. A Collin-test has been conducted to detect the existence of multicollinearity among the continuous variables by using the Variance Inflation Factor (VIF) and the result of the test showed that there was no serious problem of multicollinearity. Moreover, the pair-wise correlation was used to check the correlation coefficients between dummy variables, which are not strongly correlated. In addition to this, a link test was applied to check whether the model is specified correctly or not, and the result estimation indicates that the p-value is insignificant for the hat square, which shows that the model is specified correctly (Appendix 4).

5.3.1. Characteristics of the respondents' demographic and socio-economic status

The survey found that 47.5% of the respondents adopted improved crop varieties. The average number of adopters and non-adopters in the family, was 5.92 and 5.24 respectively as indicated in Table 5.2. Adopters and non-adopters had a mean difference in their responses. Likewise, the result indicates that landholding, farm experience, livestock ownership, and extension contact have a significant result on the certified seed adoption at a 1% level of significance. This demonstrates that the mean differences in the variables between the two categories were found to be statistically significant. On the other hand, the household head's age and market distance are statistically insignificant in determining the adoption decision of the households (Table 5.2).

Table 5.2: Household characteristics for continuous explanatory variables

Variable	Adopter (142)		Non-adopter (157)		Mean difference	T-value
	Mean	SD	Mean	SD		
Age	44.22	12.59	42.13	12.23	2.085	-1.452
Family size	5.92	2.32	5.24	1.96	0.687	-2.771***
Farm size/ land holding	2.51	1.74	1.54	0.83	0.968	-6.230***
Farming experience	25.05	10.56	15.67	7.78	9.381	8.802***
Livestock holding	7.47	5.77	5.53	4.97	1.950	-3.129***
Extension contacts	2.51	1.97	1.62	2.12	0.896	-3.778***
Market distance	6.96	3.73	7.29	3.77	0.329	0.759

Source: Survey, 2021 ****Significant at $P<0.01$*

The findings revealed that there is a statistically significant relation between adoption decision and the sex of the household head at a 10% level of significance, and at a 1% level of significance for education, income, credit access, and availability to farm input (Table 5.3). Furthermore, there is no statistical association between adoption decisions and off-farm activity and marital status. The percentage of male household heads was 88%, whereas 12% were female household heads and only 23% of respondents from both groups were no formal education, while the majority 77% of the respondents could attend formal school in the study area. The focus group discussion's findings also showed that extension workers' adult education programs at farmer training centers aid farmers in developing their reading and writing skills. Education levels have a direct impact on how much technology farmers utilize. Concerning farm income, about 61% of the respondents had income from the sales of crops and crop products. Over 50% of the households lacked credit access, while 68% of the households had farm input access.

Table 5.3: Socio-economic characteristics of the respondents for dummy variables

Variable	Category	Adopter (N=142)	Non-adopter (N=157)	Total value	Chi-square test
		N (%)	N (%)	N (%)	
Sex	Female	12 (8.5)	23 (14.7)	35 (11.7)	
	Male	130 (91.5)	134 (85.4)	264 (88.3)	0.096*
Education	No formal education	22 (0.3)	46 (29.3)	68 (22.7)	
	Gr. 1-4	47 (0.4)	70 (44.6)	117 (39.1)	
	Gr. 5-8	58 (0.2)	26 (16.6)	84 (28.1)	
	Gr. 9-10	11 (0.1)	9 (5.7)	20 (6.7)	
	Gr.11-12	2 (0.0)	3 (1.9)	5 (1.7)	
	College & above	2 (0.0)	3 (1.9)	5 (1.7)	0.000***
Income	Sales of crop	63 (44.4)	120 (76.4)	183 (61.2)	
	Sales of LS & products	65 (45.8)	14 (8.9)	79 (26.4)	
	Daily labor	1 (0.7)	3 (1.9)	4 (1.3)	
	Rented out oxen	12 (8.5)	20 (12.7)	32 (10.7)	
	Rented out land	1 (0.7)	0 (0.0)	1 (0.3)	0.000***
Off-farm	Sale of charcoal	19 (13.4)	29 (18.5)	48 (16.1)	
	Other (shops)	118 (83.1)	119 (75.8)	237 (79.3)	
	Salary	5 (3.5)	9 (5.7)	14 (4.7)	0.289
Credit	No	55 (38.7)	114 (72.6)	169 (56.5)	
	Yes	87 (61.3)	43 (27.4)	130 (43.5)	0.000***
Farm input	No	32 (22. 5)	65 (41.4)	97 (32.4)	
	Yes	110 (77.5)	92 (58.6)	202 (67.6)	0.001***
Marital status	Single	8(5.6)	4(2.6)	12(4.0)	
	Married	123(86.6)	136(86.6)	259(86.6)	
	Divorced	3(2.2)	11(7.0)	14(4.7)	
	Widowed	8(5.6)	6(3.8)	14(4.7)	0.107

Source: Survey, 2021 ****and * Significant at p<0.01and p<0.1 respectively*

5.3.2. Food security status of farm households

5.3.2.1. Food security status as measured by HFBM

The food security status of sampled households was analyzed using the household food balance model. The single most important indicator of the food adequacy level of a community is the per capita dietary energy supply measured in kilocalories. This represents the amount of average daily food that each individual in a sample family has access to. Subsequently, the households' annual available food grain supply is converted into kilograms by using the conversion factors of major crops into kilocalories. The converted findings were then divided by the number of adult-equivalent household members and the recall period's number of days. The outcomes were contrasted with the minimum demands per day for each adult equivalent unit.

The HFBM results revealed that the mean daily calorie intake of the sampled households was 1533.8 kcal/daily/adult equivalent, which only meets 73% of the Minimum Recommended Allowance (MRA-2100 kcal). The extent of the food security situation among the sample households with food availability is observed in Table 5.4, the daily per capita dietary energy level stretches along the range of 98 to 12373 kcal, which shows a great variation in the availability of food across households. The finding of the study is in line with Furgasa and Degefa's (2016) study report.

Table 5.4: Two-sample t-test with equal variance on HFBM Kcal/daily/adult

Variable	Group	Obs.	Mean	Std. Err.	Std. Dev.	Min	Max	T-value	P-value
Kcal/day/adult	Food secure	137	2397.7	121.2	1418.8				
	Food insecure	162	803.2	27.5	349.7				
	Total sample	299	1533.8	73.6	1272.0	97.8	12372.7	-13.82	0.000***

Source: Field survey, 2021

The households that are found to fall above or equal to the national minimum daily calorie requirement level ($\geq$ 2100 kcal/day/adult equivalent) categorize as food secure and households that fall below the national daily calorie requirement (< 2100 kcal/day/adult equivalent) are categorized as food insecure (EHNRI, 2000). Thus, the food security status of all sampled households obtained from the HFBM calculation indicated that 57% and 36% of the adopter and non-adopter households were food secure respectively. The remaining 43% and 64% of the adopter and non-adopter households were food insecure respectively. Overall, the result of the household food balance model revealed that from the total sample households, 46% of households were found to be food secure and fulfilled the minimum recommended daily calorie (2,100 kcal/daily/adult equivalent), while the rest 54% were food insecure (Table 5.5). This indicates that the households were exposed to a critical shortage of food, which fails to meet the minimum calorie requirement in the study area. The result shows that food-secured households have a greater capacity to produce their products, a better stock that was left from the previous production, and a greater capacity to take a food reserve for the next season.

The data output also reveals that there is a household that is supplying their household energy as net food grain buyers and sellers both the groups with food security and those with food insecurity. Furthermore, the result of the KII and FGD confirmed that the current food market price increase trends reward the net food grain sellers, while net food grain buyers are suffered from the price and make their household food security more vulnerable to external price factors for the grain market.

Table 5.5: Food security status of the HFBM

FS status of the HFBM	Adopter		Non-adopter		Total	
	No.	%	No.	%	No.	%
Food secure (≥ 2100 kcal)	81	57.0	56	35.7	137	45.8
Food insecure (< 2100 kcal)	61	43.0	101	64.3	162	54.2
Total	142	100	157	100	299	100

Source: Field survey, 2021

Household Food Availability

As depicted in Table 5.6, the difference between the three districts seems quite significant in terms of food available for consumption. The findings show that Moretina Jiru district is in a relatively better position than the other two districts. The average per capita food available at this site was 1879.1 (90% of the MRA) and about 30% of the households in this district had attained the MRA for the year under study.

Table 5.6: Average net food available for consumption in kilocalories and per capita calories

Districts	Total kg per household per year		Total kcal per household per year		Daily per capita food available in calories		
	Sum	Average	Sum	Average	Mean	SD	% of MRA
Ada'a	142654	1320.9	843159.8	7807.04	1454.5	1029.3	69.3
Bora	78229	1150.4	439293.3	6460.2	1035.1	668.4	49.3
Moretina Jiru	164624	1338.4	923203.8	7505.7	1879.1	1585.4	89.5
Total	385507	1289.32	2205656.9	7376.9	1533.8	1272.0	73.0

Source: Field survey, 2021

Ada'a district came next with a mean daily per capita calorie of 1454.5 (69% of the MRA). Some 20% of the farm households had access to food greater than the MRA. Bora district has the least mean daily per capita calories of 1035.1 (49% of the MRA). Only 7% of the households had attained the MRA in this district. In general, the distribution of households with per capita food available in the study area was 21% achieved over MRA, 36% had between 1050 and 2100 Kcal, and the remaining 43% had less than 1050 per capita calories of availability (Table 5.7).

Table 5.7: Percentage distribution of households with per capita food available

Districts	No. of HH	Households with per capita calorie of availability/day/ equivalent							
		<1050 Kcal		1050-1680 Kcal		1681 -2100 Kcal		>2100 Kcal	
		No	%	No	%	No	%	No	%
Ada'a	108	44	40.7	31	28.7	11	10.2	22	20.4
Bora	68	41	60.3	17	25.0	5	7.4	5	7.4
Moretena Jiru	123	44	35.8	27	22.0	15	12.2	37	30.1
Total	299	129	43.1	75	25.1	31	10.4	64	21.4

Source: Field survey, 2021

Food security status of households

The survey results showed that cereal and pulse grains are the major sources of food widely produced and used for home consumption. As a result, cereal and pulse grains, which are commonly used for home consumption are considered the main sources of dietary energy supply in the household, hence used to calculate the dietary energy supply of the study households. The result of the HFBM showed that the total amount of food energy available for the households was 55,982,240 kcal, giving the average daily per capita volume of 1533.76 kcal (Table 5.8). When compared to the MRA for an adult, 2100 kcal, the available dietary energy was only 73 % of the recommended daily allowance.

Table 5.8: Net food source grains available for the sampled households

Crop Type	Net available grain for consumption (kg)	Dietary energy Kcal per 100gm	Total dietary energy equivalent (kcal)	Contribution value to total dietary energy supply (%)
Wheat	115,570.41	202.2	23,368,336.64	41.7
Teff	80,167.21	184.3	14,774,816.53	26.4
Maize	38,463.60	174.6	6,715,744.35	12.0
Barley	13,247.28	245.8	3,256,182.37	5.8
Pulses	23,710.23	209.3	4,962,550.51	8.9
Vegetables	33,044.48	87.9	2,904,609.59	5.2
Total	304,203.20		55,982,240.00	100.0

Source: Field survey, 2021 and Computed based on EHNRI's food composition table

In Table 5.9, based on the survey results obtained, only 21.4 % of the households meet the minimum recommended dietary energy, of 2100 Kcal, whereas 10.4 and 25.1% of the households obtained up to 81% and 50% of the minimum recommended dietary energy respectively. The remaining 43.1% of the households obtained only about 5 % of the minimum recommended daily allowance. Although this may need further investigation, it is possible to understand that 79 % of the study households were food insecure.

Table 5.9: Distribution of dietary energy available in calories for the sampled households

Range of Dietary energy (Kcal)	Obs.	%	Minimum Dietary energy available (kcal)	Maximum Dietary energy available (kcal)	Mean Dietary energy available (kcal)	Std. Dev.	Mean % of MRA
< 1050	129	43.1	97.8	1045.9	672.3	228.5	32.0
1050-1680	75	25.1	1052.5	1651.4	1333.9	183.8	63.5
1681 -2100	31	10.4	1701.1	2098.5	1844.5	120.8	87.8
> 2100	64	21.4	2132.7	12372.7	3353.7	1587.9	159.7
Total	299	100	97.8	12372.7	1533.8	1272.0	73.0

Source: Field survey, 2021

5.3.2.2. Food Consumption Score (FCS)

The food consumption score is one of the most theoretically grounded indicators for analyzing food security, measured in kilocalories. As a result, food security analysis increasingly uses proxy indicators. Such indicators generally capture diet diversity, meaning how many different food types or food groups are included within a diet, as well as food frequency meaning how often, (over a given period) are the various food types, or food groups, consumed. WFP has adopted this approach to measuring dietary diversity and food frequency, using an indicator known as the food consumption score (FCS). It is a frequency-weighted diet diversity score that is determined by how frequently a household consumed various food groups over the seven days before the survey. (WFP, 2016). Using the collected data, FCS for the surveyed households were developed based on the weights given based on the nutrient content of that particular food group (Table 5.10).

As indicated in Table 5.10, the majority of the adopter household (52.8%) and non-adopter (51%) households consumed main staples for 5 to 7 days during the seven days previous to the survey. Tef, wheat, maize, barely, and potatoes were found to be the staples food most frequently consumed in the study areas. Regarding vegetables, the majority 38% and 32.5% of adopter and non-adopter households respectively had consumed for 3 to 4 days while a few 31.7% and 49%of adopter and non-adopter households had consumed for 1 to 2 days from this group of food respectively within the preceding seven days. Almost, the majority of the two groups of households had not consumed fruits, meat, fish, and milk within seven days period except for a few households. Regarding pulses, the food group, the majority of 91.5% and 92.4% of the adopter and non-adopter households had consumed for 5 to 7 days during the seven days before the survey. On the other hand, the highest number of adopter (95.1%) and non-adopter (87.9%) households had consumed oil and fats. Likewise, 83.8% and 77.1% of the adopter and non-adopter households had consumed sugar for 5 to 7 days within seven days period before the survey respectively. According to the results of focus group discussions, most households use sugar and oil for everyday meals traditionally and for social purposes.

Table 5.10: Percentage of food intake

Food Groups		Adopter				Non-Adopter			
		Households' food intake				Households' food intake			
		No Cons.	1-2 days	3-4 days	5-7 days	No Cons.	1-2 days	3-4 days	5-7 days
Main staples	%	14.4	21.1	11.6	52.8	13.1	23.9	12.1	51.0
Vegetables	%	9.9	31.7	38	20.4	9.6	49	32.5	8.9
Fruits	%	81	16.2	2.8	0	90.4	7.6	1.3	0.6
Meat and fish	%	79.6	12.7	3.8	4.0	85.8	8.3	3.6	2.3
Pulses	%	2.1	2.1	4.2	91.5	1.9	1.3	4.5	92.4
Milk and its product	%	69.7	10.6	9.2	10.6	82.8	8.3	7	1.9
Oil and Fats	%	2.1	0.7	2.1	95.1	4.5	3.2	4.5	87.9
Sugar /Sweets	%	7.7	4.2	4.2	83.8	13.4	4.5	5.1	77.1

Source: Field survey, 2021

Taking this information regarding the consumption patterns of different food groups by the adopter and non-adopter groups of the households, it is possible to select appropriate thresholds or cut-off points and classify the households into FCS categories. This study has preferred to use the thresholds of < 21 (for poor), 21.5 to 35 (for borderline), and > 35 (for accepted) food consumption. Based on the food consumption groups, the FS level was divided into two groups: "food insecure" if the food consumption group is categorized in the poor and borderline groups, and "food secure" if it is categorized in the acceptable group (WFP, 2009).

In Table 5.11, the relationship between food security status and certified seed adoption of the household result confirmed that from adopter categories the result was found to be 53 (37.3%), 71 (50%), and 18 (12.7%) in acceptable, borderline, and poor food consumption scores respectively. For those households which are not adopt certified seeds of improved varieties about 45 (28.7%), 69 (43.9%), and 43 (27.4%) of the households were found at acceptable, borderline, and poor consumption conditions respectively. Accordingly, the mean food consumption score of the adopter households was 33.3, and 30.3 of non-adopters. The mean variation between the two groups was found to be statistically significant at a 1% significance level.

Table 5.11: Food security status of respondents on certified seeds of improved varieties (used FCS)

Food Consumption Score Category	Adopter (N=142)		Non-Adopter (N=157)		Mean		P-value
	No.	%	No.	%	Adopter	Non-adopter	
Poor (< 21)	18	12.7	43	27.4			
Borderline (21-35)	71	50	69	43.9			
Acceptable (> 35)	53	37.3	45	28.7			
Total	142	100	157	100	33.3	30.3	0.004***

Source: Field survey, 2021 *** Show significance at p<0.01*

Therefore, the result revealed that the food security level in the study area was about 67.2% of the household food insecure and 32.8% of the household was food secure (Figure 5.1).

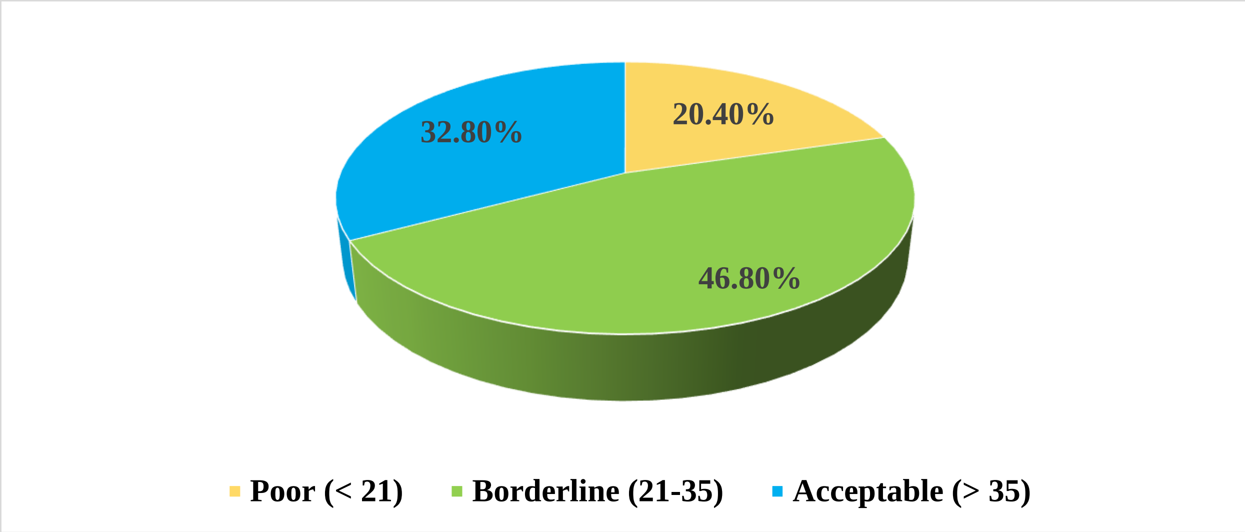

Figure 5.1: Food security level of the food consumption group; Source: Field survey, 2021

5.3.3. The propensity score estimation

It is crucial to estimate the propensity score to collect matched treated and untreated data as well as to estimate the ATT. The propensity score constructs a statistical comparison between a treated and control individual based on similarities in all observable characteristics except the treatments to compute the difference in the outcome variable. This means that the average treatment effect of the technology adoption is calculated as the mean difference in outcomes across the two groups (Brian et al., 2020). The propensity scores were estimated with a probit model which helps as a device to balance the observed distribution of covariates across the adopted & non-adopted groups.

A probit regression model identified the explanatory variables that influence the adoption of improved varieties of cereal crops along with their likely effects on the farm households' adoption decision. In this study, thirteen explanatory variables were used to fulfill the criteria of the balancing propensity. The results in Table 5.12 found that the age of the household head, educational level, farm size, farming experience, farm income, access to credit, access to farm input, and frequency of extension contact were statistically significant.

The age of the household head was significant at a 10% level of significance and negatively associated with the adoption of certified seed varieties. The marginal effect of the age of the household head, -0.004, indicates that with a one-year increase in the age of the respondents, the probability of adoption of improved wheat varieties decreases by 0.4%, ceteris paribus. This shows that older farmers less adopt new technology because their mobility and eagerness to gather new information about new technology are limited. A study by Udimal et al. (2017) found that as farmers age, they adopt technologies less as compared to young farmers, justifying that as they grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. Furthermore, a study conducted by Luchia and Hagos (2018) and Jaleta et al. (2018) is consistent with this finding.

The level of education was significant at a 5% level of significance and positively associated with the adoption of certified seed varieties. The marginal effect of 0.043 for the level of education implies that with the increase in the number of schooling years of the household head by a year, the likelihood of adoption of certified seed varieties increases by 4.3%, other things being kept constant. The study result is similar to Kebede and Tadesse (2015) and Shiferaw et al. (2014) that showed education enhances farmers' awareness of new technologies. This might be justified as education helps farmers easily process information so that they can quickly adopt the new technology.

The model output revealed that farm size or land holding had a positive and significant influence on the probability of adoption of certified seed varieties at a 1% significance level. The marginal effect further showed that a unit-hectare increase in the farm size of the household increases the probability of adoption of certified seed varieties by 8.7%. The land is one of the major productive assets where farmers carry out different agricultural production for their livelihood. Owning more land helps farmers to produce more for home consumption and sale when the production is surplus. This finding is confirmatory with the findings of the studies of Chandio (2016), Leake and Adam (2015), and Kebede et al. (2016), who found positive effects of farm size on the adoption of the new technology.

The farming experience of the respondent positively and significantly influences the extent of certified seed varieties adoption at a 1% level of significance. As the farmers' experience increased by one year, the level of certified seed varieties adoption increased by 2%, being other variables constant. Moreover, farmers with longer farming experiences in production have gotten more knowledge and skill in the intensive production of the crop itself. So farmers who have more farming experience in production adopt more than a farmer with shorter farming experience. This may be due to relatively farmers who have Longer years of experience may develop confidence in handling risk lovers, and skills in technology applications. The findings of the study are in line with Chandio and Jiang's (2018), and Ahmad et al. (2015) study reports.

The farm income of the respondents was found to influence the adoption of improved varieties positively and significantly at a 1% significance level. The marginal effect of the farm income, 0.075, shows that as the crops net income of the farmers increases by one birr, the level of certified seed varieties adoption increases by 7.5%, being other variables constant. The more the farmers' net income, the better adoption of improved varieties.

Access to credit was positive and significantly related to the adoption of certified seed varieties at a 1% significance level. The marginal effect of access to credit, 0.170 shows that the probability of those households who accessed credit was 17% higher than those households who didn't have access to credit in adopting improved varieties, keeping other variables constant. The finding is analogous to Wondale et al. (2016) study. The result might be explained as households with access to credit may have sufficient money to purchase certified seed variety along with necessary inputs as per a recommendation.

Access to farm input was positive and significantly related to the adoption of certified seed varieties at a 1% significance level. The marginal effect of access to farm input, 0.164 shows that the probability of those households who accessed seed was 16.4% higher than those households who didn't have access to seed in adopting improved varieties, keeping other variables constant.
The finding agrees with Ghimire et al. (2015) and Shilomboleni's (2017) studies that increasing the availability of improved varieties to smallholder farmers by fostering an input market is a way to increase crop productivity.

The frequency of extension contact positively and significantly associated with households' adoption decision of certified seed varieties at a 5% level of significance. The marginal effect of the frequency of extension contact, 0.022, suggests that with the increase in the frequency of extension contact by one day, the likelihood of households' adoption of improved wheat varieties increases by 2.2%, ceteris paribus. The finding of this result is analogous to Suvedi et al. (2017). Farmers who have regular contact with extension agents are likelier to adopt than those with less access to extension contact.

Table 5.12: Estimation of propensity score: A probit model

Variables	Coef.	dy/dx	Std. Err.	z
Sex of the household head	0.170	0.414	0.307	0.56
Age of the household head	-0.016	-0.004	0.009	-1.81*
Family size	-0.059	-0.014	0.053	-1.12
Education level	0.176	0.043	0.090	1.95**
Farm size/ land holding	0.357	0.087	0.112	3.20***
Farming Experience	0.082	0.019	0.013	6.44***
Livestock holding (TLU)	-0.013	-0.003	0.021	-0.62
Farm income	0.309	0.075	0.098	3.17***
Off-farm	0.181	0.044	0.217	0.83
Access to credit	0.701	0.170	0.183	3.82***
Access to farm input	0.675	0.164	0.199	3.39***
Extension contact	0.092	0.022	0.046	2.01**
Market distance	-0.014	-0.003	0.026	-0.55
_cons	-3.548		0.684	-5.19

*Source: Survey, 2021. Significant levels are indicated by ***, **, and *, which are 1%, 5%, and 10% respectively; Number of observation =299, LR chi^2 (13) = 157.98, Probability > chi^2= 0.000, Pseudo R^2 = 0.3818; Log-likelihood = -127.88425*

5.3.4. Impacts of improved wheat, teff, and maize varieties adoption on food security

The impact of the adoption of improved varieties was analyzed with the estimation of propensity score matching (PSM), choosing a matching algorithm, balancing testing, and average treatment effect on treated (ATT). Prior to introducing the matching exercise, propensity scores should first be expected values that are estimated for all households. Its purpose is to forecast the propensity score of traits not impacted by the treatment variable. Second, a common support situation needs to be applied to household propensity score distributions. The region is known for the highest and lowest propensity scores for adopters and non-adopters. The third step is to discard observations whose estimated propensity scores are outside the common support zone. In order to determine if the matching quality was satisfied or not, the balance test is checked at the end.

5.3.4.1. Estimated propensity score distribution and common support region

Estimate the propensity score after using the probit model. As shown in Table 5.13, the distribution of estimated propensity score varies between 0.0227 and 0.9993 with a mean score of 0.7169 for treated households and between 0.0064 and 0.9915 with a mean score of 0.2560 for untreated/control households. The common support region, where the values of propensity scores of both treated and untreated groups can be found, is given in the range between 0.0227 and 0.9915 which means households whose estimated propensity scores are less than 0.0227 and larger than 0.9915 are not considered for the matching purpose. Thus, nine households (from the treated group, the green color on the graph) outside this range were dropped or rejected from the estimation.

Table 5.13: Distribution of the estimated propensity scores

Groups	Obs.	Mean	Std. dev.	Min	Max
Treated	142	0.7169452	0.2517773	0.0227692	0.9993667
Untreated	157	0.2560114	0.2408880	0.0063533	0.9915010
Total	299	0.4749164	0.3369418	0.0063533	0.9993667

Source: Survey, 2021

The density distribution of the propensity score for treated and control variables is shown in figure 5.2, the bottom part of the graph shows the propensity score distribution of untreated (non-adopters), whereas the upper part denotes treated (adopters) households. The treated on support indicates, the farmers in the adoption group who found an appropriate match and untreated designates the control groups, and treated off support specifies the households in the adoption group who did not find a proper match. The balancing procedure tests whether adopters and non-adopters have the same distribution of propensity scores, and if not, they need a check-up. Therefore, in this study, a complete and strong specification that satisfied the balancing tests was carried out. Moreover, the figure shows that there is a wide area in which the propensity score of both the treatment and the control groups are similar leading to a possibility of matching the two groups using the common support region.

The result revealed that from the total treated observations, 6.3% of the households were off-support, while 93.7% were on-support, and all the control households are included in the common support region. Each treated unit is matched only with the control units whose propensity scores fall into a predefined common support region of the propensity score matching (Figure 5.2).

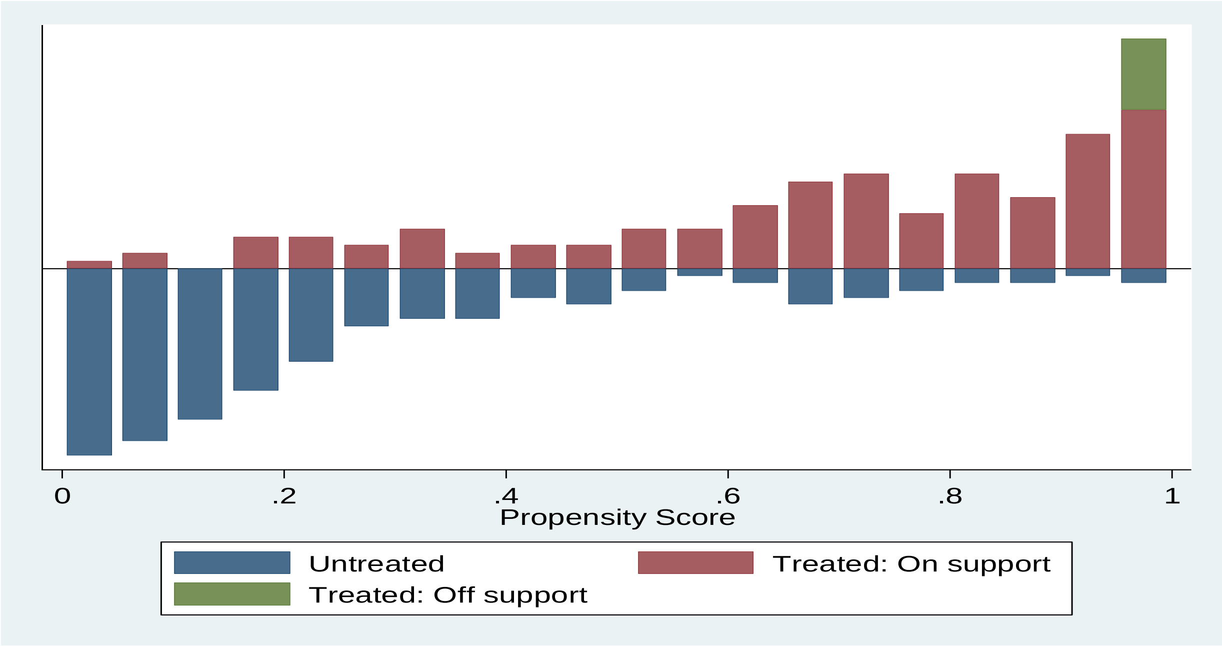

Figure 5.2: Propensity score distribution and common support region graph; *Source: Survey, 2021*

5.3.4.2. Choice of matching algorithm

To estimate the average treatment effect of the adoption of improved varieties of cereal crops on food security, alternative matching algorithms were searched to match the treatment and control groups in the common support region. The matching algorithms were chosen and utilized in this analysis based on a criterion. These are nearest neighbor matching, radius caliper matching, and kernel bandwidth matching.

According to Austin (2014), and Heinz et al. (2022) the decision on the final choice of an appropriate matching estimator is based on three different criteria. First, the equal means test (referred to as the balancing test) suggests that a matching estimator which balances all explanatory variables (i.e., insignificant mean differences between the two groups) after matching is preferred. Second, a matching estimator that generates the smallest pseudo-R^2 value is preferable. Third, it is preferable to use a matching estimator that upshots in the most matched sample sizes. Based on these criteria, the Kernel bandwidth (0.25) was found to be an appropriate matching algorithm for the estimation (Table 5.14).

Table 5.14: Matching algorithm alternative

Matching algorithm types	Performance criteria	
	Psuedo-R^2	Matched sample size
Nearest Neighbor matching (0.03) no replacement (NNM)	0.056	209
Nearest Neighbor matching (0.03) common (NNM)	0.073	287
Radius caliper matching (0.01) common (RM)	0.056	250
Radius caliper matching (0.25) common (RM)	0.060	290
Radius caliper matching (0.5) common (RM)	0.122	290
Kernel Band Width matching (0.1) common (KM)	0.063	290
Kernel Band Width matching **(0.25) common** (KM)	**0.054**	**290**
Kernel Band Width matching (0.5) common (KM)	0.082	290

Source: Survey, 2021

5.3.4.3. Two sample t-tests on outcome variables before matching

The study utilized a two-sample t-test to check whether the adoption of certified seed varieties has a significant impact on household food security or not. In Table 5.15, the results showed that the HFBM mean value of food availability for the treated group was 1771 and for the control group 1319 kcal per day. The degree of freedom used for the test is 297. The mean was different between the two groups and accept the null hypothesis. The test has a significant p-value of 0.002 at a 1% level of significance. The mean value of FCS for the treated group was 33 and for the control group 30 kcal per day. The test has a significant p-value of 0.005 at a 1% level of significance. The mean value of the total yield gained for the treated group was 46 and for the control group was 29 quintals per hectare in the study area. Therefore, the finding revealed that there is a significant p-value between the two groups at a 1% level of significance.

Table 5.15: Two-sample t-test with equal variance

Outcome variables	Groups	Obs.	Mean	Std. Err.	Std. Dev.	t-test
HFBM kcal/Day/Adult	Treated	142	1771.198	128.528	1531.588	0.002***
	Control	157	1319.014	74.569	934.351	
	Mean diff.		452.184	145.209		
FCS	Treated	142	33.295	0.804	9.579	0.005***
	Control	157	30.274	0.707	8.853	
	Mean diff.		3.022	1.066		
Yield Total	Treated	142	46.253	2.896	34.507	0.000***
	Control	157	29.210	1.503	18.838	
	Mean diff.		17.043	3.175		

*Source: Survey, 2021; *** Significant at a 1% level*

5.3.4.4. Testing the balance of covariate using propensity score (matching quality)

The balancing test of covariates before and after matching was checked using different procedures by applying the selected matching algorithm (KBM-0.25). The similarity of the subsample of control cases compared with the treated cases was tested using “pstest”. This test helps to balance information for propensity scores and each covariate before and after matching. The balancing powers of the estimations are ensured by different testing methods such as the standardized bias difference between treated and control samples were used as a convenient way to quantify the bias between the matched and unmatched households, equality of means using t-test, and chi-square test for significance of the variables.

Table 5.16, presents the pstest result of the covariate balancing test of the hypothesis that both groups have almost the same distribution in covariates after matching. The result revealed the covariates mean, the percentage bias, and the p-value difference in mean before and after matching. Before matching the standardized bias among the covariates was between 6.5% and 101.2%, but, after matching, the standardized bias for almost all covariates lay between 2.3% and 22.3%.

Moreover, the p-values indicated that before matching 77% of chosen variables exhibited a statistically significant difference, but after matching all covariates have statistically insignificant differences. In almost all cases, it was evident that sample differences in the unmatched data significantly exceed those in the samples of matched cases. Therefore, the process of matching thus creates a high degree of covariate balance between the treatment and control samples that are used in the estimation procedure.

Table 5.16: Testing of covariance balance using propensity score (testing the matching quality)

Covariates (Variables)	Samples	Mean		Percent reduction		t-test	
		Treated	Control	% bias	Bias	T	p>|t |
Sex of the household head	UM	0.91549	0.8535	19.4		1.67*	**0.097**
	M	0.91729	0.96038	-13.5	30.5	-1.47	0.144
Age of the household head	UM	44.218	42.134	16.8		1.45	0.148
	M	43.639	42.281	10.9	34.9	0.91	0.361
Family size	UM	5.9225	5.2357	32.0		2.77***	**0.006**
	M	5.7895	5.9215	-6.1	80.8	-0.53	0.593
Education level	UM	2.507	2.121	37.4		3.22***	**0.001**
	M	2.4962	2.7005	-19.8	47.1	-1.36	0.174
Farm size/ land holding	UM	2.5111	1.5427	71.0		6.23***	**0.000**
	M	2.2487	2.0052	17.9	74.9	1.67	0.960
Farming Experience	UM	25.049	15.669	101.2		8.80***	**0.000**
	M	24.128	22.058	22.3	77.9	1.83	0.680
Livestock holding (TLU)	UM	7.4714	5.5268	36.1		3.13***	**0.002**
	M	6.8888	6.5461	6.4	82.4	0.62	0.536
Farm income	UM	1.7535	1.5096	25.3		2.18**	**0.030**
	M	1.7519	1.5923	16.6	34.6	1.33	0.185
Off-farm	UM	1.9014	1.8726	6.5		0.56	0.574
	M	1.9023	1.9481	-10.4	-59.3	-1.06	0.289
Access to credit	UM	0.61268	0.27389	72.3		6.26***	**0.000**
	M	0.6015	0.63045	-6.2	91.5	-0.48	0.629
Access to farm input	UM	0.77465	0.58599	41.2		3. 54***	**0.000**
	M	0.78195	0.77155	2.3	94.5	0.20	0.839
Extension contact	UM	2.5141	1.6178	43.8		3.78***	**0.000**
	M	2.406	2.5261	-5.9	86.6	-0.47	0.641
Market distance	UM	6.963	7.293	-8.8		-0.76	0.448
	M	6.8609	6.6626	5.3	39.9	0.44	0.657

*UM=Unmatched, M=Matched; ***, **, and * Significant at a 1%, 5%, and 10% respectively*

The post-estimation test in Table 5.17 revealed that the pseudo-R^2 is minimized to 0.054, the low value of pseudo-R^2 indicated that both treated and control groups have an identical distribution in the covariates after matching and the impact of certified seeds of improved varieties adoption could be easily evaluated since the adopters and the non-adopters are similar in their pre-intervention observable characteristics. The t-test was significant and the mean bias and beta are also minimized after matching, this all indicates the matching was good.

Table 5.17: Mean bias and chi-square test for the significance of variables

Sample	Ps R^2	LR chi^2	P>chi^2	Mean Bias	Med Bias	B
Unmatched	0.382	157.98	0.000	39.4	36.1	167.6*
Matched	0.054	20.03	0.095	11.0	10.4	55.3*

Source: Survey, 2021

5.3.4.5. The average treatment effect on the treated (ATT)

The ATT was computed based on the three alternative matching methods algorithms namely, nearest neighbor matching (NNM), radius caliper matching (RM), and kernel bandwidth matching (KBM). However, based on the criteria, the Kernel bandwidth matching method was selected over the others for the estimation. The outcome variables were the household food balance model (calorie intake per adult equivalent per capita), food consumption score (frequency of eating diversified food per week), and total grain yield obtained (quintal per hectare) by the farm household. The adoption impact is shown by ATT with different algorithms, the t-statistics are based on bootstrapped standard errors with 50 replications which were used to verify whether the observed effect was significant or not (Table 5.18).

The ATT results from the common support range in Table 5.18, show that adopters of certified seed varieties had an average availability of food for HFBM was 436.13 kcal, which is 33% higher than the non-adopters significantly at a 1% level, estimated using the case of nearest neighbor matching method. The results of the radius caliper matching method also confirm the mean difference between the adopters and the non-adopters was 391.63 kcal which is about 29% higher than the non-adopters in terms of food availability. The difference is significant at a 1% level. Using a kernel bandwidth matching method, the average treatment effect on the treated estimated was 384.35 Kcal which was greater than that of the non-adopters by about 28%. The FCS result also found that using the NNM, RM, and KBM methods on average, certified seed adopters of households have increased the frequency of eating diversified food per week by about 10, 7, and 8% than non-adopters respectively. The difference between the two groups was still significant at a 1% level. On the other hand, the finding revealed that on average at a 1% level of significance, the adopter households obtained a yield of about 12, 10, and 11% of quintals per hectare higher than the non-adopters using the NNM, RM, and KBM methods respectively. This result shows that the adoption of certified seeds of improved crop varieties has a significant and positive impact on the average food availability, food consumption, and yield obtained by households. Similarly, the ATT results in Table 5.18, from estimation by different algorithms indicate that the adoption of certified seeds of improved varieties positively and significantly affects HFBM at a 1% level of significance, the increase in food availability per day per adult equivalent ranges from 414 in the case of kernel bandwidth matching to 442 Cal per day in the case of radius caliper matching. A comparative analysis shows that adopters are better than non-adopters by 421 calories per day in terms of the level of food availability using the nearest neighbor matching with replacement and this gain was statistically significant at a 1% level of significance. The finding revealed that using the NNM, RM, and KBM methods, the FCS of the certified seed adopters' at the household level on average increase the frequency of eating diversified food per week by about 4.51, 3.15, and 5.14 kcal than non-adopters respectively. The results also show the adoption of improved crop varieties significantly affected the total grain yield obtained by the farm household at a 1% level of significance. The increase in yield obtained varies from 9.54 in the case of nearest neighbor matching to 13.25 quintals per hectare in the case of radius caliper matching. According to the kernel bandwidth matching, the causal effect of technology adoption is significant and equal to 9.87 quintal per hectare, which is the average crop production difference between adopters and non-adopters.

Therefore, the ATT result suggests that the impact of the adoption of certified seeds of improved wheat, teff, and maize varieties significantly on average increased the yield obtained by about 9.54 to 13.25 quintals per hectare than the non-adopters. This is the average change in the productivity of farm households that is contributed by a change in technological status. The study is in line with studies (Ahmed and Mesfin, 2017; Khonje et al., 2018).

Table 5.18: ATT after matching and estimation with different algorithms

Outcome variables	Matching algorithm types	Matched samples		ATT After matching			ATT Estimation	BS. Std. Err.	t-test
		Treated	Control	Treated	Control	Diff.			
HFBM	NNM	142	45	1753.84	1317.70	436.13	420.53	187.02	2.249***
	RM	142	151	1752.12	1360.49	391.63	441.54	138.24	3.194***
	KBM	**142**	**151**	**1752.12**	**1367.77**	**384.35**	**414.42**	**170.54**	**2.430*****
FCS	NNM	142	45	32.49	29.52	2.97	4.51	2.01	2.239***
	RM	142	151	32.46	30.32	2.14	3.15	1.43	2.201***
	KBM	**142**	**151**	**32.46**	**30.07**	**2.39**	**5.14**	**1.74**	**2.961*****
Yield	NNM	142	45	40.89	36.64	4.25	9.54	5.78	1.650***
	RM	142	151	41.03	37.48	3.56	13.25	3.64	3.636***
	KBM	**142**	**151**	**40.86**	**36.85**	**4.01**	**9.87**	**5.65**	**1.748*****

*Source: Survey, 2021; *** Significant at a 1% level; BS= Bootstrapped*

5.4. Conclusion and Recommendations

This study analyzed the impacts of improved crop varieties adoption on household food security among the adopters and non-adopters farmers in Central Ethiopia. The findings revealed that the use of improved teff, wheat, and maize varieties was identified as a major crop technology adoption in the study area and the adopters are significantly better than the non-adopters in terms of food availability at the household level, which is a good indicator of food security. Likewise, it was found that households with access to crop technology would improve the status of food availability and consumption.

Using both propensity score matching and probit regression models, the study further shows that the adoption of improved crop varieties leads to a significant increase in consumption expenditure, yield gained, and food security. The propensity score was estimated with a probit model which helps as a device to balance the observed distribution of covariates. A propensity score matching approach was also used to compare adopter with non-adopters households in terms of their outcome variables HFBM, FCS, and yield gained level. The identified factors affecting the adoption of improved crop varieties were the age of the household head, educational level, farm size, farming experience, farm income, access to credit, access to farm input, and frequency of extension contact statistically significant variables. This finding implies that creating a conducive production environment for farmers plays a vital role in the adoption of crop technologies.

The average treatment effect (ATT) results from estimation by different algorithms indicate that the adoption of certified seeds of improved crop varieties significantly impacts the average increase in food availability calorie intake/ day per adult equivalent, the food consumption scores on average increase the frequency of eating diversified food per week at the household level, and the yield obtained per hectare by the adopter farm households on average increased than the non-adopters. This is the average change in the productivity of farm households that is contributed by a change in technological status.

Therefore, the study suggested that a significant effort is required on the part of the government, NGOs, agricultural research institutions, and extension services to make new, improved crop varieties and technology available to smallholder farmers in the district. Further studies should be needed to examine the relationship between the adoption of improved crop varieties and food security and to provide more dynamic evidence on the implication of the adoption of improved crop varieties for food security.

Chapter 6: Synthesis of Main Findings, Conclusion, and Implications

6.1. Introduction

The specific goal of this study was to investigate the systemic restrictions of the seed system and to comprehend the roles, responsibilities, and linkages of the seed actors. It also assesses the seed supply system, access to certified seed and its effect on farm households' food security; the determinants of adopting certified seeds of enhanced crop varieties; and the impact of adopting improved crop varieties on food security. The research was underpinned on the pragmatist paradigm, which combines quantitative and qualitative methodologies. A structured questionnaire survey was used to collect quantitative data from 299 farm households from the three *Woredas*, while key informant interviews, focus group discussants, and personal observation were used to collect qualitative data. The quantitative data were analyzed using several descriptive statistics, econometric models, and employed techniques of food security measurements. The qualitative data was analyzed via transcription, categorization, narration, interpretation, and discussion. This chapter presents a summary of the key findings of each research objective, conclusions reached, implications for possible interventions, and suggestions for future research.

6.2. Synthesis of the main findings

This section highlights and discusses the main research findings of addressing the core research objective of seed systems, adoption of improved crop varieties, and their impact on food security in central Ethiopia. Chapter-II addressed the fundamental research questions: How does the current seed system is operating? What are the gaps in the roles, responsibilities, and linkages of the seed actors? Based on this research question, the seed system characterizes organizational, institutional and individual operations associated with the development, multiplication, processing, storage, distribution, and marketing of seeds in the country. The system classifies as formal, informal, and intermediary (ATA, 2017). The findings revealed several constraints in the seed systems: a lack of a clear seed policy; inadequate seed marketing information and infrastructure; inefficient extension service; limited collaboration within the seed sector; private companies tend to concentrate on profitable crops; inadequate improved and basic seed supply. The study also identified that the Ethiopian seed policy has not been revised for a long time to guide its development and has negative consequences for plant genetic resources conservation, plant breeding research & development, and seed production and distribution system (Dawit *et al.*, 2018).

Gloria *et al.* (2017) indicated in their study the Ethiopian seed policy provisions have a much larger positive impact on the formal seed sector than on the informal sector. This study discovered a linkage gap between the seed system actors: a lack of coordination between the production, processing, and delivery of certified seeds of improved varieties; limited EGS of improved varieties for use in participatory trials; insufficient quantities of certified seeds and lack of EGS supply by the public seed enterprises; distribute varieties that are not recommended for the specific agro-ecology. The findings revealed that the linkages among actors were weak due to poor management capacity, an inappropriate organizational structure, unfavorable reward systems, ineffective planning, monitoring, and evaluation of the interaction process, different organizational cultures, expectations, and operating procedures, a lack of integration among actors, a poor marketing system, and ineffective seed multiplication schemes.

The research topics addressed in Chapter-III are what factors influence seed access and supply systems, and what feasible options exist for improving household food security. According to FAO (2020), it is possible to create changes that will improve the standard of living, improve food security, and promote the transformation toward a sustainable commercial agricultural sector. Dalle and Westengen's (2020) study shows how maintaining seed security is a central concern for households and drives a number of practices in the seed supply system. The finding shows that smallholder farmers largely rely on their own saved seed and from neighboring farmers. Girma and Amanuel (2017) explained increasing agricultural production is one of the measures taken to assure food security and livelihood enhancement in rural areas, but this improvement can only be effective and sustainable if subsistence farmers have access to affordable certified seeds through the seed supply system. The finding also identified that the depth and intensity of food insecurity are influenced by poor functioning of seed supply and marketing systems and other household socioeconomic factors. This result was confirmed by Sani and Kemaw (2019), Adebayo *et al.* (2021), and Jabo *et al.* (2016). The finding indicated that farmers could access seeds from different sources: own saved seed (46.2%), farmers-to-farmers seed exchange (19.4%), district bureau of agriculture (10.4%), unions (10.4%), cooperatives (7.7%), seed enterprises (3.3%), local market (1.3%), and research centers (1.3%). This result is in line with Bassa *et al.* (2018). Despite the fact that the formal seed sector accounts for a larger share of certified seed dissemination, the majority of farmers still used seed via informal seed systems, such as their own-saved seed and exchanges with neighbors. In general, the study reveals that the occurrence of household food insecurity, as measured by the HFIAS, is linked to three major domains of food insecurity (access). The result of the occurrence of the severity of household food insecurity and access-related conditions showed that about 90% of the households faced shortage of food, 72% were insufficient quality of food, and 20% insufficient food intake and physical effects. The findings also revealed that 19% of the households, were food secure, 32% were mildly food insecure, 41% were moderately food insecure, and 9% were severely food insecure. Smallholders can benefit from certified seed access and supply systems in a variety of ways, including increased food security and income, improved nutrition, and more resilience to climate pressures (FAO, 2018). The study found that almost the entire seed supply is based on the rain-fed seed production system, which is a major factor leading to the shortage of better seed supply in the study area.

Chapter-IV attempts to provide responses to the research questions. What factors affect the adoption of improved wheat, teff, and maize varieties? The probit and Logit models were used in the study to assess the factors influencing the adoption of improved crop varieties. The results of this study show that the adoption of improved crop varieties is statistically significant and positively associated with the variables (education level, land holding, farming experience, livestock holding (TLU), and source of income, access to credit, extension contacts, seed access, and distance to the market). The association between significant variables and the adoption of improved varieties implies that the food security status of smallholder seed producers. As a result, for effective interventions, emphasis must be paid to the characteristics that influence farmer adoption decisions. The lack of seeds combined with ineffective promotion schemes is the major factor, further contributing to lower agricultural productivity due to inefficiencies in the country's seed system. According to CSA (2020), nationally, about 16 million smallholder farmers are engaging into use of non-certified seeds and six million smallholder farmers are using certified seeds. Non-certified seeds covered 79.7% of the total cereal crop area, while certified seeds covered 20.3%. In terms of inputs, certified maize, wheat, and teff technologies were used in proportions of 45.8%, 41.7%, and 3.5% of the total cereal, respectively.

Chapter-V addresses the research question "To what extent does the adoption of improved crop varieties contribute to food availability, consumption, yield, and household food security?" The survey results showed that cereal and pulse grains are the major sources of food widely produced and used for home consumption. As a result, cereal and pulse grains, which are commonly used for home consumption are considered the main sources of dietary energy supply in the household, hence used to calculate the dietary energy supply of the study households. The result of the HFBM revealed that the mean daily calorie intake of the sampled households was 1533.8 kcal/daily/adult equivalent, which only meets 73% of the Minimum Recommended Allowance (MRA-2100 kcal). A probit regression model identified the explanatory variables that influence the adoption of improved varieties of cereal crops along with their likely effects on the farm households' adoption decision. The results found that the age of the household head, educational level, farm size, farming experience, farm income, access to credit, access to farm input, and frequency of extension contact were statistically significant. The finding revealed that the average treatment effect on the treated (ATT) results from estimation by different algorithms, the nearest neighbor matching (NNM), radius caliper matching (RM), and kernel bandwidth matching (KBM) methods. The adoption of certified seeds of improved varieties indicated positively and significantly affects HFBM at a 1% level of significance, the increase in food availability per day per adult equivalent ranges from 414 in the case of KBM to 442 Cal per day in the case of RM. The result revealed that using the NNM, RM, and KBM methods, the FCS of the certified seed adopters at the household level on average increase the frequency of eating diversified food per week by about 4.51, 3.15, and 5.14 kcal than non-adopters respectively. The results also show the adoption of improved crop varieties significantly affected the total grain yield obtained by the farm household at a 1% level of significance. The increase in yield obtained varies from 9.54 in the case of NNM to 13.25 quintals per hectare in the case of RM. According to the KBM, the causal effect of technology adoption is significant and equal to 9.87 quintal per hectare, which is the average crop production difference between adopters and non-adopters.

6.3. Conclusion

This study investigated the systemic restrictions of the seed system and comprehended the roles, responsibilities, and linkages of the seed actors; assesses the seed supply system and access in improving the food security of farm households'; analyze the factors that determined adopting certified seeds of enhanced crop varieties; and measuring the impact of adopting improved crop varieties on food security. Based on the research findings the following conclusions were reached.

Increasing the production and productivity of the crop sub-sector is one of the measures taken in Ethiopia to assure the food security of people and escape from the persisting poverty in the country. Access to and uses of seeds are critical factors for the ability of smallholder farmers to increase agricultural production and productivity, ensuring food security and improving livelihoods. However, in order for the seed to be a key factor in agricultural productivity, it must be channeled into a system. In Ethiopia, the formal seed supply is inefficient, the informal system is extremely important for the seed security of the nation because the majority of smallholder farmers are largely dependent on this system mainly through a farm-saved seed exchange. In addition to this for a sustainable national seed industry development, it is necessary that private seed sector participation flourishes. The formal seed sector meets around 10-20% of the country's actual demand, whereas certified seed covers less than 10% of the cultivated area. The informal seed system accounted for about 80-90% of the local seed used by smallholder farmers.

The major challenges of Ethiopia's seed system were insufficient seed marketing information and infrastructure, a lack of a clear seed strategy, inefficient extension service, limited collaboration within the seed sector, private companies tending to concentrate on profitable crops for their own pocket, a lack of awareness and knowledge gap about seed production, formulation and implementation of a clear seed strategy.

The adoption of improved varieties increased by raising farmers' knowledge that makes them more rational when using improved technology; making land more economical by encouraging farmers to cultivate their potential land; improving income by promoting market opportunities; providing agricultural inputs based on credit, promoting timely delivery of agricultural inputs, and providing frequent extension visits by increasing the number of agents.

The result indicated that farmers can access seeds from different sources. The identified sources of certified seeds were own-saved seed, farmers-to-farmers seed exchange, *woreda* bureau of agriculture, unions, cooperatives, seed enterprises, local market, and research centers. In the study area, seed systems are still largely informal and can supply up to 60%. The most common reasons farmers quoted for not using improved crop seeds in the study area were no supply of seed at the right time and the high price of certified seed.

The findings revealed that the use of improved teff, wheat, and maize varieties was identified as a major crop technology adoption in the study area and the adopters are significantly better than the non-adopters in terms of food security. Likewise, it was found that households with access to improved wheat, teff, and maize varieties would increase the status of food availability and consumption.

6.4. Implications

In this section, the implications of the results found in chapter 2, 3, 4 and 5 and several appropriate interventions are recommended to address systemic restrictions and associated variables of seed systems, as well as the adoption and impact of improved wheat, teff, and maize varieties, following the discussion of the main research findings. It has been acknowledged that the future approach to tackling the issues of changing crop production systems should focus on developing intervention solutions. The following suggestions are necessary to strengthen the seed system in general and address systemic constraints that influence seed system performance, the adoption, and impact of improved crop varieties.

- The current national seed policy focuses only on formal seed sectors, it should be reviewed and updated to support and encourage the development of both formal and informal seed sectors, including community-based and small-scale seed enterprises.

- Seed system strategy should be strengthened in terms of quality, time and place of supply, and fair pricing; fill the huge gap between seed demand and supply; establish clear and simple institutional and functional linkages between research and seed-producing organizations.

- A joint vision and development program should be developed between research institutes, public seed producers, private seed companies, cooperatives, and farmers to simplify the roles and responsibilities gap among seed actors, along with a regular discussion forum to highlight and mitigate any issues.

- Improve the operational performance of public seed enterprises, such as through improved assessments of farmer demand and revised seed production plans. Joint visions and regular multi-stakeholder discussions are needed between the public seed actors and farmers.

- Policymakers and agricultural development partners must focus more on delivering effective agricultural services to solve low adoption rate challenges and, as a consequence, enhance production and productivity, food self-sufficiency, and food security.

- A key barrier to adoption was a lack of certified seed, thus methods for delivering certified seed needed to be improved to meet the demands of the farmers.

6.5. Suggestion for future research

The current study has examined the seed systems, adoption, and impact of improved crop varieties on household food security in central Ethiopia. The function of the seed systems and ensuring food security are the belongings of the seed supply system, access to certified seed, and adoption of certified seeds of improved crop varieties. The finding of the research may not fully represent farmers in a different area and the study has some limitations. Due to resource constraints and a lack of financing, the sample size was limited. Limitations of this study is that it relied on a sample size (research areas as well as investigated farmers) was quite small, which may restrict the representativeness of the findings and make generalization or extrapolation to a wider population problematic. Therefore, the following recommendations are suggested for future research.

- Investigate the association between seed systems, adoption, and food security employing a larger sample size that covers a wider geographical area. This is vital to address the gap and determine the factors that affect the adoption of improved crop varieties.

- Given the possibly high opportunity cost of the seed system, further research is required to compare the seed supply and seed access to food security of farm households. This would help to identify complementary strategies that would improve the contribution of seed systems to food security.

- More research should be conduct on the links between formal and farmer-managed systems, as well as the contributions of informal community-based systems to seed systems; what mechanisms and opportunities exist to link informal seed systems to formal channels. This is important for perception of people working in the informal sector have about developing or maintaining those links.

- Evaluate the long term impact of the availability and accessibility of high-quality seeds on income and food security and assessing the impact of certified seeds of improved varieties. This provides a more precise and technology-specific information for policy makers to justify policy recommendations.

References

Abadi Teklemariam, Muluken Gezahegn, & Abadi Teklehaimanot (2017). Analysis of Factors Affecting Adoption of Exotic Chicken Breed Production in North Western Zone of Tigray, Ethiopia. *International Journal of Economics, Commerce and Management*, *4*(11), 127-137.

Abdoulaye, T., Sanogo, D., Langyintuo, A., Bamire, S. A., & Olanrewaju, A. (2009). Assessing the Constraints Affecting Production and Deployment of Maize Seed in DTMA Countries of West Africa: *International Institute of Tropical Agriculture*, Ibadan, Nigeria.

Abebe Atilaw (2010). A Baseline Survey on the Ethiopian Seed Sector. Submitted to the African Seed Trade Association. Addis Ababa, Ethiopia.

Abebe Atilaw, Dawit Alemu, Zewdie Bishaw, Tekeste Kifle, & Karta Kaske (2017). Early Generation Seed Production and Supply in Ethiopia: Status, Challenges, and Opportunities. *Ethiopian Journal of Agricultural Science*, *27*(1), 99-119.

Addis Endalew (2015). Implementation of Government Development Strategies on Afar Pastoralists in Ethiopia: Challenges and Opportunities. *The intricate road to development*, *106*.

Adebayo, I.O., Samuel, O., Kabir, K.S., Abiodun O., Kehinde, O., &and Adeyemi O.A. (2021). Socio-economic Drivers of Food Security among Rural Households in Nigeria: Evidence from Smallholder Maize Farmers. *Social Indicators Research*, 155, 583–599. https://doi.org/10.1007.

Adugna Enyew (2017). Access to improved seeds and its effect on food security of poor farmers. *International Journal of Development Research*, 7(7), 13655-13663

Ahmed Musa & Hiwot Mekonnen (2017). The impact of agricultural cooperatives membership on the wellbeing of smallholder farmers: empirical evidence from eastern Ethiopia. *Agricultural and Food Economics*, *5*(1), 1-20.

Ahsanuzzaman, A. (2014). Three Essays on Adoption and Impact of Agricultural Technology in Bangladesh. *Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics, Agriculture and Life Sciences.*

Almekinders, C., Thiele, G., & Daniel, D. L. (2007). Can Cultivars from Participatory Plant Breeding Improve Seed Provision to Small-Scale Farmers? *Euphytica*, 153:363–72. Doi: 10.1007/s10681-006-9201-9.

Almekinders, C., & Louwaars, N. (2007). The Importance of the Farmer's Seed Systems in A Functional National Seed System.

Ariga, J., Mabaya, E., Waithaka, M., & Wanzala-Mlobela, M. (2019). Can Improved Agricultural Technologies Spur A Green Revolution in Africa? A Multicounty Analysis of Seed and Fertilizer Delivery Systems. *Agric. Econ., 50*, 63–74.

Asenso-Okyere, K., Mekonnen Daniel, & Zerfu Elias (2013). Determinants of Food Security in Selected Agro-pastoral Communities of Somali and Oromia Regions, Ethiopia. *Journal of Food Science and Engineering, 3*, 453-471.

Asfaw Solomon, Bekele Shiferaw, Simtowe, F., & Lipper, L. (2012). Impact of Modern Agricultural Technologies on Smallholder Welfare: Evidence from Tanzania and Ethiopia. *Food Policy, 37,* 283-295.

ATA (2015). Seed system development strategy: Vision, systemic challenges, and prioritized interventions. Ethiopian Agricultural Transformation Agency (ATA). Working strategy document, Addis Ababa, Ethiopia.

ATA (2017). Seed System Development Strategy: Vision, Systemic Challenges, and Prioritized Interventions. Agricultural Transformation Agency. *Working strategy document*, Addis Ababa, Ethiopia.

Austin, P. C. (2014). A comparison of 12 algorithms for matching the propensity score. *Statistics in medicine*, *33*(6), 1057-1069.

Ayana Amsalu, Borman, G., Subedi, A., Fetien Abay, Hussien Mohammed, Kedir Nefo, Nigussie Dechassa & Tadesse Dessalegn (2013). Integrated Seed Sector Development in Ethiopia: Local Seed Business Development as an Entrepreneurial Model for Community-Based Seed Production in Ethiopia. In: Community Seed Production, Workshop Proceedings, Ojiewo, C.O., Kugbei, S., Bishaw Zewdie, & Rubyogo, J.C., Eds.; *FAO and ICRISAT: Addis Ababa, Ethiopia*, 88–97.

Bassa Zekarias, Erchafo Tessema, Tyohannis Seifu, & Bashe Alemayehu (2018). Status of Improved Crop Seed Utilization System across Small-Scale Farmers in Southern Ethiopia: The Case of Sodo Zuirya in Wolaiyta, Mareka in Dawuro, and Kacha Birra in Kembata Tembaro Zones. *Open Access Journal of Science*, *2*(6), 331–337. https://doi. org/10.15406/oajs.2018.02.00107

Bayissa Debella (2015). Factors Hindering the Linkage of Farmers with Researchers in Agricultural Research in Ethiopia: From Agricultural Innovation System Perspectives. *American Journal of Human Ecology*, *4*(3), 33-46.

Beneberu Assefa & Biazin Alemu (2020). Small-Scale Irrigation and Its Effect on Food Security of Rural Households in North-West Ethiopia: A Comparative Analysis. *Ethiopian Journal of Science and Technology*, *13*(1), 31-51.

Berihun Kassa, Bihon Kassa, & Kibrom Aregawi (2014). Adoption and Impact of Agricultural Technologies on Farm Income: Evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics*, 2(4).

Beyene Fekadu & Mequanent Muche (2010). Determinants of Food Security among Rural Households of Central Ethiopia : An Empirical Analysis. *Journal of International Agriculture, 49*(4), 299–318.

Birara Endalew, Muche Mequanent, & Samuel Tadesse (2015). Assessment of food security situation in Ethiopia: a review. *Asian Journal of Agricultural Research,* 9(2), 55-68.

Bishaw Zewdie, Struik, P.C., & van Gastel, A.J.G. (2010). Wheat Seed System in Ethiopia: Farmers Varietal Perception, Seed Sources, and Seed Management. *J. New Seeds, 11*, 281–327.

Bjornlund, V., Bjornlund, H., & van Rooyen, A. (2022). Why Food Insecurity Persists in Sub-Saharan Africa: A Review of Existing Evidence. *Food Security*, *14*(4), 845-864.

Bozsik, N., Cubillos, T., Stalbek, B., Vasa, L., & Magda, R. (2022). Food security management in developing countries: Influence of economic factors on their food availability and access. *Journal of PloS One 17*(7): e0271696. https://doi.org/10.1371/ l. 0271696

Brian, G. V., Gillen, D. L., & Stern, H. S. (2020). Optimally balanced Gaussian process propensity scores for estimating treatment effects. *Journal of the Royal Statistical Society. Series A, (Statistics in Society), 183*(1), 355.

Bryman, A. (2012). Social Research Methods. 4th ed. Oxford: *Oxford University Press*

Challa Merga (2013). Determining Factors and Impacts of Modern Agricultural Technology Adoption in West Wollega, *Munich, GRIN Publishing GmbH*, http://www.grin.com/en/e-book/280336/

Chalachew Shibabaw (2018). The Effects of Crop Market Participation in Improving Food Security among Smallholder Crop Producer Farmers: The Case of Central Ethiopia, Ada'a Woreda. *Journal of Development and Agricultural Economics*, *10*(9), 298-316. DOI: 10.5897/JDAE2018.0953

Chandio, A., & Jiang, Y. (2018). Factors Influencing the Adoption of Improved Wheat Varieties by Rural Households in Sindh, Pakistan. *AIMS Agriculture and Food*, *3*(3), *216-228.* https://doi.org/10.3934/agrfood.2018.3.216

Chandio, A.A., Jiang, Y., & Joyo, M.A. (2016). Impact of the area under cultivation, water availability, credit disbursement, and fertilizer off-take on wheat production in Pakistan. *J. Appl. Environ. Biol. Sci. 6*: 10–18.

Chandio, A.A. & Jiang, Y. (2018). Determinants of adoption of improved rice varieties in northern Sindh, Pakistan. *Rice Sci. 25*: 103–110.

Clay, E. (2002). Food Security: Concepts and Measurement. Paper for FAO Expert Consultation on Trade and Food Security: Conceptualizing the Linkages, Rome, 1-7.

Coates, J., Swindale, A. & Bilinsky, P. (2007). Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator guide. Washington DC. *Food and Nutrition Technical Assistance Project, Academy for Educational Development.*

Cohen, L., Manion, L., & Morrison, K. (2007). Research Methods in Education (6th ed.). New York, NY: Routledge.

Crotty, M. (2003). The Foundation of Social Research: Meaning and Perspective in the Research Process. Thousand Oaks, CA: Sage.

Coomes, O., McGuire, S., Garine, E., Caillon, S., McKey, D., & Demeulenaere, E. (2015). Do Farmer Seed Networks Make A Limited Contribution to Agriculture? Four Common Fallacies. *Food Policy, 56*, 41–50.

Craycroft, J. A., Huang, J., & Kong, M. (2020). Propensity score specification for optimal estimation of average treatment effect with binary response. *Statistical Methods in Medical Research, 29*(12), 3623-3640.

Creswell, J.W. (2014). Research Design: Qualitative, Quantitative, and Mixed Methods Approach, 3rd edition. Thousand Oaks: Sage.

CSA (2017). Federal Democratic Republic of Ethiopia, Central Statistical Agency. Population Projection of Ethiopia for All Regions at the Woreda Level from 2014- 2017. Addis Ababa.

CSA (2020). Annual Agricultural Sample Survey Area and Production of Major Crops. The Federal Democratic Republic of Ethiopia, Central Statistical Agency, Addis Ababa, Ethiopia.

Dalle, S. P., & Westengen, O. T. (2020). Seed security in theory and practice: a comparative study of seed security frameworks and their use.

Dawit Alemu (2010). The Political Economy of Ethiopian Cereal Seed System: State Control, Market Liberalization and Decentralization. *Future Agriculture,* Addis Ababa, Ethiopia.

Dawit Alemu (2011). Farmer-based Seed Multiplication in the Ethiopian System: Approaches, Priorities, and Performance. *Future Agricultures Working Paper 036*.

Dawit Alemu, Wilfred, M., Mandefro Negussie, & David, S.J. (2018). The Maize Seed System in Ethiopia: Challenges and Opportunities in Drought-Prone Areas. *African Journal of Agricultural Research, 3*(4), 305-314. http://www.academicjournals.org/AJAR

Dawit Alemu, Shahidur, R., & Rob, T. (2019). Seed System Potential in Ethiopia: Constraints and Opportunities for Enhancing the Seed Sector. *International Food Policy Research Institute*, 1-59. https://doi.org/10.21955/gatesopenres.1115840.1

DBoA (2021). Performance report of 2020/21 Cropping Season. District Administration Bureau of Agriculture, East and North Shewa, Ethiopia.

De Boef, W., Dempewolf, H., Byakweli, J., & Engels, J. (2010). Integrating genetic resource conservation and sustainable development into strategies to increase the robustness of seed systems. *Journal of Sustainable Agriculture*, *34*, 504–531. DOI: 10.1080/10440046.2010.484689

De Boef, W., & Edeme, J. (2013). Integrated Seed Sector Development in Africa: A Basis for Seed Policy and Law. *Journal of Crop Improvement, 27*, 186-214.

Degefa Tolossa (1996). Belg Crop Production as a Strategy of Households' Food Security: A Comparative Study of Belg Grower and Non Belg Grower Farmers in Munessa woreda, Arsi Region. M.A Thesis. Addis Ababa University, Addis Ababa.

Degefa Tolossa (2002). Household Seasonal Food Insecurity in Oromia Zone, Ethiopia: Causes. *Social Science Research Report Series, No.26*: OSSREA, Ethiopia, Addis Ababa

Degefa Tolossa (2002). Household Seasonal Food Insecurity in Oromia Zone, Ethiopia: Causes. *Social Science Research Report Series,* No.26: OSSREA, Ethiopia, Addis Ababa

Degefu Kebede, Mengistu Ketema, Nigussie Dechassa & Feyisa Hundessa (2017). Determinants of Adoption of Wheat Production Technology Packages by Smallholder Farmers: Evidence from Eastern Ethiopia. *Turkish Journal of Agriculture-Food Science and Technology, 5*(3), 267-274.

Deitchler, M., Ballard, T., Swindale, A., & Coates, J. (2011). Introducing a Simple Measure of Household Hunger for Cross-Cultural Use.

Dejen Bekis (2021). Status of Seed System in Ethiopia. *Journal of Advances Crop Science and Technology. 9*(4). ISSN: 2329-6879.

Delle, Site, P., Kilani, K., Gatta, V., Marcucci, E., & de Palma, A. (2019). Estimation of consistent Logit and Probit models using best, worst, and best–worst choices. *Transportation Research Part B: Methodological*, *128*, 87-106.

Demeku Mesfin, Addisu Damtew & Maru Ahmed (2015). The Status of Food Availability in the Face of Climate Change and Variability in Choke Mountain Watersheds, Central Ethiopia. *Journal of Development and Agricultural Economics*, *7*(10), 358-372.

Devereux, S. (2006). Distinguishing Between Chronic and Transitory Food Insecurity in Emergency Needs Assessments, *Institute of Development Studies,* Rome Italy

Diiro, G. (2013). Impact of Off-farm Income on Technology Adoption Intensity and Productivity: Evidence from Rural Maize Farmers in Uganda. *International Food Policy Research Institute,* Working Paper

Djido, A., & Sanders, J. H. (2013). A Matching Approach to Analyze the Impact of New Agricultural Technologies: Productivity and Technical Efficiency in Niger.

EHNRI (2000). Food Composition Table for Use in Ethiopia, Part III. A Research Project Sponsored By the Government of Ethiopia through the Former Ethiopian Nutrition Institute (ENI). pp34.

Ertiro Birhanu, Girum Azmach, Tolera Keno, Temesgen Chibsa, Beyene Abebe, Girma Demissie, Dagne Wegary, Legese Wolde, Adefris Teklewold & Mosisa Worku (2019). Fast-Tracking the Development and Dissemination of a Drought-Tolerant Maize Variety in Ethiopia in Response to the Risks of Climate Change. *The Climate-Smart Agriculture Papers: Investigating the Business of a Productive, Resilient and Low Emission Future*, pp 79-86.

Etwire, P.M., Atokple, I.D., Buah, S.S., Abdulai, A.L., Karikari, A.S., & Asungre, P. (2013). Analysis of the Seed System in Ghana. *International Journal of Advance Agricultural Research*, *1*(1), 7-13.

Fadda, C., van Etten, J. (2019). Generating Farm-Validated Variety Recommendations for Climate Adaptation. The Climate-Smart Agriculture Papers: Investigating the Business of a Productive, Resilient and Low Emission Future, Rosen stock; Nowak, T.S., Girvetz, E.A., Eds.; *Springer International* Publishing: Cham, Switzerland, pp. 127–138.

FANTA (2007). "Measuring Household Food Insecurity Workshop, April 15-16, 2004 Workshop Report." Washington, D.C: Food and Nutrition Technical Assistance Project, FHI 360, 2007

FAO (2002). Food Supply Situation and Crop Prospects in Sub-Saharan Africa. Rome: Global Information and Early Warning System on Food and Agriculture. *Africa Report No. 3.* Pp 68.

FAO (2004). FAO statistics. Food and Agriculture Organization of the United Nations, Statistic Division, Socio-Economic Statistics and Analysis Service.

FAO (2005). Assessment of the World Food Security Situation. Committee on World Food Security, Thirty-First Session, Food and Agricultural Organization, Rome, Italy

FAO (2016). Seed Security Assessment: A Practitioner's Guide. Rome, Italy.

FAO (2018). The State of Food Security and Nutrition in the World 2018. Building Climate Resilience for Food Security and Nutrition; *Food and Agriculture Organization*, Rome, Italy. 1-202.

FAO (2020). National Community Seed Bank Platform for Strengthening Informal Seed System in Ethiopia. Benefit Sharing Fund Project - Fourth Cycle. Food and Agriculture Organization of the United Nations.

FAO (2020). The State of Food Security and Nutrition in the World. Safeguarding Against Economic Slowdowns and Downturns, Rome. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/CA5162EN.

FAO (2021). The State of Food Security and Nutrition in the World: Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for All. Rome: Food and Agriculture Organization of the United Nations. Doi: 10.4060/cb4474en.

Feleke Shiferaw, Kilmer, R.L., & Gladwin, C.H. (2003). Determinants of Food Security in Southern Ethiopia at the Household Level. *Agricultural Economics*, *33*(3), 351-363.

Fikre Asnake, Wakjira Adugna, Mekbib Firew & Gebeyehu Setegn (2012). Practices and Developments in the Informal Seed System of Ethiopia. In The Defining Moment in Ethiopian Seed System; Teklewold Adefris, Fikre Asnake, Alemu Dawit, Desalegn Lemma & Kirub Abebe Eds.; *Ethiopian Institute of Agricultural Research*: Addis Ababa, Ethiopia, pp. 237–252.

Fischer, R., & Edmeades, G. (2010). Breeding and Cereal Yield Progress. *Journal of Crop Science Society of America*, *50*, 85-98. DOI: 10.2135. | 677 S. Segoe Rd., Madison, WI 53711 USA.

Fredenburg, P. (2015). Strengthening national seed systems for household food security in developing countries. *Beirut, Lebanon: International Center for Agricultural Research in the Dry Areas (ICARDA)*.

Furgasa Derara & Degefa Tolossa (2016). Household food security situation in Central Oromia, Ethiopia: a case study from Becho Wereda in Southwest Shewa Zone. *Global Journal of Human-Social Science Research*, *16*(2).

Gebissa Yigezu Wendimu| (2021). The challenges and prospects of Ethiopian agriculture. *Cogent Food & Agriculture, 7*(1), 1923619, DOI: 10.1080/23311932.2021.1923619

Getachew Tadesse, Mengistu Metema, Degye Goshu, & Degnet Abebaw (2020). Technical Efficiency of Wheat Producers in North Shewa Zone of Amhara Region, Central Ethiopia. *Sustainable Agriculture Research, 9*, 77-86.

GFSI (2022). Performance of Countries Based on their Food Security Score. A Report from the Economist Intelligence Unit, Global Food Security Index. http://foodsecurityindex.eiu.com/

GHI (2022). Country Profiles. Economist Impact Global Food Security. Global Hunger Index. https://impact.economist.com/sustainability/project/food-security-index/.

Ghimire, R., Huang, W. C., & Shrestha, R. B. (2015). Factors affecting the adoption of improved rice varieties among rural farm households in central Nepal. *Rice Science*, *22*(1), 35–43. https://doi.org/10.1016/j.rsci.2015.05. 006.

Girma Gezimu (2012). Determinants of Food Insecurity Among Households in Addis Ababa City, Ethiopia, Aksum University, Shire Campus Investment potentials of Ethiopia, Addis Ababa, *10*(2), 159-173.

Girma Abebe & Amanuel Alemu (2017). Role of Certified seeds towards Improving Livelihood and Food Security at Ethiopia: *International Journal of Research* - Grant, *5*(2), 338-356. https://doi.org/10.5281/zenodo.376076.

Gishu Nigatu, Yohannes Mare & Agidew Abebe (2018). Determinants of Adoption of Improved (BH-140) Maize Variety and Its Management Practices in the Case Of South Ari Woreda, South Omo Zone, SNNP, Ethiopia. *International Journal of Research Studies in Biosciences*, *6*(9), *35-43*. https://doi.org/10.20431/2349-0365.0609004

Giusti, V. (2004). On-Farm Seed Production, a Practical and Participatory Proposal for Seed Production. FAO, Rome, Italy

Gloria, A., Travis, W., Altinay, K., & Isabel, L. (2017). Implications of Seed Policies for On-Farm Agro Biodiversity in Ethiopia and Uganda. Journal of Sustainable Agricultural Research. 6(4): ISSN 1927-050X E-ISSN 1927-0518.

Govind, K.C., Karki, T.B., Shrestha, J., & Achhami, B.B. (2015). Status and Prospects of Maize Research in Nepal. *Journal of maize research and development*, *1*(1), 1-9.

Greene W.H. (2012). Econometric Analysis (Seventh Ed.). Boston: Pearson Education. pp. 803–806. ISBN 978-0-273-75356-8.

Gujarati, D.N. (1995). Basic econometrics. 3rd edition, McGraw Hill, Inc., New York.

Hailu Shiferaw, Getachew Tesfaye, Habtamu Sewnet & Leulseged Tamene (2022). Crop Yield Estimation of Teff (Eragrostis tef) Using Geospatial Technology and Machine Learning Algorithm in the Central Highlands of Ethiopia. *Sustainable Agriculture Research, 11*(1), *34-44*. https://doi.org/10.5539/sar.v11n1p34

Hailu Mekonnen (2012). Causes of Household Food Insecurity in Rural Bosset Woreda: Causes, Extent and Coping Mechanisms to Food Insecurity. Germany: *Lap Lambert Academic Publishing.*

Hailu Berihun, Bihon Kassa & Kibrom Aregawi (2014). Adoption and Impact of Agricultural Technologies on Farm Income: Evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics, 2*(4), 91–106.

Hagos Afework & Zemedu Lemma (2015). Determinants of Improved Rice Varieties Adoption in Fogera District of Ethiopia. *Science, Technology and Arts Research Journal*, *4*(1), 221–228. https://doi.org/10.4314/star.v4i1.35

Hall, B.H., & Khan, B. (2003). Adoption of New Technology: National Bureau of Economic Research.

Heinz, P., Wendel-Garcia, P. D., & Held, U. (2022). Impact of the matching algorithm on the treatment effect estimate: A neutral comparison study. *Biometrical Journal*.

Hirpa Adane, Meuwissen, M.P., Tesfaye Agajie, Lommen, W.J., Oude Lansink, A.G., Tsegaye Admasu, & Struik, P.C. (2010). Analysis of Seed Potato Systems in Ethiopia. *American Journal of Potato Research, 87*, 537–52. Doi: 10.1007/s12230-010-9164-1.

Hiwot Hailu & Degefa Tolossa. (2022). Impacts of Adopting Improved Wheat Varieties on Household Food Security in Girar Jarso District, Ethiopia. *Review of Agricultural and Applied Economics (RAAE)*, *25*(1340-2022-642), 73-86.

Hussein Bekele (2006). Major Causes of Household Food Insecurity in Wuchale-Jidda Woreda, Oromia National Regional State. MA Thesis. Addis Ababa University

Hussein, W., & Janekarnkij, P. (2013). Determinants of Rural Household Food Security in Jigjiga District of Ethiopia. *Kasetsart J. (Soc. Sci.), 34*, 171-180.

IPMS (2007). Improving productivity and market success (IPMS), Ada'a Woreda IPMS Atlas. www.ipms-ethiopia.org

Jabo, M.S., Ismail, M., Shamsuddin, M.N., Abdullah, A.M., & Maikasuwa, A.M. (2016). Examining the Incidence, Depth, and Severity of Food Insecurity among rural Households in Nigeria. *Journal of Economics and Sustainable Development*, (5)26, 32-41.

Jaleta Moti, Menale Kassie, Marenya, P., Chilot Yirga, & Erenstein, O. (2018). Impact of Improved Maize Adoption on Household Food Security of Maize Producing Smallholder Farmers in Ethiopia. *Food Security*, *10*(1), 81-93.

Joshi, A.K., & Braun, H.J. (2022). Seed Systems to Support Rapid Adoption of Improved Varieties in Wheat. In *Wheat Improvement: Food Security in a Changing Climate.* pp 237-256. Cham: Springer International Publishing.

John, G.H., Anthony, J.C., Birte, B., Thomas, G.C., & Phil, R. (2016). Climate Change: Seed Production and Options for Adaptation. *Journal of Agriculture*, 6, 33. https://doi: 10.3390.

Kalsa Karta & Dey, B. (2022). Forage Seed System Performance of Ethiopia: An Overview Based on Key Indicators.

Kassa Tarekegn & Merkine Mogiso (2020). Assessment of improved crop seed utilization status in selected districts of Southwestern Ethiopia. *Cogent Food & Agriculture*, 6(1). https://doi.org/ 10.1080/23311932.2020.1816252

Kansiime, M.K., & Mastenbroek, A. (2016). Enhancing Resilience of Farmer Seed System to Climate-Induced Stresses: Insights from A Case Study In West Nile Region, Uganda. *Journal of rural studies*, *47*, 220-230.

Kebede Degefu, Ketema Mengistu, & Nigussie Dechassa (2016). Determinants of adoption of wheat production technology package by smallholder farmers: Evidence from eastern Ethiopia. *Turkish J. Agric. Food Sci. Technol. 5*: 267–274.

Kebede Wuletaw & Daniel Tadesse (2015). Determinants affecting adoption of malt-barley technology: evidence from North Gondar Ethiopia. *J. Food Sec.* https://doi.org/10.12691/jfs-3-3-2.

Khonje, M., Manda, J., Alene Arega, & Menale Kassie (2015). Analysis of adoption and impacts of improved maize varieties in eastern Zambia. *World Development*, *66*, 695-706.

Kinuthia, B.K., & Mabaya, E. (2017). The Impact of Agricultural Technology Adoption on Farmer Welfare in Uganda and Tanzania.

Kothari, C.R. (2004). Quantitative Techniques, New Delhi, *Vikas Publishing House Pvt. Ltd.*, p.64, 1978.

Kumulachew Alemu (2015). Seed Production and Dissemination Systems Analyses: The Case of Ethiopia. *Seed*, *35*.

Kutoya Kusse, & Kebede Kassu (2019). Access, Supply System and Utilization of Improved Seed Varieties in Debub Omo Zone, SNNPR, Ethiopia. *Journal of Agricultural Science Food Research*. 10, 258.

Leake Gebresilassie & Adam Bekele (2015). Factors determining the allocation of land for improved wheat variety by smallholder farmers of northern Ethiopia. *Journal of Development and Agricultural Economics, 7*: 105–112.

Legese Getachew, Jaleta Moti, Langyintuo, A., Mwangi, W., & La Rovere, R. (2010). Characterization of Maize Producing Households in Adami Tulu-Jido Kombolcha and Adama Districts in Ethiopia

Loch, D.S., & Boyce, K.G. (2003). Balancing Public and Private Sector Roles in an Effective Seed Supply System. *Field Crop Research, 84*, 105-122.

Loevinsohn, M., Sumberg, J., Diagne, A. (2013). Under What Circumstances and Conditions Does Adoption of Technology Result in Increased Agricultural Productivity? Protocol. London: EPPI Centre, Social Science Research Unit, Institute of Education, University of London.

Lohse, S. (2017). Pragmatism, Ontology, and Philosophy of the Social Sciences in Practice. *Philosophy of the Social Sciences, 47,* 3-27. https://doi.org/10.1177/0048393116654869

Louwaars, N., De Boef, W., & Edeme, J. (2013). Intermediate Seed Sector Development in Africa: A Basis for Seed Policy and Law. *Journal of Crop Improvement, 27*, 186–214.

Louwaars, N., & De Jonge, B. (2021). Regulating Seeds. A Challenging Task. *Journal of Agronomy*, 11, 2324. https://doi.org/10.3390/

Louwaars, N.P. (2022). Policies and strategies for seed system development. In Proceedings of the Conclusions of the International Workshop on Integrated Seed Systems for Low-Input Agriculture, RILET, Malang, Indonesia, 24–27.

Luchia Tekle & Hadush Hagos (2018). Determinants of the intensity of bread wheat packages adoption in Tigray, Northern Ethiopia. *Turkish Journal of Agriculture-Food Science and Technology, 6*(9), 1101-1107. https://doi.org/10.24925/

Manda, J., Gardebroek, C., Kuntashula, E., & Alene Arega (2018). Impact of improved maize varieties on food security in Eastern Zambia: A doubly robust analysis. *Review of Development Economics, 22*(4), 1709-1728.

Marja, H.T., Zewdie Bishaw, Abdurrahman Beshir & Walter, S. (2008). Farmers, Seeds and Varieties. Wageningen International, the Netherlands.

Maxcy, S.J. (2003). Pragmatic Threads in Mixed Methods Research in the Social Sciences: The Search for Multiple Modes of Inquiry and the End of the Philosophy of Formalism. Edited by Abbas Tashakkori & Charles Teddlie. *Thousand Oaks: Sage*, 51–89.

Maxwell, S., & Smith, M. (1992). Household Food Security: A Conceptual Review. Maxwell, S. & Franken Berger T.R. (eds.) Household Food Security: Concepts, indicators, measurements. A technical review, 1-72. Rome: UNICEF and IFAD.

Mayer, I. (2015). Qualitative Research with a Focus on Qualitative Data Analysis. *International Journal of Sales, Retailing & Marketing*, *4*(9), 53-67.

McGuire, S. (2005). Getting Genes: Rethinking Seed System Analysis and Reform for Sorghum in Ethiopia. *Ph.D. Thesis, Wageningen University,* Wageningen, the Netherlands.

McGuire, S.J. & Sperling, L. (2011). The Links between Food Security and Seed Security: Facts and Fiction That Guide Response. *Development in Practice 21*, 493-508.

McGuire, S., & Sperling, L. (2016). Seed Systems Smallholder Farmers Use. *Food Security*, 8, 179–195. https://doi.org/10.1007/s12571-015-0528-8

Mekonnen Tigist (2017). Productivity and Household Welfare Impact of Technology Adoption: Micro-Level Evidence from Rural Ethiopia. *UNU-MERIT Working Paper Series*, *7*.

Menale Kassie, Haile Mariam Teklewold, Moti Jaleta, Paswel, M., & Olaf, E. (2015). Understanding the Adoption of a Portfolio of Sustainable Intensification Practices in Eastern and Southern Africa. *Land use policy*, *42*, 400-411.

Meskerem Abi & Degefa Tolossa (2015). Household Food Security Status and Its Determinants in Girar Jarso Woreda, North Shewa Zone of Oromia Region, Ethiopia. *Journal of Sustainable Development in Africa*, *17(*7). *ISSN: 1520-5509 Clarion University of Pennsylvania.*

Mishra, K., Sam, G.A., Miranda, M., & Diiro, M.G. (2015). Gender and Dynamics of Technology Adoption: Evidence from Uganda. Selected Paper Prepared For Presentation *At the Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting.* San Francisco.

Mitchell, A. (2018). A Review of the Mixed Methods, Pragmatism and Abduction Techniques. *The Electronic Journal of Business Research Methods, 16,* 103-116. http://www.ejbrm.com/volume16/issue3/p103

MoA (2021). Crop Variety Register. Ministry of Agriculture, Plant Variety Release, Protection, and Seed Quality Control Directorate. Addis Ababa, Ethiopia. Issue No. 24.

Mohamed Abduselam (2017). Food Security Situation in Ethiopia: A Review Study. *International journal of health economics and policy, 2(*3), 86-96.

Morgan, D.L. (2007). Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research, 1*(1), 48-76.

Moroda Getachew, Degefa Tolossa & Negussie Sime (2018). Food insecurity of rural households in Boset district of Ethiopia: a suite of indicators analysis. *Journal of Agriculture & Food Security*, 7, 65. https://doi.org/10.1186/s40066-018-0217

Muhhuku, F. (2002). Seed Industry Development and Seed Legislation in Uganda. *Journal of new seeds*, *4*(1-2), 165-176.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and sustainable development*, *6*(5).

Neesham, C. (2018). Philosophical foundations of qualitative organizational research. The Routledge companion to qualitative research in organization studies.

Obayelu, A.E., & Ajayi, D.O. (2018). Economic Impact and Determinants of Adoption of Improved Maize Production Technologies. *Journal of Agricultural Sciences (Belgrade)*, *63*(2), 217-228.

OCHA (2023). Ethiopian humanitarian response plan. Office for the Coordination of Humanitarian Affairs. Situation report, February 2023. https://

Ojiewo, C., Keatinge, D. J., Hughes, J., Tenkouano, A., Nair, R., Varshney, R., & Silim, S. (2015). The role of vegetables and legumes in assuring food, nutrition, and income security for vulnerable groups in Sub-Saharan Africa. *World Medical & Health Policy*, *7*(3), 187-210.

Oluwole, O.B., & Olagunju-Yusuf, O.F. (2022). Food and Nutrition Insecurity in Africa: The Primary Drivers and Sustainable Strategies to Improve the Current Status. In *Food Security and Safety, 2: African Perspectives*, 265-282. Cham: Springer International Publishing.

Ormston, R., Spencer, L., Barnard, M., & Snape, D. (2014). The Foundations of Qualitative Research. In Ritchie, J., Lewis, J., Nicholls, C., & Ormston, R. (Eds.), Qualitative Research Practice: *A Guide for Social Science Students and Researchers*, 1-25. Los Angeles: Sage.

Otieno, G., Lacasse, H., Fadda, C., Reynolds, T.W., & Recha, J.W. (2018). Social Seed Networks for Climate Change Adaptation in Western Kenya Results from a Study to Better Understand Farmers' Primary Sources of Seed Information in the Nyando Climate-Smart Villages; CCAFS Info note; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS): Wageningen, The Netherlands. 1–4.

Poku, A. G., Birner, R., & Gupta, S. (2018). Why do maize farmers in Ghana have a limited choice of improved seed varieties? An assessment of the governance challenges in seed supply. *Food security*, *10*(1), 27-46.

Richards, K. (2003). Qualitative Inquiry in TESOL. Basingstoke: Palgrave Macmillan.

Rogers, E.M. (2003). Diffusion of Innovations. *Free Press. New York*, 551.

Sani Seid, & Kemaw Biruk (2019). Analysis of households' food insecurity and its coping mechanisms in Western Ethiopia. *Journal of Agricultural and Food Economics.* 7(5), 1-20. https://doi.org/10.1186

Scoones, I., & Thompson, J. (2011). The Politics of Seed in Africa's Green Revolution: Alternative Narratives and Competing Pathways. *IDS Bull*, *42*, 1–23.

Sen, A. (1981). Poverty and Famine: An Essay on Entitlement and Deprivation. Oxford: Claredon Press.

Shiferaw Bekele, Menale Kassie, Moti Jaleta, Chilot Yirga (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*.

Shilomboleni, H. (2017). A sustainability assessment framework for the African green revolution and food sovereignty models in southern Africa. *Cogent Food & Agriculture, 3*(1), 13281. https://doi.org/10.1080/ 23311932.2017.1328150

Shimelis Altaye, Frans, J.H., Verhees, M., Hans, C., & Trijp, M. (2018). Customer Evaluation of Supply Systems: The Case of Ethiopian Seed Supply Systems. *Journal of African Business*, *19*(4), 550–570. https:// doi.org/10.1080/15228916.2018.1480247

Sisay Dawit Tsegaye, Verhees, F.J., & Van Trijp, H.C. (2017). Seed Producer Cooperatives in the Ethiopian Seed Sector and Their Role in Seed Supply Improvement: A review. *Journal of crop improvement*, *31*(3), 323-355.

Sisay Debebe (2016). Agricultural Technology Adoption, Crop Diversification and Efficiency of Maize-Dominated Smallholder Farming System in Jimma Zone, Southwestern Ethiopia. *(Electronic Dissertation). Haramaya University*, Haramaya, Ethiopia

Snape, D., & Spencer, L. (2003). The Foundations of Qualitative Research. In Richie, J., & Lewis, J. (Eds.), Qualitative Research Practice. pp 1-23. Los Angeles: Sage.

Solomon Yokamo (2020) Adoption of Improved Agricultural Technologies in Developing Countries: Literature Review. *International Journal of the Science of Food and Agriculture*, *4*(2), 183-190. DOI: 10.26855/ijfsa.2020.06.010

Solomon Yokamo & Endrias Oyka (2018). Participatory demonstration of maize (Zea Mays L.) variety with its full packages in south Ethiopia, Adv. *Crop Sci. Tech.*, *6*, 342.

Sperling, L., & McGuire, S.J. (2010). Understanding and Strengthening Informal Seed Markets. *Experimental Agriculture*, *46*, 119-136.

Sperling, L., Louwaars, N., de Ponti, O., Smale, M., Baributsa, D., & van Etten, J. (2020). Viewpoint: COVID-19 and seed security response now and beyond. *Food Policy*, 102000.

Stellmacher, T., & Kelboro Girma (2019). Family Farms, Agricultural Productivity, and the Terrain of Food (In) Security in Ethiopia. *Sustainability (Switzerland)*, *11*(18). 4981.

Sthapit, B., Rana, R., Chaudhari, P., Bania, B., & Shrestha, P. (2008). Informal Seed Systems and On-farm Conservation of Local Varieties. Pp 133-151.

Suvedi, M., Ghimire, R., & Kaplowitz, M. (2017). Farmers' participation in extension programs and technology adoption in rural Nepal: a logistic regression analysis. *The Journal of Agricultural Education and Extension*, *23*(4), 351-371.

Tadesse Tasew & Tariku Gebremedhin Zeleke (2022). The impact of the productive safety net program (PSNP) on food security and asset accumulation of rural households: evidence from Gedeo zone, Southern Ethiopia. *Cogent Economics & Finance*, *10*(1), 2087285.

Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. *Procedia manufacturing*, *22*, 960-967.

Tefera Zeray, Amsalu Ayana, Mohammed Hassena, Amsalu Mengistu, Abeneazer Adam, Dawit Alemu, and Mandefro Nigussie (2020). Status of Seed Quality Control and Assurance in Ethiopia: Required Measures for Improved Performance.

Tekeste Kifle, Degefa Tolossa, Admasu Shibru, & Dawit Alemu (2022). Analysis of Seed System Actors' Role, Responsibilities, and Linkages in Central Ethiopia. *Ethiopian Journal of Agricultural Science*, 32(2), 71-97.

Temesgen Teresa (2019). Demand and Supply Status of Certified seed and Factor governing it in Ethiopia. *Journal of Biology, Agriculture and Healthcare*, *9*(3), 33–39.

Tesfaye Mamaru & Paulos Gutema (2022). Impact of Improved Forage Technology Adoption on Dairy Productivity and Household Income: A Propensity Score Matching Estimation in Northern Ethiopia.

Tesfaye Gemechu (2017). Actors' Linkage for Rural Innovation: A Case Study on the Factors Hindering Effective Linkage between Actors Working in Agriculture and Rural Development in East Shoa zone, Ethiopia. *International Journal of Agricultural Education and Extension*, *3*(1), 058- 071.

Teshome Lakew & Dawit Alemu (2018). Approaches and Procedures of Seed Demand Assessment in the Formal Seed Sector. Seed Demand Assessment practices, challenges, and options. (Eds.) Adefris Teklewold, Dawit Alemu, Shiratori Kiyoshi, and Abebe Kirub. Series No. 5, 1-8.

Teshome Mulesa, Dalle, S.P., Makate, C., Haug, R., & Westengen, O.T. (2021). Pluralistic Seed System Development: A Path to Seed Security? *Agronomy*, *11*(2), 372.

Tripp, R. (1997). New Seed and Old Laws: Regulatory Reform and the Diversification of National Seed Systems. Alternative strategies for smallholder seed supply. *Hyderabad, India: International Center for Research in the Semi-Arid Tropics.*

Tura Motuma, Dejene Aredo, Tsegaye W., La Rovere, R., Tesfahun Kassie, Mwangi, W., & Mwabu, G. (2010). Adoption and Continued Use of Improved Maize Seeds: Case study of Central Ethiopia. *African Journal of Agricultural Research, 5*(17), 2350-2358.

Udimal, T.B., Jincai, Z., Mensah, O.S., & Caesar, A.E. (2017). Factors influencing the agricultural technology adoption: the case of improved rice varieties (Nerica) in the Northern Region, Ghana. *J. Econ. Sustain. Dev. 8*(8):134.

UN (1975). Report of the World Food Conference. Rome, New York, United Nations.

UN OCHA (2022). Horn of Africa Drought: Humanitarian Update. Press release, https://reliefweb. Int/report/Ethiopia/. (United Nations Office for the Coordination of Humanitarian Affairs.

USAID & MoARD (2016). An Atlas of Ethiopian Livelihoods. The Livelihood Integration Unit. USAID and Government of Ethiopia Disaster Risk Management and Food Security Sector, Addis Ababa.

Vernooy, R., Jai, R., Ahlawat, S.P., Malik, S.K., Mbozie, H., Mugisha, J., Nyabasha, S., Otieno, G., Patil, S., & Roy, S. (2020). Community Seed Banks as Seed Producers: Cases from India, Nepal, Uganda, and Zimbabwe; *Working Paper Series No. 2, CGIAR Research Program on Grain.*

WHO, IFAD, UNICEF, WFP & FAO (2020). The State of Food Security and Nutrition in the World. In brief Rome. Pp 12. Doi: 10.4060/ca9699en.

Wikipedia (2020). Wikipedia, the Free Encyclopedia. https://en.wikipedia.org/wiki/Moretna_Jiru and Bora.

WFP (2019). Comprehensive Food Security and Vulnerability Analysis: The State of Food Security in Ethiopia. World Food Program.

WFP (2009). Food Consumption Analysis: Calculation and Use of the Food Consumption Score in Food Consumption and Food Security Analysis; Technical Guidance Sheet; World Food Program: Rome, Italy.

WFP (2020). The State of Food Security and Nutrition in the World. Transforming food systems for affordable healthy diets. Rome, FAO. https://doi.org/10.4060/ca9692en

Wondale Laduber, Molla Dessalegn & Tilahun Daniel (2016). Logit analysis of factors affecting adoption of improved bread wheat (Triticum aestivum L.) variety: The case of Yilmana Densa District, West Gojam, Ethiopia. *Journal of Agricultural Extension and Rural Development, 8* (12): 258-268. DOI: 10.5897/JAERD2016.0768.

Wordofa Muluken, Hassen Jemal, Endris Getachew, Aweke Chanyalew, Moges Dereje, & Rorisa Debebe (2021). Adoption of improved agricultural technology and its impact on household income: a propensity score matching estimation in eastern Ethiopia. *Agriculture & Food Security*, *10*(1), 1-12.

World Bank (2018). World Development Indicators: Agriculture for Development. Washington, DC: World Bank.

World Fact Book (2021). Ethiopian Economy: The World Fact Book of the United States Central Agency and Other Sources. https://theodora.com/wfbcurrent/ethiopia/ethiopia_economy.html

Yehuala Kassa (2019). A Review on the Seed Sector of Ethiopia: Prospects and Challenges of Faba bean Seed supply. *South Asian Journal of Development Research,* 1(1), 44-54.

Yu, B., & Nin-Pratt, A. (2014). Fertilizer Adoption in Ethiopia Cereal Production. *Journal of Development and Agricultural Economics*, *6*(7), 318-337.

Zegeye Mesele, Abebaw Hailu, & Anteneh Bizualem (2022). Impact of agricultural technology adoption on wheat productivity: Evidence from North Shewa Zone, Amhara Region, Ethiopia. *Cogent Economics & Finance*, *10*(1), 2101223.

Zewdie Bishaw & Dawit Alemu (2017). Farmers' perceptions on improved bread wheat varieties and formal seed supply in Ethiopia. *International Journal of Plant Production*, 11 (1), 117-130.

Appendices/Annexes

Appendix 1: Household survey Questionnaire

Dear Respondent

My name is Tekeste Kifle, and I am a Ph.D. student at Addis Ababa University in the College of Development Studies, Center for Food Security Studies. The study intends to examine the seed systems, adoption, and impact of improved crop varieties on household food security in Ada'a, Bora, and Moretna Jiru districts. Hence, your replies are extremely valuable and will be used just for the sake of this research's study. Therefore, we cordially request you that provide information to the best of your knowledge and assure you that no information will be processed using the names of informants.

Thank you in advance for your cooperation.

PART – I

GENERAL INFORMATION

No.	Questions	Response Options	Code
1	Household Identification Number (ID):		[.........]
2	Date of interview (Date/Month/Year):		[..../...../.......]
3	Name of Enumerator:	1= Bizuwork Tafese 2= G/kidan Feleke 3= Dagne Bekele 4= Girma Ashe	[.........]
4	Region:	1= Oromia 2= Amhara	[.........]
5	Zone:	1= East Shewa 2= North Shewa	[.........]
6	Woreda:	1= Ada'a 2= Bora 3= Moretina jiru	[.........]
7	Kebele:	1= Dire Arerti 2= Gobosaye 3= Tube suti 4= Dalota mati 5= Gerba segenet 6= Mangudo	[.........]
8	Agro ecological zone:	1= Dega 2= Weynadega 3= Kola	[.........]

PART – II

DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS OF THE HOUSEHOLD

No.	Questions	Response Options	Code
1	Name of the household head:		[.............................]
2	Relationship with the household head	1= Spouse 2= Son 3= Daughter 4= Other	[.........]
3	Sex of the household head:	1= Male 0= Female	[.........]
4	Age of the household head:	Respondent's age in years	[.........]
5	Marital status of the household head:	1= Single 2= Married 3= Divorced 4= Widowed 5= Others	[.........]
6	Household size: **In Number**	 1= < 5 yrs. 2= 5-17 yrs. 3= 18-35 yrs. 4= 36-59 yrs. 5= > 60 yrs.	Male Female Total [.....] [.....] [....] [.....] [.....] [....] [.....] [.....] [....] [.....] [.....] [....] [.....] [.....] [....]
7	Religion:	1= Orthodox 2= Muslim 3= Protestant 4= Catholic 5=Others	[.........]
8	Educational level of the household Head:	1= Not read and write (Illiterate) 2= 1st cycle primary school (Gr. 1-4) 3= 2nd cycle primary school (Gr. 5-8) 4= High school (Grade 9 -10) 5= Preparatory (Grade 11-12) 6= College and above	[.........]
9	Landholdings of the household in the last season: In **Ha. or *Kert***	1= Total cropland 2= Total grazing land 3= Total home garden land	[.........] [.........] [.........]
10	Experience of household in agricultural activities. **In Years**		[.........]
11	Do you rear livestock?	1= Yes 0= No	[.........]
12	If yes, how many livestock do you have? **In Number**	1= Oxen- Farm 7= Goat 2= Oxen- Fatten 8= Donkey 3= Milking Cows 9= Horse 4= Heifers 10= Poultry 5= Calves 11= Camel 6= Sheep 12= Pigs	[.........] [.........] [.........] [.........] [.........] [.........] [.........] [.........] [.........] [.........] [.........] [.........]
13	For what purpose you use mainly livestock and their products	1= For cash income 2= For food 3= Both for food and cash 4= For animal power (oxen)	[.........] [.........] [.........] [.........]
14	Which of the following are the constraints to rearing livestock?	1= Shortage of grazing land 2= Lack of additional forage	[.........] [.........]

No.	Questions	Response Options	Code
	(multiple answers possible)	3= Disease prevalence 4= Lack of Veterinary services 5= Conflict on grazing land & water	[.........] [.........] [.........]
15	What were your main sources of income in the last season? (At least three important ones)	1= Sales of crop & crop products 2= Livestock sale & LS products 3= On-farm daily labor 4= Rented out oxen for plowing 5= Rented out land	1st [.........] 2nd [.........] 3rd [.........]
16	Are you engaged in off-farm activity?	1= Yes 0= No	[.........]
17	What are your main sources of off-farm income?	1= Sale of charcoal/fuel wood 2= Other business (shops, trade, etc 3= Salaried employment	[.........]
18	Are you able to save some cash from the income you earned?	1= Yes 0= No	[.........]
19	If Yes, how much total saving the household has now?	1= <5,000 Birr 2= 5,000 – 10,000 Birr 3= >10,000	[.........]

PART – III

INSTITUTIONAL FACTORS OF THE HOUSEHOLD

No.	Questions	Response Options	Code
1	Do any members of the household have access to credit in the last season?	1= Yes 0= No	[.........]
2	If yes, amount of credit that you have taken	1= <5,000 Birr 2= 5,000 – 10,000 Birr 3= >10,000	[.........]
3	What was the main purpose of the credit services? (multiple answers possible)	1= Purchase farm inputs (e.g. seeds, fertilizers) 2= Buy livestock 3= Rent land 4= Buy machinery and equipment 5= Payment of labor costs 6= Household consumption	[.........] [.........] [.........] [.........] [.........] [.........]

No.	Questions	Response Options	Code
4	Do you have access to farm input?	1= Yes 0= No	[.........]
5	If yes, which type of input (multiple answers possible)	1= Uncertified seed of Improved Variety 2= Certified seed of Improved Variety 3= Fertilizer 4= Insecticide - chemical 5= Herbicide - chemical 6= Fungicide - chemical	[.........] [.........] [.........] [.........] [.........] [.........]
6	Do any agricultural extension agents visit you related to farm inputs?	1= Yes 0= No	[.........]
7	If yes, how often the extension agents visit you in last season? **In times**		[.........]
8	Are you participating in any social institution in your village?	1= Yes 0= No	[.........]
9	If yes, in which institution currently participate? (multiple answers possible)	1= agricultural cooperative 2= Farmer's research group 3= Saving and credit cooperative 4= Equb 5= Edir	[.........] [.........] [.........] [.........] [.........]
10	Do you sell crop and livestock production?	1= Yes 0= No	[.........]
11	How far is the village market place from your residence? in minutes or hrs.	1= Crop market 2= Livestock market	[.........] [.........]
12	How far is the *woreda* market place from your residence? in minutes or hrs.	1= Crop market 2= Livestock market	[.........] [.........]

PART – IV

CROP PRODUCTION AND SEED SYSTEMS

1. Crop Production:

Crops grown in previous main (meher) season:

No.	Details	Major Crops							
		Wheat	Tef	Barely	F. Bean	H. Bean	Chickpea	Lentils	Maize
1.1.	Have you plant these crops in the last season? 1= Yes 0= No								
1.2.	Total area cultivated, in Ha or Kert.								
	Owned								
	Rented in								
	Rented out								
	Shared in								
	Shared out								
	Clustered with others								
	Total								
1.3.	Main purpose of crop Production: 1= Consumption 2= Market 3= Both								
1.4.	Did you apply/ using **inorganic** fertilizer on your farm? 1= Yes 0= No								
1.5.	Which type of seed used on your farm? 1= Certified improved variety 2= Non-certified improved varieties 3= Local varieties								
1.6.	Amount of seed used: Improved variety (Kg)								
	Local variety (Kg)								
1.7.	Chemical Used: Herbicide (Liter)								
	Fungicide (Liter)								
	Insecticide (Liter)								
1.8.	What is the average yield gained? In Quintal								

No.	Questions	Response Options	Code
1.9.	Did you use **organic** fertilizer	1= Yes 0= No	[.........]
1.10.	If yes, what type of organic fertilizer?	1= Compost manure 2= Animal manure 3= Green manure 4= Others (specify) _____________	[.........]
1.11.	What was the cropping practice?	1= Mixed farm 2= Sole crop	[.........]
1.12.	What did you use to prepare your farmland for seed production?	1= Tractor 2= Oxen plow 3= Both	[.........]
1.13.	If you used a tractor, where did you get it?	1= Own 2= Rented 3= Through subsidy	[.........]
1.14.	If you used oxen to plow, how did you access it?	1= Own 2= Rented 3= Shared with other farmers'	[.........]

2. Seed System:

No.	Questions	Response Options	Code
2.1.	Are you adopt /using/ certified seed on your farm?	1= Yes 0= No	[.........]
2.2.	If yes/no, what was/were your source(s) of seed of improved varieties? (Multiple answers are possible)	1= Own saved seed 2= Neighboring farmers 3= Local market 4= *Woreda* B. of agriculture 5= Research centers 6= Seed enterprises 7= Unions 8= Agricultural cooperatives 9= NGOs	1st [.........] 2nd [.........] 3rd [.........]
2.3.	Was there enough seed from this source?	1= Yes 0= No	[.........]
2.4.	What quantity of seed did you plant from this source? **In Kg.**	1= Own saved seed 2= Neighboring farmers 3= Local market 4= *Woreda* B. of agriculture 5= Research centers 6= Seed enterprises 7= Unions 8= Agricultural cooperatives 9= NGOs	[.........] [.........] [.........] [.........] [.........] [.........] [.........] [.........] [.........]

No.	Questions	Response Options	Code
2.5.	At what time was the seed available? (seed supply time)	1= Before the planting season 2= At the start of the season 3= Mid-season 4= Towards the end of the season	[.........]
2.6.	How did you access the seed from the source? (Multiple choices are possible)	1= Purchase/cash 2= Gift 3= Loan/Credit 4= Exchange/ Barter 5= Revolving seed	[.........] [.........] [.........] [.........] [.........]
2.7.	How was the price or term of trade? (ask only those who acquired by cash, or credit or bartered)	1= Affordable 2= Expensive 3= Very expensive	[.........]
2.8.	Was the seed clean?	1= Clean (no impurities, no damage) 2= Fairly clean (some impurities, no damage 3= Not clean (some impurities & damage)	[.........]
2.9.	What is the main reason for not using certified seed? (Multiple choices are possible)	1= No difference in productivity than the local one 2= No supply 3= Unaffordable price 4= No loan basis provision 5= No provision on an exchange basis 6= Long distance to get 7= Old/ obsolete variety 8= Susceptible for pests 9= Lack of source seed	1st [.........] 2nd [.........] 3rd [.........]
2.10.	What are the major advantages of acquiring local seed varieties? (Multiple choices are possible)	1= Easy to access 2= Quality assurance 3= Reliability 4= Timely supply 5= Affordable price	1st [.........] 2nd [.........] 3rd [.........]
2.11.	What are the major disadvantages of acquiring local seed varieties? (Multiple choices are possible)	1= Poor Quality and adulteration 2= Variety characteristics is unknown 3= Low productivity 4= Unfair exchange 5= Unreasonable price	1st [.........] 2nd [.........] 3rd [.........]
2.12.	What are the desirable characteristics of quality seed? (multiple choices are possible)	1= Good grain size 2= No impurities 3= Disease-free 4= Adaptability to local condition	1st [.........] 2nd [.........] 3rd [.........]

No.	Questions	Response Options	Code
		5= Marketability	
2.13.	What are the selection criteria you used for seed multiplication? Or Selection criteria for adopting certified seed varieties (multiple choices are possible)	1= Disease, pest, and weed tolerance 2= Early maturity 3= Good germination 4= Seed color 5= Marketability 6= Home consumption 7= Longevity in storage	1st [.........] 2nd [.........] 3rd [.........]
2.14.	Do you recycle your own saved seed?	1= Yes 0= No	[.........]
2.15.	If yes, how many times for planting?	1= One 2= Two 3= Three 4= Four 5= More than four	[.........]
2.16.	To whom do you sell your grain? (multiple choices are possible)	1= Local traders 2= Consumers on the open market 3= Cooperatives 4= Creditors 5= Seed enterprises	[.........]
2.17.	Where did you sell the grain seed?	1= Farm get 2= Nearby markets 3= Markets where prices are good 4= Delivery to crop store	[.........]
2.18.	When do you sell the grain seed? (multiple choices are possible) (Do not read the suggested responses)	1= Before harvest 2= Right after harvest 3= When I hear the price is higher than my expectation 4= Any time family needs cash	[.........] [.........] [.........] [.........]

3. Seed Storage

No.	Questions	Response Options	Code
3.1.	Do you have any separate stores for your seed production/purchased?	1= Yes 0= No	[.........]
3.2.	If yes, who owns the store?	1= Own 4= Shared in 2= Family 5= Government 3= Rented in 6= Cooperatives	[.........]
3.3.	Do you store the seed until the next planting time?	1= Yes 0= No	[.........]
3.4.	If yes, for how long do you store?	1= Less than a month 2= Two-three months 3= Three – six months 4= Six months to one year 5= More than a year	[.........]
3.5.	How do you store your seed after production/ purchase?	1= Bagging and in a separate room 2= Bagging and in the living room 3= Underground hall 4= In the grain store	[.........]
3.6.	What do you use the packing materials to store the seed?	1= Ordinary bags(jute, polypropylene) 2= Hermetic bags (PICS, Grain-pro) 3= local seed/grain store (Gotera) 4= on the canvas at home 5= Using bins 6= Earthen pots 7= Underground pit	[.........]
3.7.	Have you encountered any seed quality problems at the time of storage?	1= Yes 0= No	[.........]
3.8.	If yes, what was the quality problem?	1= Loss of germination due to insect damage 2= Loss of germination due to diseases 3= Increase in moisture content 4= Impurities due to rodents & birds attack	[.........]

PART – V

FOOD SECURITY SITUATION AT HOUSEHOLD LEVEL

No.	Questions	Response Options	Code
1	What are the main staple foods that your household consumes? (multiple choices are possible)	1= Wheat 2= Teff 3= Barley 4= F.Bean 5= H.Bean 6= Chick pea 7= lentils 8= Maize	[......] [....] [.....] [......] [....] [.....] [......] [....]
2	Which foodstuffs are consumed at home? (multiple choices are possible)	1= Injera 2= Bread 3= Pulses 4= Meat 5= Chicken and/or eggs 6= Milk, cheese, and/or Butter 7= Vegetables 8= Fruits	[......] [....] [.....] [......] [....] [.....] [......] [....]
3	Have you ever faced with a shortage of specific foods due to crop failure in the last season?	1= Yes 0= No	[.........]
4	Would you tell us the amount of grain and other foodstuffs that covers the annual consumption food requirements of your household members? **in Kg**	1= Cereals (Tef, wheat, barely, maize, sorghum, rice) 2= Pulses (bean, pea, chickpea, lentils) 3= Oil seeds (linseed, sesame, ground nut) 4= Vegetables (cabbage, carrot, potato) 5= Fruits (papaya, banana, mango)	[.........] [.........] [.........] [.........] [.........]
5	Do you meet the all-year-round food requirements of your household members from your production?	1= Yes 0= No	[.........]
6	If No, for how many months food shortage was critical in the last years?	1= 1-2 months 2= 3-5 months 3= More than 5 months	[.........]
7	What do you think are the main reasons for being food insecure? (multiple choices are possible)	1= Inability to produce sufficient grain and to rear livestock 2= Inability to rear sufficient amount of livestock 3= Inadequate income from non-farm activities 4= Instability owing to frequent changes in rural policies 5= Failure to properly utilize own production and other earnings	[.........] [.........] [.........] [.........] [.........]
8	How do you cope with the problem of food shortage? Coping strategy (multiple choices are possible)	1= Livestock dispersal or de-stocking 2= Changing cropping patterns 3= Migration to nearby towns for wage labor 4= Consuming famine period or less preferred foods 5= Borrow grains from relatives	[.........] [.........] [.........] [.........] [.........]

No.	Questions	Response Options	Code
		6= Borrow grain or cash from money lenders	[.........]
		7= Migrate to other rural areas for wage labor	[.........]
		8= Sell off small animals	[.........]
		9= Firewood and charcoal selling	[.........]
		10= Rely on relief grains	[.........]
		11= Sell off-farm oxen	[.........]
		12= Lease outland	[.........]
		13= Sell of land	[.........]
		14= Distress migration	[.........]

9. Household Food Balance Model (HFBM):

Different sources of household consumption obtained during the previous season (In Kg.)										
Type of Crops	Total grain produced/ year/HH **(GP)**	Total grain bought /year/ HH **(GB)**	Total grain obtained from remittance **(GR)**	Total grain left from previous season **(GPS)**	Total grain for Post-harvest losses **(PHL)**	Total grain reserved (utilized) for seed **(GRS)**	Total grain marketed (sold out) **(GM)**	Total grain is given to others as a gift **(GG)**	Total grain planned for next season **(GNS)**	Net grain available **(NFG)**
Wheat										
Tef										
Barely										
Maize										
Faba Bean										
Haricot Bean										
Pea										
Chickpea										
Lentils										
Potato										
Onion										
Tomato										
Carrot										
Cabbage										

10. Household Food Consumption Score (FCS):

Asking about 12 food groups they consumed during the day or night prior to the survey, whether consumed within the household or prepared within the household. Put **"0"** if the household did not eat and put **"1"** if the household ate the food group. The frequency of the food group eaten will be collected for the **past 7 days only** for **breakfast, lunch, and dinner**. If there is any fasting or special ceremony in the house, please ask about the day before that day.

No.	**Questions (Food group)**	**Days**						
		1	2	3	4	5	6	7
1	Any **cereal** crops? wheat, teff, sorghum, maize, rice, millet, or any other foods made from cereals							
2	Any **root and tuber** crops? potatoes, sweet potato, yams, beat root, cassava or any other foods made from roots or tubers							
3	Any **vegetables**? Spinach, carrot, cabbage, pumpkin, beet root...							
4	Any **fruits**? Orange, apple, mango, pineapple, avocado, banana, lemon, strawberry.							
5	Any **meat, poultry**? Beef, pork, sheep, goat, chicken etc.							
6	Any other **eggs**?							
7	Any **fish and sea food?** fresh or dried fish or shellfish							
8	Any **pulses**? Beans, peas, lentils, chickpea, grass pea or nuts							
9	Any **milk and milk products**? Milk cheese, yogurt etc.							
10	Any **oil and fats**? Oil, fats or butter added to food							
11	Any **sweets?** Sugar, honey**,** sweetened soda, juice, cookies & cakes							
12	Any **condiments, beverages**? Spices, salt, coffee, tea, alcoholic							

Source: Kennedy *et al.* 2013

11. Household Food Insecurity Access Scale (HFIAS):

No	Questions	Response Options	Code
1	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip to Q2) 1 = Yes	[.........]
1a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]
2	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = No (skip to Q3) 1 = Yes	[.........]
2a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]
3	In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = No (skip to Q4) 1 = Yes	[.........]
3a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]
4	In the past four weeks, did you or any household member have to eat some foods that you did not want to eat because of a lack of resources to obtain other types of food?	0 = No (skip to Q5) 1 = Yes	[.........]
4a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]

No	Questions	Response Options	Code
5	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to Q6) 1 = Yes	[.........]
5a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]
6	In the past four weeks, did you or any household member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to Q7) 1 = Yes	[.........]
6a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]
7	In the past four weeks, was there ever no food to eat of any kind in your household because of a lack of resources to get food?	0 = No (skip to Q8) 1 = Yes	[.........]
7a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]
8	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (skip to Q9) 1 = Yes	[.........]
8a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]
9	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No 1 = Yes	[.........]
9a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	[.........]

Source: Coates, Swindale & Bilinsky (2007)

Appendix 2: Key Informants Interview (KII) Guide

1. Where do farmers get improved and local seeds?
2. What are the major seed supply channels and the advantages and disadvantages?
3. How do you see the seed supply system in your area? In terms of seed type, quality, timeliness, availability, etc.
4. What are the major farmers' seed management practices? (Seed selection, storage, etc.)
5. What are the strengths and weaknesses of the seed supply system in the study area?
6. What are the challenges of the seed supply system in the study area?
7. What opportunities are there to improve the seed supply system in general?
8. What are seed production/multiplication activities performed by the farmer?
9. How the farmer get benefit from being involved in seed multiplication activities?
10. How the institutional arrangement of the seed supply system looks like?
11. What are the main actors involved in the seed supply system in your district and their role?
12. How is the linkage between seed system actors look like?
13. Is there a background seed insecurity story in the study area?
14. What are the seed aid histories in your district?
15. What are the main constraints you face in acquiring seed?
16. What do you think the government should do to help the farmer’s access and use improved varieties?
17. What do you think the role of the government to strengthen the seed supply system?
18. What do you suggest to improve the seed supply system in the district?
19. What is the food security situation of the community in your district?
20. How do you explain the concepts of food security and food insecurity?

Appendix 3: Focus Group Discussions (FGDs) Guide

1. What are the types of crops and their varieties are grown in your area? (List of improved and local varieties with their existing status, social purpose, and problems)
2. What are the advantages and disadvantages of the local and certified seed varieties?
3. What are the sources for local seeds in your area?
4. What are the sources for certified seed varieties in your area? (Own, Neighbors, Market, NGOs, Bureau of Agriculture, Cooperatives)
5. What are the main seed actors involved in the seed supply system and their roles?
6. Which actor positively or negatively influences the seed supply system?
7. What are the main criteria considered by farmers while selecting seeds?
8. How and by whom the seed selection activity has been undertaken?
9. What are the advantage and disadvantage of the farmer-to-farmer seed exchange system?
10. What are the challenges to use the seed supply system effectively?
11. What are the opportunities to improve the seed supply system?
12. Do farmers have better access to certified seed varieties in your area?
13. What are the traditional farmer seed exchange systems?
14. What do you suggest to improve the seed supply system in your area?
15. How do you explain the concepts of food security and food insecurity?
16. Which type of households in your community can be considered food secure and food insecure?

Appendix 4: Multicollinearity Test

```
  ___  ____  ____  ____  ____ (R)
 /__    /   ____/   /   ____/
___/   /   /___/   /   /___/   14.2   Copyright 1985-2015 StataCorp LP
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Notes:
      1.  Unicode is supported; see help unicode_advice.
      2.  More than 2 billion observations are allowed; see help obs_advice.
      3.  Maximum number of variables is set to 5000; see help set_maxvar.
      4.  New update available; type -update all-

. use "E:\TK PhD Research Data\Stata & Spss analysis\TK PhD data-Excel-spss-Age-Km-8.dta",
clear
```

Continuous Variables Regression:

```
. regress Adopt_NonAdopt AGE_OF_THE_HH FAMSZ_Total FARM_SIZE_HA EXPERIENCE_FARM TLU
EXTENSION_VIST_TIME DISTANCE_WOREDA_TO_MARKET_CROP_M

      Source |       SS           df       MS      Number of obs   =       299
-------------+----------------------------------   F(7, 291)       =     17.26
       Model |  21.8759641         7  3.12513773   Prob > F        =    0.0000
    Residual |  52.6859088       291  .181051233   R-squared       =    0.2934
-------------+----------------------------------   Adj R-squared   =    0.2764
       Total |  74.5618729       298  .250207627   Root MSE        =     .4255

----------------------------------------------------------------------------------------
                  Adopt_NonAdopt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------------------------+------------------------------------------------------
                   AGE_OF_THE_HH |  -.0059294   .0023058    -2.57   0.011    -.0104674   -.0013913
                     FAMSZ_Total |  -.0075474   .0131183    -0.58   0.566    -.0333662    .0182714
                    FARM_SIZE_HA |   .0755207   .0211626     3.57   0.000     .0338695    .1171718
                 EXPERIENCE_FARM |   .0222585   .0029022     7.67   0.000     .0165466    .0279704
                             TLU |  -.0016057   .0054325    -0.30   0.768    -.0122976    .0090862
             EXTENSION_VIST_TIME |   .0344494   .0119325     2.89   0.004     .0109645    .0579343
DISTANCE_WOREDA_TO_MARKET_CROP_M |  -.0037968   .0066959    -0.57   0.571    -.0169753    .0093817
                           _cons |   .1404828   .1067321     1.32   0.189     -.069582    .3505476
----------------------------------------------------------------------------------------
```

Variance Inflation Factor:

```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
FARM_SIZE_HA |      1.50    0.668211
EXPERIENCE~M |      1.48    0.677881
         TLU |      1.44    0.694576
AGE_OF_THE~H |      1.35    0.740600
 FAMSZ_Total |      1.33    0.753846
DISTANCE_W~M |      1.04    0.963172
EXTENSION_~E |      1.03    0.973314
-------------+----------------------
    Mean VIF |      1.31
```

Covariance matrix of coefficients of regress model

. vce

```
       e (V) | AGE_OF_T~H  FAMSZ_To~l  FARM_SIZ~A  EXPERIEN~M     TLU      EXTENSIO~E
DISTANCE~M  _cons
-------------+--------------------------------------------------------------------------
-------------------
AGE_OF_THE~H |  5.317e-06
 FAMSZ_Total | -4.693e-06   .00017209
FARM_SIZE_HA |  1.079e-07  -.00004052   .00044785
EXPERIENCE~M | -2.758e-06  -7.011e-06  -.00001053   8.423e-06
         TLU |  4.961e-07  -.00001332  -.00004997  -7.117e-07  .00002951
EXTENSION_~E |  2.229e-06   2.284e-06  -.00002608  -2.741e-06   6.484e-07   .00014238
DISTANCE_W~M | -1.672e-06  -6.402e-06   .00001022   1.071e-06  -3.980e-06   1.400e-06
.00004484
       _cons | -.00014369  -.00040562  -.00016151    .0000121   3.791e-06  -.00030657 -
.00023144 .01139175
```

Correlation matrix of coefficients of regress model

. vce, corr

```
       e(V) | AGE_OF~H  FAMSZ_~l  FARM_S~A  EXPERI~M      TLU    EXTENS~E  DISTAN~M
_cons
-------------+--------------------------------------------------------------------------
---
AGE_OF_THE~H |   1.0000
 FAMSZ_Total |  -0.1551    1.0000
FARM_SIZE_HA |   0.0022   -0.1460    1.0000
EXPERIENCE~M |  -0.4122   -0.1841   -0.1715    1.0000
         TLU |   0.0396   -0.1869   -0.4346   -0.0451    1.0000
EXTENSION_~E |   0.0810    0.0146   -0.1033   -0.0792    0.0100    1.0000
DISTANCE_W~M |  -0.1083   -0.0729    0.0721    0.0551   -0.1094    0.0175    1.0000
       _cons |  -0.5839   -0.2897   -0.0715    0.0391    0.0065   -0.2407   -0.3238
1.0000
```

Dummy Variables Regression:

```
. regress Adopt_NonAdopt SEX_OF_THE_HH EDUCATIONAL_LEVEL_OF_THE_HH INCOME_SOURCE OFF_FARM
CREDIT_ACCESS FARM_INPUT_ACCESS

      Source |       SS           df       MS      Number of obs   =       299
-------------+----------------------------------   F(6, 292)       =     11.19
       Model |  13.9397979         6  2.32329965   Prob > F        =    0.0000
    Residual |   60.622075       292  .207609846   R-squared       =    0.1870
-------------+----------------------------------   Adj R-squared   =    0.1702
       Total |  74.5618729       298  .250207627   Root MSE        =    .45564
-------------------------------------------------------------------------------------
             Adopt_NonAdopt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------------------+--------------------------------------------------------------
              SEX_OF_THE_HH |   .1050842    .083221     1.26   0.208    -.0587048    .2688733
EDUCATIONAL_LEVEL_OF_THE_HH |   .0629299   .0254382     2.47   0.014     .0128643    .1129954
              INCOME_SOURCE |   .0624621   .0277899     2.25   0.025     .0077681     .117156
                   OFF_FARM |     .01786   .0616293     0.29   0.772    -.1034339     .139154
              CREDIT_ACCESS |   .3131818   .0535859     5.84   0.000     .2077182    .4186455
          FARM_INPUT_ACCESS |   .1817734   .0568108     3.20   0.002     .0699628     .293584
                      _cons |  -.1570649   .1571615    -1.00   0.318    -.4663777    .1522479
-------------------------------------------------------------------------------------
```

Variance Inflation Factor:

. vif

```
    Variable |       VIF       1/VIF  
-------------+----------------------
    OFF_FARM |      1.06    0.940253
INCOME_SOU~E |      1.05    0.953128
SEX_OF_THE~H |      1.03    0.970021
EDUCATIONA~H |      1.03    0.974263
FARM_INPUT~S |      1.02    0.981598
CREDIT_ACC~S |      1.02    0.983982
-------------+----------------------
    Mean VIF |      1.03
```

Covariance matrix of coefficients of regress model
. vce

```
        e(V) | SEX_OF_T~H  EDUCATIO~H  INCOME_S~E    OFF_FARM   CREDIT_A~S  FARM_INP~S
_cons
-------------+--------------------------------------------------------------------------------
-------
SEX_OF_THE~H |  .00692574
EDUCATIONA~H | -.00023059    .0006471
INCOME_SOU~E | -5.323e-06  -.00001515   .00077228
    OFF_FARM |  .00059822   .00001792  -.00035602   .00379817
CREDIT_ACC~S | -.00003706  -.00012562   -.0000483   .00008405   .00287145
FARM_INPUT~S | -.00027078  -.00007707   .00009702  -.00023994  -.00021544   .00322747
       _cons | -.00650438  -.00119004  -.00058865   -.0070297  -.00086075  -.00137517
.02469972
```

Correlation matrix of coefficients of regress model
. vce, corr

```
        e(V) | SEX_OF~H  EDUCAT~H  INCOME~E  OFF_FARM  CREDIT~S  FARM_I~S     _cons
-------------+----------------------------------------------------------------------
SEX_OF_THE~H |   1.0000
EDUCATIONA~H |  -0.1089    1.0000
INCOME_SOU~E |  -0.0023   -0.0214    1.0000
    OFF_FARM |   0.1166    0.0114   -0.2079    1.0000
CREDIT_ACC~S |  -0.0083   -0.0922   -0.0324    0.0255    1.0000
FARM_INPUT~S |  -0.0573   -0.0533    0.0614   -0.0685   -0.0708    1.0000
       _cons |  -0.4973   -0.2977   -0.1348   -0.7258   -0.1022   -0.1540    1.0000
```

. linktest

```
      Source |       SS           df       MS      Number of obs   =       299
-------------+----------------------------------   F(2, 296)       =     35.32
       Model |  14.3642582         2  7.18212912   Prob > F        =    0.0000
    Residual |  60.1976147       296   .20337032   R-squared       =    0.1926
-------------+----------------------------------   Adj R-squared   =    0.1872
       Total |  74.5618729       298  .250207627   Root MSE        =    .45097

------------------------------------------------------------------------------
Adopt_NonA~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        _hat |   1.720359   .5130461     3.35   0.001     .7106786    2.730039
      _hatsq |  -.7546399   .5223542    -1.44   0.150    -1.782639    .2733589
       _cons |  -.1367222   .1136969    -1.20   0.230     -.360479    .0870346
------------------------------------------------------------------------------
```

Appendix 5: Conversion factors used to estimate Tropical Livestock Unit (TLU)

Livestock	Conversion factor
Cow and Ox	1.00
Bull/Oxen fatten	0.60
Calf	0.20
Heifers	0.75
Donkey and Mule	0.70
Horse	1.10
Sheep and Goats (young)	0.13
Goat and Sheep (adult)	0.06
Poultry	0.013

Source: Stock, et al., 1991

Appendix 6: Conversion factors for grain produced (HFBM)

1 Kg of	Calorie equivalent (Kcal/100g)
Teff	3450
Wheat	3440
Maize	3630
Sorghum	3550
Barley	3390
Bean	3390
Potato	750
Cabbage	280
Onion	480

Source: ENHRI, 2000

Appendix 7: Standard Food Groups and standard weights (FCS)

Food groups	Weight	Justification
Cereals/Root and tuber (G1+G2)	2	Energy eaten in larger quantities, but contain a lower content of protein compared to legumes
Vegetables (G3)	1	Low in energy, protein, and fat, but provide micronutrients
Fruits (G4)	1	Low in energy, protein, and fat, but provide micronutrients
Meat/Egg/Fish (G5+G6+G7)	4	Have high quality protein and easily absorbable micro-nutrients and provide high energy and a considerable amount of fat. Even if eaten in small quantities, they can improve diet substantially
Pulses (G8)	3	Provide high energy and protein, but of lower quality than meat. Provide micro-nutrients and have low fat content
Milk (G9)	4	Provides high quality protein, micro-nutrients, vitamin A, and energy
Oil/Fats/Butter (G10)	0.5	Provides high energy, but has no micro-nutrients and is usually consumed in small quantities
Sweets/Sugar (G11)	0.5	Usually eaten in small quantities and therefore provides an insignificant amount of calories
Condiments (G12)	0	These foods are by definition eaten in very small quantities and not considered to have an important impact on overall diet

Source: Adapted from WFP (2009)