IMPACT OF LIMU MAIZE VARIETY ADOPTION ON RURAL HOUSEHOLDS' FOOD SECURITY IN DALE WABARA DISTRICT, KELLEM WOLLEGA ZONE, OROMIA, ETHIOPIA

M.SC. THESIS

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Impact of Limu Maize Variety Adoption on Rural Households' Food Security in Dale Wabara District, Kellem Wollega Zone, Oromia, Ethiopia

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DEDICATION

I dedicate this thesis to my Father, Tesfa Kebeda, and my Mother, Damme Dasalo. You sacrificed so much to bring me up to this level. I love you both and I appreciate everything that you have done for me. This thesis also dedicated to my uncle, Gospel Preacher Fikadu Kebeda, for his continuous prayer in my life and academic success.

STATEMENT OF AUTHOR

I the undersigned, hereby declare that the thesis- Impact of Limu maize variety adoption on rural households' food security in Dale Wabara district, kellem wollega zone, Oromia, Ethiopia is the outcome of my own work and all sources of materials used for this thesis have been duly acknowledged.

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BIOGRAPHICAL SKETCH

The author was born on April 17, 1994 in Meki Dimbar Kebele, Dale Wabara District, Kellem Wollega Zone, Oromia regional state Ethiopia. He attended his elementary, Secondary and Preparatory at Meki Dimbar elementary school, Chanka Secondary school and Kake Preparatory School respectively. After successfully passed Ethiopian general secondary examination certificate in early 2013, he joined Gondar University in 2013 and graduated with BSc degree in Agricultural Economics on July 06, 2016.

After graduation, he joined Ethiopian Food, Beverage and Pharmaceutical Development Institute where he used to serve as junior investment officer from August 01, 2017 – October 29, 2017. Then after he has been employed at Mettu University and served as assistant lecturer for about one year from November 01, 2017 until he joined Jimma University School of Graduate Studies on October 24, 2018 to pursue his M.Sc. degree in Agricultural Economics program.

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LISTS OF ABBREVIATIONS AND ACRONYMS

AE	Adult Equivalent
ATE	Average Treatment Effect
ATT	Average Treatment Effect on the Treated
CIA	Conditional Independence Assumption
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistics Agency
DA	Development Agent
ECHO	European Commission Humanitarian Aid
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
IDTM	Improved Drought Tolerant Maize
IMV	Improved Maize Variety
ITS	Intervention interrupted time-series
MoA	Ministry of Agriculture
MoANR	Ministry of Agriculture and Natural Resource
ODI	Overseas Development Institute
OPVs	Open Pollinated Varieties
PSM	Propensity Scores Matching
RCTs	Randomized Control Trials
SNNP	Southern Nation Nationalities and Peoples
TLU	Total Livestock Unit
UNDP	United Nation Development program
USD	United State Dollar
WHO	World Health Organization

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IMPACT OF LIMU MAIZE VARIETY ADOPTION ON RURAL HOUSEHOLDS' FOOD SECURITY IN DALE WABARA DISTRICT, KELLEM WOLLEGA ZONE, OROMIA, ETHIOPIA

ABSTRACT

Adopting improved agricultural technology is one of the instruments to overcome the current low agricultural productivity and ensuring household food security. There is, however, limited empirical evidence on the adoption and impacts of adoption of improved maize varieties grown by smallholder farmers. Consequently, the study examined the impact of Limu maize variety adoption on rural households' food security in Dale Wabera District. Qualitative and quantitative data were collected from primary and secondary sources. A Multi-stage sampling technique was employed to select 319 households for primary data collection. The data were analyzed using descriptive statistics, double hurdle model and Propensity score matching techniques. A double hurdle model was used to analyze the determinants of adoption and adoption intensity of Limu maize variety, Propensity score matching was used to investigate the impact of Limu maize variety adoption on rural household food security. The result from first hurdle model indicates that, Limu maize variety adoption was positively and significantly influenced by family size of the household, education level of the household head, total land size, livestock ownership, frequency of extension contact and membership in a farmers' cooperative. The result from truncated regression model revealed that intensity of Limu maize variety adoption was affected by livestock ownership, membership in a farmers' cooperative, frequency of extension contact and distance to the main market. The result of Propensity score shows a positive and statistically significant mean difference between adopters and non-adopters in terms of daily calorie intake per adult equivalent. The average treatment effect on the treated shows that the daily calorie intake per adult equivalent was 458.9 Kcal implying adopters of Limu maize variety consume 458.9 Kcal per adult equivalent higher than non-adopters. It is therefore recommended that wider supply and distribution of Limu maize variety has to be prioritized to improve food insecurity in the study areas. In this regard, it is better if concerned government institutions, other non-governmental organizations and private companies create a sustainable seed supply chain in the study areas. In addition, to sustain the positive impact of Limu maize variety, emphasis should be given to remove the major obstacles hindering households' adoption of Limu maize variety in the study area.

Key words*:* Adoption, logistic regression, Impact, Food security, Propensity Score matching, Limu maize variety

1. INTRODUCTION

1.1.Background of the Study

Maize (Zeamays) is the most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socioeconomic conditions typically under rain-fed production (Dawit *et al.,* 2014). Ethiopia is Africa's third largest producer of maize. Smallholder farmers almost in all regions of Ethiopia dominantly produce maize which covers over 95% of the national maize production (MoANR, 2016). In 2017/2018 cropping season 2.13 million hectares of land was covered by maize and about 83.96 million quintals was produced (Cochrane and Bekele, 2018).

Maize is a major food source and instrumental for the food security of Ethiopian households (Dawit *et al.*, 2014). More than 80% of the Ethiopians depend on maize for food (MoANR, 2016). Three fourth of the maize produced is consumed at the house hold level by the small-scale producers themselves (CSA, 2017). No other cereal crop produced reaches to this level in terms of retention for home consumption. Thus, for smallholder farmers in maize-based systems, their perception on own food security status is directly related to the amount of maize grain they produced in a given year (Moti *et al.*, 2015). Thus, maize is a key food security crop in Ethiopia.

In Ethiopia, maize is produced mainly for food, especially, in major maize producing regions, particularly for low-income groups, it is used as staple food (CSA, 2017). It is consumed as "*Injera*," Porridge, Bread and "*Nefro*." It is also consumed roasted or boiled as vegetables at the green stage. Maize also constitutes more than 60% of the caloric intake of a typical household (Getachew *et al.,* 2010). In addition, maize is used to prepare local alcoholic drinks known as "*Telia*" and "*Arekie*." Besides its food value, the leaf and stalk are used for animal feed and also dried stalk and cob are used for fuel. It is also used as industrial raw material for oil & glucose production (MoANR, 2016).

Despite the importance of maize as a principal food security crop, its average yield in Ethiopia (3.6 tons per hectare) is still lower than that of the world's average (5.6 tons per hectare in 2016) (FAO, 2017). According to on-farm trials, when cultivated with modern technologies the maize production potential were 4.7 tons per hectare. However, maize yield in 2008/09 was only 2.2 tons per hectare.

These deviations from potential yields are raised from using local farming technologies (Musa *et al.*, 2011). This implies that if smallholder farmers are able to adopt the improved maize technologies, they can produce more and ensure their food security.

The Ethiopian government has promoted technology-led initiatives to enhance agricultural productivity. Reforming agricultural extension programs; which is the means to transfer technology, and pursuing other relevant strategies were undertaken to increase maize productivity. Improving maize technology through facilitating research system is the other packages of the agricultural policies promoted to enhance maize production and productivity and to improve the food security status of the maize producer farmers. Developing high yielding, disease resistant and stable varieties of maize were one of the measurements taken by the government. Accordingly, more than 40 maize varieties, both open pollinated varieties (OPVs) and hybrids have been generated for different agro-ecologies of the country. However, the adoption of maize variety is very low (Moti *et al.,* 2015). For instance, according to a survey conducted in 2013 only about 31% of the farmers planted improved maize varieties in Ethiopia (De Groot *et al.,* 2014). This shows that, there is the low adoption rate of improved maize varieties.

The Dalle Wabera district is one of potential maize producing districts in Kellem Wollega zone. However, farmers in the study area are suffering from the problem of low maize yield. In the study area, farmers started using improved maize varieties to overcome the problem of low maize productivity before two decades. However, the production and productivity of maize, which confronting the food security of rural peoples, are still quite low. This may be due to low utilization of improved maize technology. For instance, during 2017/18 cropping season maize covered a total of 3,236 ha of land, of which, 2,023ha and 1213ha were covered by local varieties and improved varieties yielding an average of 20 and 46 quintals per ha (DWANRO, 2019). The yield gap between local and improved maize variety was 26 quintals per ha which is substantial for achieving food security. In terms of land coverage, 62.5% of the land allocated for maize production is covered by the local maize varieties and 37.5% by the improved maize varieties. This shows that the low productivity of maize is linked to the lower utilization of improved maize variety among maize producing farmers.

Hence, understanding the adoption status of Limu maize variety, factors affecting the Limu maize variety adoption, intensity of LMV adoption and impact of LMV adoption on rural household food security in the study area is vital in promoting the utilizations of the improved maize varieties in order to enhance maize production and thus food security status in the study area in particular.

1.2.Statements of the Problem

Low agricultural production and productivity is the main problem in Ethiopia. This low agricultural productivity could partly be due to the low adoption of improved agricultural technology which limits the income of farmers and subsequently lead to poverty and food insecurity (Danso-Abbeam *et al.*, 2017). It is apparent that agricultural productivity can be improved among farmers through improved agricultural technologies which had been developed at the research centers and disseminated to farmers' mainly through extension services (ODI., nd). Hence, to tackle the problem of food security, the link between agricultural productivity and improved agricultural technology has to be given due attention (Minten and Barrett, 2008). This calls for the adoption of productivity enhancing technologies and improvement in the productivity of the sector as it is becoming no longer possible to increase output by expanding the area under cultivation (Solomon *et al.*, 2012). This implies that improved agricultural technologies are important input that contributes to an increase in agricultural productivity thus food security.

Of all the inputs used in agricultural technologies, none has the ability to affect productivity more than improved seed (Morris *et al.*,1999). Hence, to increase maize productivity, more than 40 improved varieties of maize are developed and released in the last four decades (MoA, 2011). Limu maize variety is also released and disseminated to farmers in 2012 in Ethiopia (MoANR, 2016). However, the adoption of maize variety by smallholder farmers is still low (Moti *et al.*, 2015).

Some studies were conducted in Ethiopia on adoption of improved maize varieties (Shiferaw and Tesfaye, 2005; Yishak and Punjabi, 2011; Abadi *et al*., 2015). The focus of these studies was to identify determinants of adoption of improved maize varieties or to assess the intensity of adoption. However, types of improved maize seed were not well considered. Some studies were also conducted to assess the welfare impacts of adopting the improved maize varieties (Abadi, 2014; Moti *et al.,* 2015; Musa *et al.,* 2017). However, few studies were conducted on the impact of improved maize variety adoption on the rural household food security in Ethiopia. In addition, as to the knowledge of the researcher, no study has been conducted on the adoption status of Limu maize variety, factors affecting Limu maize variety adoption and its use intensity LMV adoption as well as on the impact of Limu maize variety adoption on rural household food security in the study area. Hence, it was not well known to what extent Limu maize variety adopter households are better off than non-adopter households in terms of their food consumption in the area. Therefore, this study generates evidence to fill the gaps of past studies by assessing the impact of Limu maize variety adoption on rural household food security in the Dale Wabera district, Kellem wollega zone, Oromia regional state of Ethiopia.

1.3.Research Questions

1. What is the status of Limu maize variety adoption by rural households in the study area?
2. What are the determinants of Limu maize variety adoption by smallholder farmers in the study area?
3. What are the determinants of farm land allocation under Limu maize variety in the study area?
4. Does adoption of LMV improves households' food security in the study area?

1.4.Objectives of the Study

1.4.1. Overall objective

To assess the impact of Limu maize variety adoption on maize producers' food security in the Dale Wabera district, Kellem Wollega, Oromia, Ethiopia.

1.4.2. Specific objectives

The specific objectives of the study are:

1. To examine rural households' adoption status of Limu maize variety in the study area.
2. To analyze the determinants of Limu maize variety adoption by smallholder farmers in the study area.
3. To assess the determinants of intensity use of Limu maize adoption in the study area.
4. To investigate the impact of LMV adoption on rural household food security in the study area.

1.5.Significance of the Study

The findings of this study will benefit Agricultural and Natural Resource Office and different NGO in the study area in terms of improving the knowledge base for the adoption of Limu maize variety and its impact on rural households' food security. Understanding factors that hinder households to adopt Limu maize variety and adoption intensity of Limu maize variety in the study area can help local development planners to make an appropriate plan that addresses households' needs. Further, it provides baseline information on the impact of Limu maize variety adoption on rural household farmers' food security in the study area. On top of this, the findings of the research work also provide information for policy makers and to researchers interested to study in other similar research theme.

1.6.Scope and Limitations of the Study

A variety of studies have been conducted on adoption of various agricultural technologies and its impacts on households' livelihood. As such, there is an extensive body of literature on the economic theory of technology adoption. Several factors have been found to affect technological adoption. These include government policies, technological change, market forces, environmental concerns, demographic factors, institutional factors and delivery mechanism. However, the study is concerned only with demographic, socioeconomic and institutional factors to assess factors that affect farmers' decisions to adopt LMV and adoption intensity of Limu maize variety and its impact on rural farmers' household food security of Dale Wabara district. It was limited to four peasant administrations of Dale Wabara district, Kellem Wollega zone of Oromia National Regional State. The study was limited to identifying only the above problems by considering only 2019 data year. The study was also limited to 319 sample households' in the kebele administrations which only represent the study area. Maximum effort was made to gather reliable information by convincing farm households to address the objectives of the study.

1.7.Organization of the Thesis

This study is organized into five chapters. Concepts and definition used in the present study along with a review of the past works are discussed in chapter two. Chapter three describes the study area and research methodology applied. Chapter four deals with descriptive results and discussions, econometric analysis results and discussions, Chapter five, deal with summary, conclusion and recommendations.

2. LITERATURE REVIEW

2.1. Theoretical Literature Review

2.1.1. Concepts and definitions

Adoption

Various authors define adoption in different ways. Loevinsohn *et al. (*2013) defines adoption as the integration of a new technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation. Rogers (1983) also defined adoption as use or nonuse of a new technology by a farmer at a given period of time. Feder *et al. (*1985) defines adoption as a mental process an individual passes from first hearing about an innovation to final utilization of it. However, for rigorous theoretical and empirical analysis definition given by Feder and Umali (1993) were adopted. This definition is given by classifying adopter as those who have ever used and continue to use technology while non-adopters are farmers who have never used and those who have only used technology at some point in time, thereby incorporating time dimension in the adoption definition.

Food security

Food security concept is believed to have originated four decades ago in the mid-1970s in the first world food conference and was narrow in its coverage and definition. This concept initially paid attention to the national and international level and was defined from the perspective of the food supply with special attention to stable food price and food availability (Young *et al.*, 2001). Food security is a situation where all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996).

Food security concept encompasses the following four components: food access, food availability, food utilization, and sustainability (FAO, 2006 and Gregory *et al.,* 2008). Food access is ensured when households and all individuals within them have adequate resources to obtain appropriate foods for a nutritious diet. Additionally, food availability is said to be achieved when sufficient quantities of food are consistently available to all individuals within a country (FAO, 2006; Schmidhuber and Tubiello, 2007; Ingram, *et al*., 2008). Food utilization refers to the consumption of food through adequate diet, clean water, sanitation, and health care to reach a state of nutritional well-being where all physiological needs are met. Food sustainability, on the other hand, refers to a situation where the above three components of food security are fulfilled at any time (FAO, 2006).

Impact evaluation

According to Khandker *et al*. (2010) impact evaluation is the act of studying whether the changes in outcome variable are indeed due to a given program intervention. An impact evaluation assesses the changes in the well-being of individuals, households, communities or firms that can be attributed to a particular intervention, such as a project, program or policy, both the intended ones, as well as ideally the unintended ones. This involves a comparison between what actually happened and what would have happened in the absence of the intervention. In other words, looking for the changes in outcome that are directly attributable to a program (White, 2009). Impact evaluations measure treatment effects, for which treatment means being exposed to an intervention, such as a new technology or policy or project, and effects are the difference that exposure makes to outcomes, such as food security, income, productivity, poverty, health, and many other aspects (White and Raitzer, 2017).

2.1.2. Theory of adoption

A number of theories have been developed to explain about adoption of new technologies. For instance, the Theory of Reasonable Action (Fishbein and Ajzen, 1975) is one of the most popular theories used and is about one factor that determines behavioral intention of the person's attitudes toward that behavior. Fishbien and Ajzen, (1975) defined "attitude" as the individual's evaluation of an object and defined "belief" as a link between an object and some attribute, and defined "behavior" as a result or intention. Attitudes are affective and based upon a set of beliefs about the object of behavior. A second factor is the person's subjective norms of what they perceive their immediate community's attitude to certain behavior.

Rogers (1995) proposed that the theory of 'diffusion of innovation' was to establish the foundation for conducting research on innovation acceptance and adoption. According to this theory Adoption of a new idea, behavior, or product (i.e., "innovation") does not happen simultaneously in a social system; rather it is a process whereby some people are more apt to adopt the innovation than others. Diffusion of innovation theory explained that the innovation and adoption happened after going through several stages including understanding, persuasion, decision, implementation, and confirmation.

Ajzen (1991) developed Theory of Planned Behavior which is about one factor that determines behavioral intention of the person's attitudes toward that behavior. The first two factors are the same as Theory of Reasonable Action (Fishbien and Ajzen, 1975). The third factor that is known as the perceived control behavior is the control which users perceive that may limit their behavior.

Decomposed Theory of Planned Behavior (Decomposed TPB) was introduced by Taylor and Todd (1995) . The Decomposed TPB consists of three main factors influencing behavior intention and actual behavior adoption which are attitude, subjective norms and perceived behavior control. Shih and Fang (2004) examined the adoption of internet banking by means of the TPB as well as Decomposed TPB. There has been a great deal of research on the Theory of Reasoned Action (Fishbein and Ajzen, 1980; Sheppard *et al.*, 1988). Theory of Planned Behavior (Ajzen, 1991) and Decomposed Theory of Planned Behavior, (Taylor and Todd, 1995) but mostly used for products already in the marketplace and included the view of society (Subjective norm).

Technology Acceptance Model (TAM) was introduced by Fred Davis in 1986. An adaptation of Theory of Reasonable Action, TAM is specifically tailored for modeling users' acceptance of technologies (Venkatesh and Davis, 2000).

2.1.3. Farmers' decision-making behavior on technology adoption

Several literatures suggest that the decision to adopt a new technology or innovation is determined by different factors. Studies by Rogers and Shoemaker (1971) and Rogers (1983) described the technology adoption decision process, as the mental process from the first knowledge of an innovation to the decision to adopt or reject. These are (1) awareness or the initial knowledge of the technology (2) interest and persuasion toward the technology, (3) evaluation or the decision whether or not adopt the technology (4) trial and confirmation sought about the decision made, and (5) adoption. Similarly, according to Rogers (2003) as cited by

Abadi (2014) the decision to adopt a new technology involves five stages including: knowledge (awareness); persuasion, potentially by gaining sufficient information on the characteristics, benefits, and costs of a new technology; decision; implementation; and confirmation.

According to Feder *et al.* (1985) the adoption decision involves the choice of how much resource (i.e. land) to be allocated to the new and the old technologies if the technology is not divisible (e.g. mechanization, irrigation). However, if the technology is divisible (e.g., improved seed, fertilizer and herbicide), the decision process involves area allocations as well as level of use or rate of application. Thus, the process of adoption decision includes the simultaneous choice of whether to adopt a technology or not and the intensity of its use. Besides, before adoption choices are made a farmer makes a set of several interdependent decisions (Hassan, 1996).

Similarly, Mignouna *et al.* (2011) stated that, the characteristic of the technology play a critical role in adoption decision process. They argued that farmers who perceive the technology being consistent with their needs and compatible to their environment are likely to adopt since they find it as a positive investment. Farmers' perception about the performance of the technologies significantly influences their decision to adopt them.

According to the Rational Decision-making Model; a model in which decisions are made systematically and based consistently on the principle of economic rationality people strive to maximize their individual economic outcomes (Taher, 1996; Mendola, 2007). Information about all possible alternatives, their outcomes and the preference of decision makers is assumed available.

Taher (1996) emphasized influence of the community on the farmer. He argues that decisions in farming will be determined not only by the goal of maximizing the benefit or of reducing the risk, but also by willingness to accept criticism from the community (depending very much on a farmer's social position in different groups).

2.1.4. Food security situation in Ethiopia

Drought and famine have become the recurrent challenge food production in Ethiopia. According to the FAO (2018) 41% of the Ethiopian population lives below the poverty line and more than 31 million people are undernourished. However, the latest undernourishment numbers show a positive trend in this year's (1990- 1992: 71% of the population; 1995-1997: 64%; 2000-2002: 50%; 2004-2006: 44%). The same source show that the concentrations of food insecurity and malnutrition are prevalent in rural areas with a population of six to seven million chronically food insecure and up to 13 million seasonally food insecure.

The country has faced three major famines and numerous famines like situations in the past three decades. The recurrent of famine in 1970s, 80s and 90s has affected significantly the country's food production. During the period between 1958 and 1977 over 25 million people were directly affected by famine and drought. The number of death was estimated between three and five million people. The 1984/85 famine alone had taken the lives of 300,000 people. It was estimated that close to 58 million were affected by famine between 1973 and 1986 (Berhanu, 2001).

A series of successive droughts had already weakened Ethiopia's food situation, with "poor and erratic rainfall over the last two years." Global conditions such as the high food and fuel prices that have persisted in the country since 2008 and the global financial crisis have also contributed to Ethiopia's failing food security. Ethiopia is considered a least developed country ranked 171 out of 182 countries in the UNDP Human Development Index for 2009 (Birara *et al.*, 2010). In the 2010 Global Hunger Index, which ranks developing countries and countries in transition based on proportion of undernourished people, proportion of underweight children under five, and child mortality rate, Ethiopia was given a 29.8, on a scale of 0-100, with 0 being the best and 100 the worst possible score. Ethiopia is one of the countries that made the most absolute progress improving its score between 1990 and 2010; in 1990 it had a score of 43.7, and now it's down to 29.8. However, this score is still highly troubling – it's currently ranked 80th out of 84 countries (Sisay, 2003).

According to ECHO (2014), in Ethiopia the overall food security is deteriorating following poor rains, both in livestock keeping and farming areas. Around 12 million people in the country regularly exposed to droughts. These regular shocks have many negative consequences such as forced internal displacements of population, destruction of assets and livelihoods, extreme poverty, under nutrition and extreme food insecurity. In 2015, El Niño Ethiopia also faces a massive drought and food insecurity crisis. According to FAO (2016) around 10.2 million people require food aid in 2015, in addition to the 7.9 million people receiving assistance through the Government Productive Safety Net Program. The Humanitarian Country Team predicts 2.2 million cases of moderate acute malnutrition and 435,000 cases of severe acute malnutrition in 2015. The some report reveals that pastoralists in Ethiopia were the first and hardest hit by drought of 2015. Around 1.8 million pastoralists, agro pastoralists and smallholder farmers affected by El Niño and need support in Ethiopia.

To address problem, the government of Ethiopia is taking a strong leadership role with programs that meet the varying needs of vulnerable households. In addition to tackling the underlying drivers of food insecurity and the long-term impacts of climate change the government of Ethiopia is providing leadership in this response. several assessments is undertook during 2015, it given a clear steer to regional authorities to scale up their efforts and had released $381million of its own funds to respond to the situation (FAO, 2016).

2.1.5. Analytical framework

Analytical framework for adoption and intensity of adoption

The dependent variables in this study are the adoption decision of the farmers and intensity of adoption of Limu maize variety. Since one of the dependent variables of this study, household's adoption decision is dichotomous (binary), it takes a value of 1 if the household has adopted Limu maize variety and zero otherwise. If the scope of this study is only the adoption decision of the farmers, it is possible to use either binary logit or binary probit model. As indicated in Gujarati (1995), logit or probit models are widely applied to analysis of determinant studies for a limited dependent variable and their result is similar. These two models are used only for the analysis of probability of adoption in particular technology. This means they are only suited in determining the probability models but not for linear models. Tobit model, Heckman two step and Double hurdle model are the models suited to analyze the factors determining the probability of adoption and intensity of adoption under different underlying assumptions.

Tobit model is an improvement to probit model and it can be used to analyze both the adoption decision of the farmers (Limu maize variety adoption) and the intensity of adoption (proportion of land under Limu maize variety) by the farm households in this particular study by the use of single non-linear least square estimation using maximum likelihood method. The likelihood-function consists of two parts, that is probit-part or the slope of the line in the Tobit part and linear part which is the uncensored part of the model. Therefore, Tobit model can be used to analyze the factors influencing household's LMV adoption decision and its intensity of adoption by the farmers simultaneously using a single coefficient (Gujarati, 2004).

Another alternative model for such study is Heckman two-step procedure proposed by James Heckman (Heckman, 1979). The Heckman two-step procedure is an improvement to Tobit model. It accounts for sample-selection bias. This alternative consists of a two-step estimating procedure. The first estimation is the probability of adoption, which is done on the basis of the probit model as determinants of adoption. Then we estimate the second, OLS regression model by adding the variable called inverse mills ratio (IMR) calculated using our selection equation as an independent variable, if it is significant, for intensity of adoption. Heckman treats the selection bias as an omitted variable bias. The Heckman procedure yields consistent estimates of the parameters as of Tobit model, but they are not as efficient as Tobit model maximum likelihood estimates.

Different scholars use different models for the purpose of adoption decision and intensity of adoption. For instance double hurdle model was used by Efa *et al.* (2016), in conducting a study on determinants of market participation and intensity of marketed surplus of teff producers by reasoning out double hurdle model is an improvement to standard Tobit model. Really double hurdle is an improvement to standard Tobit model but it has its own additional assumption under which we can use a double hurdle instead of Tobit model. The assumption of double hurdle model is that the two dependent variables are independent and they are to be determined by different sets of explanatory variables (Burke, 2009).

Double hurdle model have two parts which are estimated by two hurdles. The first one is the probit model used in estimating the factors determining the probability of adoption of LMV and the second one is truncated regression that is used to estimate the intensity of adoption of LMV by the farmers. Based on Burke (2009) double hurdle model with the two parts are specified using two different latent variables, to model each decision process, with a probit model to determine adoption decision and a truncated regression model to determine the intensity of adoption of LMV.

Framework for impact evaluation approach

Impact evaluation is an important policy issue either to improve the program intervention or strengthening the existing activity to be sustainable. But evaluating the impacts of improved technologies is not straightforward because they are designed and implemented in a complex and ever-changing environment (Stern *et al.,* 2012). Another problem is the bias resulting from self-selection in the adoption of the technological innovation (Caliendo and Kopeinig, 2005; Khandker *et al.*, 2010). Furthermore, there may be a hidden bias that results from unobserved heterogeneity in the participation decision, which can, in turn, influence the outcome of participating in a technological innovation (Smith and Todd, 2005).

To know the impact of improved maize varieties (IMVs) adoption on food security, we must compare the observed outcome with the outcome that would have resulted had that individual not participated in the intervention. However, two outcomes cannot be observed for the same individual. In other words, only the factual outcome can be observed. Thus, the fundamental problem in any social intervention evaluation is the missing data problem (Bryson *et al.*, 2002; Ravallion, 2005).

Estimating the impact of the participation requires separating its effect from involving factors which may be correlated with the outcomes. This task of "netting out" the effect of the program from other factors is facilitated if control groups are introduced. "Control groups" consist of a comparator group of individuals or households who did not involve in the intervention, but have similar characteristics as those involving in the intervention, called the "treatment groups". Identifying these groups correctly is a key to identifying what would have occurred in the absence of the treatment (Ezemenari *et al.,* 1999). In theory, evaluators could follow three main methods in establishing control and treatment groups: randomization/pure experimental design; non-experimental design and quasi-experimental design. In practice, in the social sciences, the choice of a particular approach depends, among other things, on data availability, cost, and ethics to experiment. In what follows, brief descriptions of the main impact evaluation methods mentioned above are given.

Experimental Method

Under experimental evaluations, the treatment and comparison groups are selected randomly and isolated both from the intervention, as well as any interventions which may affect the outcome of interest. These evaluation designs are referred to as randomized control trials (RCTs). In experimental evaluations the comparison group is called a control group. When randomization is implemented over a sufficiently large sample with no contagion by the intervention, the only difference between treatment and control groups on average is that the latter does not receive the intervention. Random sample surveys, in which the sample for the evaluation is chosen randomly, should not be confused with experimental evaluation designs, which require the random assignment of the treatment.

The experimental approach is often held up as the 'gold standard' of evaluation. It is the only evaluation design which can conclusively account for selection bias in demonstrating a causal relationship between intervention and outcomes. Randomization and isolation from interventions might not be practicable in the realm of social policy and may be ethically difficult to defend (Ravallion, 2009), although there may be opportunities to use natural experiments. Bamberger and White (2007) highlight some of the limitations to applying RCTs to development interventions. Methodological critiques have been made by Scriven (2008) on account of the biases introduced since social interventions cannot be fully blinded, and Deaton (2009) has pointed out that in practice analysis of RCTs falls back on the regression-based approaches they seek to avoid and so are subject to the same potential biases. Other problems include the often heterogeneous and changing contexts of interventions, logistical and practical challenges, difficulties with monitoring service delivery, access to the intervention by the comparison group and changes in selection criteria and/or intervention over time. Thus, it is estimated that RCTs are only applicable to 5 percent of development finance (Bamberger and White, 2007).

Non-experimental Method

Non-experimental impact evaluations are so-called because they do not involve a comparison group that does not have access to the intervention. The method used in non-experimental evaluation is to compare intervention groups before and after implementation of the intervention. Intervention interrupted time-series (ITS) evaluations require multiple data points on treated individuals before and after the intervention, while before versus after (or pre-test post-test) designs simply require a single data point before and after. Post-test analyses include data after the intervention from the intervention group only. Non-experimental designs are the weakest evaluation design, because to show a causal relationship between intervention and outcomes convincingly, the evaluation must demonstrate that any likely alternate explanations for the outcomes are irrelevant. However, there remain applications to which this design is relevant, for example, in calculating time-savings from an intervention which improves access to amenities. In addition, there may be cases where non-experimental designs are the only feasible impact evaluation design, such as universally implemented programs or national policy reforms in which no isolated comparison groups are likely to exist (Blundell, 2000).

Quasi-experimental method

Quasi-experimental methods form a comparison group by statistical methods, rather than by random assignment. It involves matching program (in this case improved maize varieties) participants with a comparable group of individuals who did not participate in the program. This simulates randomization but need not take place prior to the intervention (Kerr *et al.,*, 2000). This method can remove bias arising from selection on observables and, where panel data are available, time invariant unobservable.

These include Randomized evaluations, Matching methods, specifically Propensity Score Matching (PSM), Double- Difference (DD) methods, Synthetic Controls, Instrumental Variable (IV) methods, Regression Discontinuity (RD) design and pipeline methods, Distributional impacts, and Structural and other modeling approaches (Khandker *et al.*, 2009). Each of these methods carries its own assumptions about the nature of potential selection bias in program targeting and participation, and the assumptions are crucial to developing the appropriate model to assess the ex-post impacts.

These methods vary by their underlying assumptions regarding how to resolve selection bias in estimating the program treatment effect (Khandker *et al.*, 2009).

Randomized evaluation: involves a randomly allocated initiative across a sample of subjects (communities or individuals, for example); the progress of treatment and control subjects exhibiting similar pre-program characteristics is then tracked over time. Randomized experiments have the advantage of avoiding selection bias at the level of randomization (UNDP, 2009).

Double- Difference: assumes that unobserved selection is present and that it is time invariant the treatment effect is determined by taking the difference in outcomes across treatment and control units before and after the program intervention. DD methods can be used in both experimental and non-experimental settings (Stern *et al.,* 2012).

Synthetic Controls: Synthetic controls build on the concepts of difference-in-differences approaches, in that the difference in trends between the outcome and comparison group observations provides the estimate of impact. However, synthetic controls relax the parallel trends assumption and build the control by weighting the comparison group observations such that trends in covariates and outcomes of the synthetic control match those of treatment prior to the intervention (Abadie *et al.,* 2010).

Instrumental Variable: used with cross-section or panel data and in the latter case allow for selection bias on unobserved characteristics to vary with time. In the IV approach, selection bias on unobserved characteristics is corrected by finding a variable (or instrument) that is correlated with participation but not correlated with unobserved characteristics affecting the outcome; this instrument is used to predict participation (Newey, 2003).

Regression Discontinuity and pipeline methods: are extensions of IV and experimental methods; they exploit exogenous program rules (such as eligibility requirements) to compare participants and nonparticipants in a close neighborhood around the eligibility cut off. Pipeline methods, in particular, construct a comparison group from subjects who are eligible for the program but have not yet received it (Becker and Ichino, 2002).

Propensity Score Matching: in the absence of an experiment, PSM methods compare treatment effects across participant and matched nonparticipant units, with the matching conducted on a range of observed characteristics. PSM methods therefore assume that selection bias is based only on observed characteristics; they cannot account for unobserved factors affecting participation (Rosenbaum and Rubin, 1983). The basic idea behind (PSM) is to match each adopter with an identical non-adopter and then measure the average difference in the outcome variable between the two.

2.2. Review of Empirical Studies

2.2.1. Determinants of improved maize variety adoption

Several studies on determinants of adoption of improved maize variety were conducted in Ethiopia. According to Abadi *et al. (*2014) and Bedru and Dagne (2014) age of the household positively influences adoption of improved maize variety by household. New maize varieties are more likely to be adopted in old aged households. This may be due to older farmers are assumed to have gained knowledge and experience over time and are better able to evaluate technology information than younger farmers. Conversely, studies by Arega *et al.* (2000), Feleke and Zegeye (2006) and Shiferaw and Tesfaye (2006) found no statistically significant effect of age on improved maize variety adoption. On the other hand, according to Habtemariam (2004) there is negative relationship between age of the household head in years and the adoption of improved maize varieties.

According to Bayissa (2010) sex of household head, i.e., being male-headed household has a positive and significant relationship with the adoption decision of farmers. The positive sign implies that male-headed households tend to adopt the varieties more than their female counterparts. This may be due to relatively better access of male-headed households to information and agricultural resources than females' household heads. On the other hand, Motuma *et al.* (2010) pointed out that maize technology promotion and dissemination efforts are largely gender neutral. However, some finding shows that many economic decisions made within households depend upon the characteristics of both men and women members Dawit et al. (2014). Indeed, the interests, problems, and priorities of female-headed households are likely to be different from male-headed households.

Getachew *et al.* (2010) reported that education level of household head has a positive and significant relationship with the probability of adoption of improved maize variety. This implies that educated farmers are more likely to adopt improve maize variety than those who are not educated. This may be due to fact that relatively educated farmers have more access to information and they become aware of new technology, and this awareness enhances the adoption of improved maize varieties (IMVs). Similarly, according to the findings of Feleke and Zegeye (2006), Motuma *et al.* (2010) and Gishu *et al.* (2018) there is a positive relationship between educational levels of households and improved maize varieties adoption. According to Moti *et al.* (2015), farm households with better educated heads tend to adopt improved maize varieties. Farmers with higher levels of education, therefore, are more likely to adopt improved maize varieties than those who do not.

According to Abadi *et al.* (2015), family size is positively related with the speed of adoption of hybrid maize. For each additional family member in the household, households were more likely to adopt the improved maize varieties, holding other variables constant. This suggests that large family size provides more labor for farm operation and an increased incentive to produce more output on farm. Large family size is normally associated with a higher labor endowment that would enable a household to accomplish various agricultural tasks on timely bases. Evidence in Ethiopia suggests that farm households with large family size are more likely to adopt improved maize technologies such as improved maize varieties and inorganic fertilizer (Arega *et al.,* 2000; Motuma *et al.,* 2010). Empirical evidence, therefore, suggests that the influence of household size on the decision to adopt improved maize varieties is positive.

Similarly, Yishak and Punjabi (2011) found that positive and significant influence of farm size on the probability of adoption of improved maize varieties. This implies that farmers with large farm size are more likely to adopt the improved maize varieties than those who have small land size. According to the Bedru and Dagne (2014), the size of the farmland owned and percent of the farm area allocated to maize production were positively associated with improved maize variety adoption

Gishu *et al.* (2018) investigated determinants of adoption of improved (BH-140) maize variety and management practice in south ari, woreda, South Omo Zone, SNNPRS, Ethiopia. They pointed out that Livestock ownership has a positive and significant relationship with the probability of adoption of improved maize variety. A farmer who has large number of livestock more likely adopted improved maize variety. This may be due to relatively having more livestock offer a means for a better propensity to buy improved maize seed and also farmers who have a large number of livestock might consider their asset base as a mechanism of ensuring any risk associated with the adoption of improved maize variety. Yishak and Punjabi (2011), also concluded that livestock ownership had a significant positive effect on adoption of improved maize varieties. Suggesting that the increase in number of livestock owned increases the likelihood of farm household's choice of improved varieties. Similarly, Solomon *et al.* (2011) reported that the likelihood of accessing improved seed for a household positively increase with ownership of wealth assets. The proxies for ownership of livestock assets farm size and monetary value of farm assets take a positive sign, all suggesting the contributing role of household wealth in accessing improved seed. This suggest that the relatively affluent farmers have better access to seed perhaps due to their ability to travel to other areas to purchase seed. Livestock was the economic variable that was highly significant in explaining the likelihood of access and adopts improved seed.

The role of off-farm income on the decision to adopt improved maize varieties has been considered in few studies in Ethiopia. Farmers with off-farm income are more likely to adopt improved maize varieties than those without sources of off-farm income (Dawit et al., 2014). Motuma *et al.* (2010) and Getachew et al. (2010) found a positive association between off-farm income and adoption of improved maize varieties. On the other hand, Arega *et al.* (2000) reports show that no statistical significance between off-farm income and improved maize use in Ethiopia.

Various studies in Ethiopia reported a strong positive relationship between access to information and the adoption behavior of farmers (Arega *et al.*, 2000; Bedassa, 2001; Yu *et al.*, 2011).

Several studies show the positive association between Extension contacts and improved maize varieties adoption**.** Feleke and Zegeye (2006**)** pointed out that the greater the number of contacts a household has with extension workers, the more likely will be the adoption decision. Gishu *et al.* (2018) reported that the number of contact with extension Agents per month had significant positive effects on the adoption of improved maize variety. Therefore, respondents who highly contact with Development Agents per month have more chance to adopt the improved maize variety. On contemporary, Getachew et al. (2010) who reported a negative and significant relationship between access to extension measured by the number of contacts a farmer had with extension agents and the likelihood of using improved maize varieties. This may be due to extension agents are being used for other purposes other than agricultural extension such as for political purposes rather than visiting farmers to advise on purely agricultural technical matters.

In case of Ethiopia, several reports show that access to credit is likely to have a positive impact on adoption of improved maize varieties. Sisay (2016) reported that use of credit correlate positively with the adoption of improved maize varieties by farmers. Similarly, Gishu *et al.* (2018) also concluded that access to credit had positively and significantly influenced the likelihood of adoption of improved maize variety. On the other hand, Abadi *et al.* (2015) pointed out that farmers who had the access to credit were less likely to adopt the new varieties of maize while the other variables were held constant. This might be due to the fact that the interest rate is higher than the paying back ability of farmers.

Distance to the market is another factor which determines improved maize varieties adoption. Almost all findings in Ethiopia report that the negative relationship between distance to market and likelihood of the adoption of the improved maize varieties (Feleke and Zegeye, 2006; Abadi *et al.*, 2015; Gishu *et al.*, 2018). According to Getachew *et al.* (2010) distance to market center has a negative and significant relationship with the probability of adoption of improved maize variety. The implication is that the longer the distance between farmers' residence and the market center, the lower will be the probability of improved maize variety adoption. This may be due to relatively Proximity to market also reduces marketing costs.

According to the report of various finding in Ethiopia, being a member of a cooperative positively influences the decision of farmers to adopt improved maize variety (Motuma *et al.*, 2010). On the other hand, Abadi *et al.* (2015), reported that farmer associations and adoption of the improved maize variety is associated negatively.

Several studies reported a positive association between access to demonstration sites and trainings and adoption of improved maize technologies (Bedassa, 2001; Habtemariam, 2004). The households who have participated in demonstrations and training have developed a positive attitude towards improved maize technology is supported by many studies in Ethiopia.

In general, according to Bedassa (2001), Physical inaccessibility of institutional services (distance to development centers and primary product markets) had a negative impact. This proves the negative impact of infrastructure related problems on improved maize variety adoption.

According various researches the perception about the attributes of improved varieties is positively related with improved maize variety adoption (Solomon *et al.,* 2011). It is the sum of perception variables (yield, disease resistance, marketability, drought resistance, and pod per plant, maturity, color and shattering resistance). It is equally important in considering the determinants of adoption decision. Farmers' perception of varieties attributes has a positive and significant relationship with probability of adoption of improved varieties (Bayissa 2010). Other studies e.g. Wubeneh (2003) considering farmers' perception of technology attributes have found that these attributes (yield, disease resistance, marketability, drought resistance, and pod per plant, maturity, color and shattering resistance) condition determines the adoption choices of farmers.

Several studies shows that the positive relationship between knowledge sharing and improved maize variety. Bayissa (2010) concluded that farmer to farmers knowledge sharing has a positive and significant relationship with probability of adoption of improved varieties. This may be due to the interpersonal communication with others farmers and neighbors improve farmers' innovativeness' and motivates them to adopt improved varieties.

2.2.2. Factors affecting intensity of IMVs adoption

Several researches were conducted on factor affecting intensity of Adoption of IMVS. A wide range of literature measuring technology adoption involves factors that are spelled by Feder, Just and Zilberman (Feder *et al.,* 1982). These explanatory indicators vary from study to study based on their contextual applicability, but traditionally include farm size, risk exposure and capacity to bear risk, human capital, labor availability, credit constraints, tenure, and access to commodity markets (Andrei, 2011).

Dawit and Abduselam (2018) examined factor affecting intensity of Adoption of IMVs in Case of Toke Kutaye District, West Shewa Zone, Ethiopia by using tobit econometric model. The result revealed that variables such as farm size, household income, access to credit, contact with extension agents and participation in training and field day were positively and significantly influenced adoption and intensity of use of improved highland maize varieties production whereas, age of household and market distance negatively and significantly influenced adoption and intensity of use of improved highland maize varieties production.

Arega *et al.* (2000) investigated determinants of adoption and intensity of use of improved maize varieties in the central highlands of Ethiopia by employing Tobit model. The estimated results indicate that level of education, household labour, farm size, extension services, farm income, and timely availability of improved maize seeds significantly influence the adoption and intensity of use of improved maize. On the other hand, Moti et al. (2013) concluded the Intensity of improved maize variety adoption is strongly affected by the level of household head's education, available family labor for farming, soil fertility and soil depth of maize plots, farmers' confidence in skills of the extension agents, and access to credit to buy seeds.

Aman and Tewodros (2019) explored the Drivers of Maize Technologies Adoption Intensity in case of SNNRP Region, Ethiopia by using tobit model. The result of Tobit model also shows that improved maize use intensity were influenced by tropical livestock unit, access to credit, distance to the nearest market, membership to the cooperative, frequency of extension contact, and annual income.

Danso-Abbeam *et al.* (2017) identified the determinants of adoption of improved maize variety (IMV) among farmers in the northern region of Ghana and subsequently assess the factors influencing the intensity of IMV adoption. Tobit regression model is employed and variables such as years in formal education, household size, distance to farm plots, attendance of demonstration fields, and membership of a farmer-based organization, farm size, and previous income are significant determinants of the intensity of IMV adoption.

In their study of Knowledge, Adoption and Use Intensity of Improved Maize Technologies in Ethiopia, Moti *et al.* (2013) assessed intensity of maize area under improved varieties at a household level by using Tobit model. The results of the model revealed that,education level of household head, extension agents and credit access have poositive impact on the intensity use of maize variety adoption.

2.2.3. Impact of improved maize variety adoption on food security

Several empirical studies in the country reported the impacts of adopting improved maize technology on farm households and its contribution to the national economy.

Moti *et al.* (2015) conducted research on impact of improved maize variety adoption on household food security in Ethiopia by using Survey data collected in 2011 from 2455 sample households in 39 districts. In the finding Endogenous switching regression model supported by binary and generalized propensity score matching methods was used to empirically assess the impact of IMV adoption on per-capita food consumption expenditure and perceived household food security status. The results of the research shows that, the average per-capita food consumption is high for adopters and the impact of improved maize varieties adoption on per-capita food consumption is slightly higher for non-adopters had they adopted improved maize varieties.

Menale *et al.* (2014) conducted research on impact of improved maize varieties on food security in Rural Tanzania and they used a generalized propensity-score matching methodology, complemented with a parametric econometric method to check the robustness of results. The results of the analysis indicate that adoption increased food security, and that the impact of adoption varied with the level of adoption. On average, an increase of one acre in the area allocated to improved maize varieties reduced the probabilities of chronic and transitory food insecurity from between 0.7 and 1.2 % and between 1.1and 1.7%, respectively.

In their study of adoption and impacts of improved maize varieties in Ethiopia, Zeng (2014), assessed Poverty impacts of Adoption of Improved Maize Varieties by exploiting the differences between the observed and counterfactual income distributions. The result of the finding show that improved maize varieties have led to 0.8-1.3 percentage drop in poverty head count ratio and relative reductions in poverty depth and severity. However, poor producers benefit the least from adoption due to their small landholdings.

According to the finding of Abadi (2014) on impact of improved maize varieties adoption on smallholder farmers' marketed maize surplus in Oromia Regional State, Ethiopia by utilizing cross-sectional household level data collected by CIMMYT in 2012/2013 from 300 randomly selected sample households. The results of the ATE model show a robust and positive increase in marketed maize grain per household which ranges from around 442kg in the case of kernel-based matching at bandwidth of 0.05 to 483kg in the case of radius matching at a radius of 0.03 at $p<0.01$. The results from this study revealed that the significant impact of adoption on improving the farmers' participation to output markets.

Musa *et al.* (2017) studied impact of improved maize varieties on farm productivity and wellbeing in East Hararghe Zone of Ethiopia. They combined propensity score matching method with endogenous switching regression to estimate the impact on the welfare of farmers and they applied the stochastic frontier corrected for sample selection to measure the impact on farm productivity. The results show that adoption of improved maize varieties leads to significant gains in wellbeing and improves farm productivity.

The research conducted on analysis of adoption and impacts of improved maize variety in Eastern Zambia by Khonje *et al.(*2015) by using data obtained from a sample of over 800 far m households. In the finding the propensity score matching and endogenous switching regressio n models are employed and the results of the model show that adoption of improved maize var ieties is leads to significant gains in crop incomes, consumption expenditure, and food security. Moreover, improve maize varieties have significant poverty-reducing impacts in eastern Zambia.

Bezu *et al.* (2013) assessed improved maize adoption in Malawi and examined the link between adoption and household welfare using a three-year household panel data. They concluded that modern maize variety adoption is positively correlated with the household's own maize consumption, income and asset holdings. The ex-post welfare impact of improved maize seed adoption is estimated using Fixed Effects models of household income and assets that control for endogeneity of the adoption decision. They found that a 1% increase in area under improved maize seed is associated with a 0.36% increase in own maize consumption, 0.26% increase in income and 0.07% increase in assets owned. With the same source, poorer households benefit more from improved maize adoption than households in the top of the wealth distribution in terms of income earned. A 1% increase in area under improved maize is associated with a 0.3% change in income for the poorest households, while for better-off households, it has no impact. This shows the importance of maize for poor farmers and how changes in maize productivity affect overall income.

Takam-Fongang *et al.,* (2019) examined impact of improved maize varieties adoption on maize yields in Cameron. They point out that the adoption of improved maize varieties enhances maize yields hence food security.

Abdoulaye *et al.,* (2019) assessed the Impacts of improved maize varieties in Nigeria. They used an endogenous switching regression approach to control for both observed and unobserved sources of heterogeneity between adopters and non-adopters. Adoption of improved maize varieties were increase maize grain yield by 574 kg/ha and per-capita total expenditure by US$ 77 (US$ 0.21/day). They concluded that the incidence of poverty among adopters would have been higher by 6% without adoption of the improved varieties.

2.3. Conceptual Framework of the Study

Adoption of improved maize varieties has interrelation with household food security. Factors such as personal and demographic, psychological and behavioral, socio economic and institution al factors determine the adoption of improved maize varieties. Practical experiences and observations of the reality as well as the empirical evidence have shown that, one factor may enhance adoption of technology in one specific area for certain period of time while it may create hindrance for other locations (Tesfaye *et al.,* 2001). Because of these reasons, it is difficult to develop a one and unified adoption model in technology adoption process for all specific locations. In the literature, the different factors supposed to affect farmers' adoption behavior particularly those, which contribute to the variations in adoption of improved maize varieties among farmers and which has impact on food security in the study area was considered. Hence, the conceptual framework presented in figure 1 below shows the most important variables expected to influence the adoption of improved maize varieties in the study area.

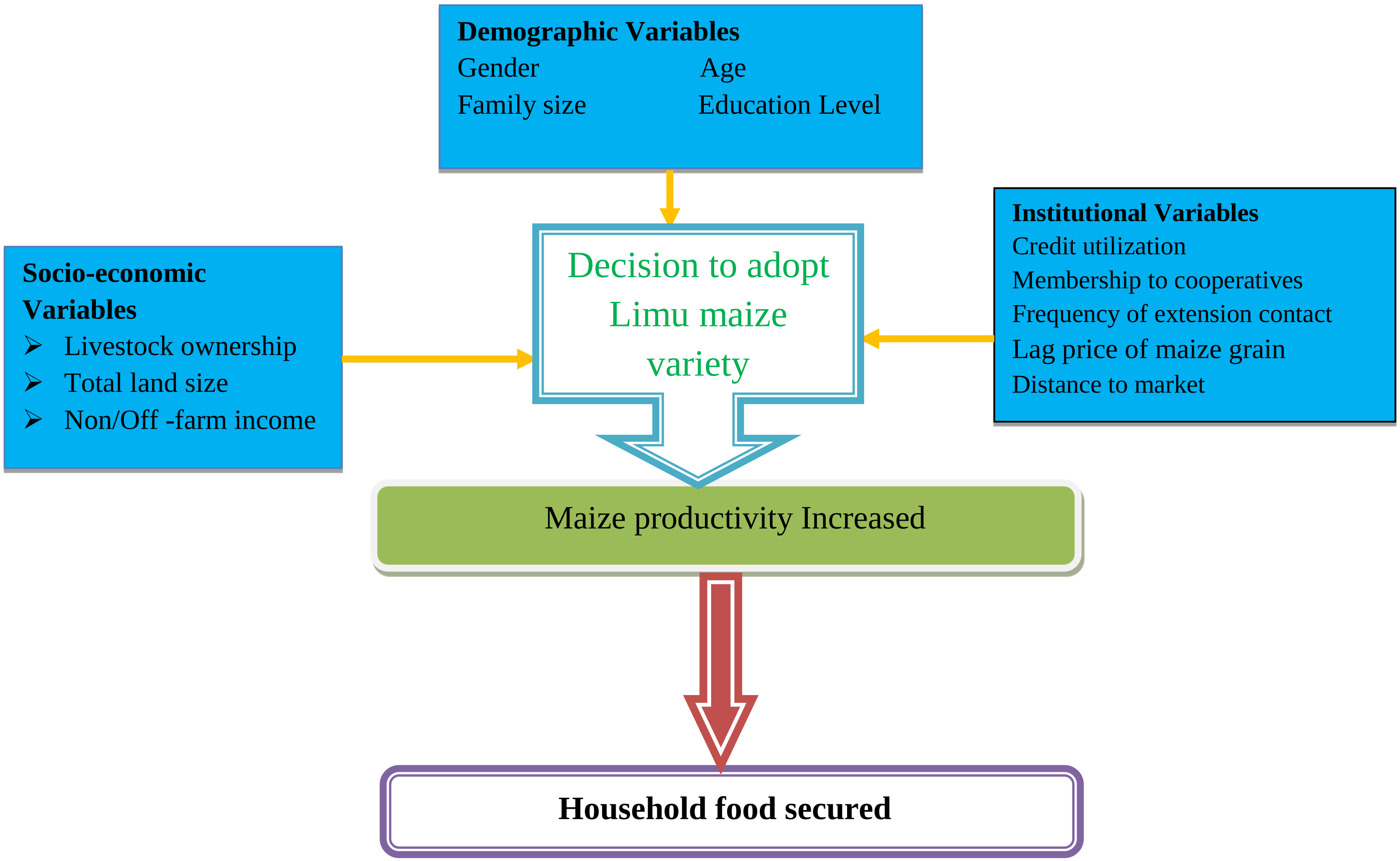


Figure 1 Conceptual framework of the study
Source: adopted from literature review

3. RESEARCH METHODOLOGY

In this chapter, description of the study area, sampling method and sample size, data type, data sources and method of data collection, method of data analysis, and description of variables and hypothesis are presented.

4.1.Study Area Description

The study was conducted at Dalle Wabara District of Kellem Wolega Zone, Oromia National Regional State of Ethiopia. The district has 22 rural and 2 town Kebeles administrations with a total of 24 Kebele administrations.

Dalle Wabara district is located at 549 km distance from Addis Ababa, along the direction of western Ethiopia and lies within the Abay Valley drainage system. The district bordered on the east by Dalle Sadi District, on the Southwest by Yamalegi Walal, on the Northwest by the Sadi Chanka, and on the northeast by the Gawo Dale districts. It has an area of 1,949.85km^2 before Gawo Dale and Sadi Chanka Districts were separated from it. Altitude of the Dalle Wabara district is lying between 1200 to 2200masl with an average altitude of 1700masl (Gemtessa and Dera, 2017). Annual rainfall varies from 1200 mm in the extreme south low land to 1800 mm in the high land with the average being 1500 mm (Gemtessa and Dera, 2017). Daily temperature in the Dalle Wabara district varies from 21^{o}c to 29^{o}c with an average daily temperature of 25^{0}c. Although detailed soil description is not available in the study area, two major soil types are dominant in the district: red soil covering about 80% of the woreda and black soil covers 17% and others 3% (DWANRO, 2019). The 2007 national census reported a total population for this woreda was 105,708, of whom 53008 were men and 52,700 were women; 14,105 or 13.51% of its population were urban dwellers. The majority of the inhabitants were Protestants, with 49.57% while 31.86% were Islam, and 18.27% observed Ethiopian Orthodox Christianity (CSA, 2007).

The economic base of the district is agriculture. The sector is rain-feed and is characterized by low productivity. The majority of the residents depend on agriculture for their livelihood. Individual small holder farms are the sole and dominate production units. Moreover, the sector is characterized by low use of farm inputs, traditional farm practices, poor soil fertility and related problems. The agro climatic condition is favorable for growing diversified crops including annual and perennial crops. Maize (Zeamays), Wheat (*Triticumaestivium)*, Teff (*Eragrostisteff*), Sorghum and finger millet are major cereals crops grown by the farmers. Coffee is the major cash crops produced in the district. Fruits and vegetables have been grown by some farmers for food and income. Irrigated agriculture using streams and springs is limited and practiced by a few farmers to grow vegetables and maize for House hold consumption and for local market (DWANRO, 2019).

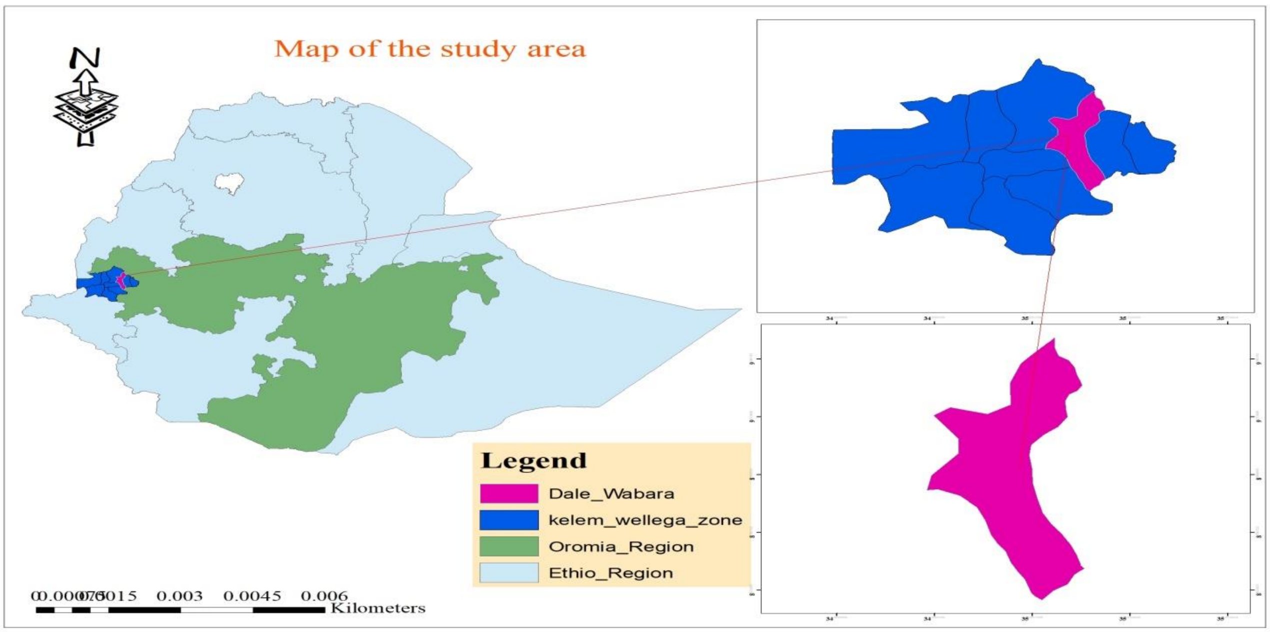


Figure 2: Map of Study Area

Source: From Ethiopian GIS

4.2.Data Types and Sources

Both quantitative and qualitative data were collected from both primary and secondary sources on a wide variety of variables. The primary data was collected through individual interviews of selected respondents and the survey was administered using structured questionnaires within individual interview. The survey collected information on several factors including household demographic characteristics (family sizes, age and sex, educational level, etc.), socio economic factors and institutional factors were included in the data.

To complement the primary data, secondary data were obtained from different unpublished and archival sources such as articles, official reports of relevant stakeholders, CSA report data and personal communications.

4.3.Sampling and Sample Size Determination

The study was done at Dale Wabera district based on cross-sectional data of the production year 2019. Multi-stage sampling techniques were applied to select the sample households. In the first stage, purposive selection of Dalle wabara district was undertaken based on infrastructural accessibility and agro-ecological suitability for maize production. In the second stage, four kebele administrations namely; Kara Jeno, Meki Dimbar, Sago Adami and Dogano Bile kebele administrations were randomly selected. Finally, farm household heads were selected using systematic random sampling technique by taking into account proportional to size of the population.

The sample size of the household heads for this study was determined using simplified formula provided by Yamane (1967) to determine the required sample size at 95% confidence level.

$$n = \frac{N}{1+N(e)^2} = 319 \qquad \text{Where N=1593} \qquad e = 0.05$$

Table 1: Samples and Sample size

No	Name of kebeles	Total HH	Non-adopters		Adopters		Total sample
			Total non-adopters HH	Sample	Total adopters HH	Sample	
1	Meki Dimbar	430	227	45	203	41	86
2	Sago Adami	425	218	44	207	41	85
3	Kara Jeno	399	203	41	196	39	80
4	Dogano Bile	339	168	33	171	35	68
	Total	**1593**	**816**	**163**	**777**	**156**	**319**

4.4.Method of Data Collection

Primary data were collected through various data collection instruments such as household surve y, Focus Group Discussion and Key Informant interview.

To generate quantitative and qualitative information at household level, household survey was undertaken by using structured questionnaire. Four enumerators, one for each peasant administrations were employed based on their ability of local language and culture, and experiences in data collection. Training was provided to the enumerators on the procedure to follow while conducting interview with respondents and deep discussion was also held to make the questionnaire clear to them.

The Four focus group discussions (FGD) were conducted with members those who were not involved in the individual household interview. Four focus group discussions, one at each study kebele administrations were conducted and each focus group discussions comprised five to eight individuals. The output of the discussion was used to get additional supporting qualitative evidence on the current situation of household food security and challenges that farmers have faced in adoption of improved maize variety in addition to the information from the survey question.

The primary data collected from sample households need to be further enriched by additional information gathered through key informant interviews. The key informant interview was conducted with two experts from Agricultural and rural development office and one development agents (DA) from each kebele administrations was included as a key informant interview.

4.5.Methods of Data Analysis

Quantitative data were analyzed using descriptive and inferential statistical tools. Mean, percentages and standard deviations were used to describe important variables, while inferential statistics such as chi square and t-test were also applied to test the statistical significance of the dummy and continuous independent variable respectively. The t-test was used to examine the mean difference between adopters and non-adopters with respect to certain continuous variables.

Double hurdle model was used to identify the major determinants of adoption decision (first hurdle) and use intensity of LMV adoption (the second hurdle). Propensity score matching (PSM) was applied to assess the effects of Limu maize variety adoption on rural household food security. Moreover, qualitative data collected from focus group discussions and key informant interview were analyzed by narrative explanation to complement quantitative data.

Before conducting model analysis, the problem of the multicollinearity was checked using Variance Inflation Factor (VIF) and Contingency Coefficients (C) in this study. The Variance Inflation Factor (VIF) was used for continuous explanatory variables. As a rule of thumb the value of VIF exceeds 10, it is used as a signal for existence of strong multicollinearity between continuous explanatory variables. Contingency Coefficients (C) was used for dummy variables. It is computed for each pair of qualitative variables. Contingency Coefficient value ranges between 0 and 1, and as a rule of thumb variable with Contingency Coefficient below 0.75 shows weak association and a value above it indicates strong association of variables.

Finally, the parameters were estimated by maximum likelihood technique with the help of (SPSS ver. 20, STATA version 14 and Ms excel).

4.5.1. Econometric model specification

Double hurdle model specification

Double hurdle model were employed to analyze determinants of LMV adoption and intensity of LMV adoption. The coefficients for the two dependent variables were absolutely different and their significant variables were not the same for the two dependent variables. Therefore, the Double hurdle model was selected and used for the sake of analyzing the determinants of adoption decision (first hurdle) and use intensity of LMV adoption (the second hurdle).

Intensity of Limu maize variety adoption by the farmers was measured in terms of the proportion of land used allotted for LMV by farmers. Therefore, this variable (proportion of land under LMV) is continuous limited dependent variable. It can be zero or some value greater than zero. Truncated regression as one part of double hurdle model has been used in estimating the intensity of farmers' LMV adoption by using the data that is truncated from below with the lower limit of proportion of maize land used.

Based on Burke (2009) the double hurdle model with the two parts is specified using two different latent variables, to model each decision process, with a probit model to determine adoption decision and a truncated regression model to determine the intensity of LMV adoption.

Adoption decision is specified as follows:

$$Y_{i1}^{*} = X_1ß_1 + \mathcal{E}_{i1}, \mathcal{E}_{i1} \sim N(0, \delta_1^2)$$

$$Y_{i1}^{*} = \begin{cases} 1, if\ Y_{i1}^{*} > 0 \\ 0, if\ Y_{i1}^{*} \leq 0 \end{cases} \quad \ldots\ldots (1)$$

Intensity of adoption equation is specified as:

$$Y_{i2}^{*} = X_2ß_2 + \mathcal{E}_{i2,} \mathcal{E}_{i2,} \sim N(0, \delta_2^2)$$

$$Y_{i2} = \begin{cases} X_2ß_2 + \mathcal{E}_{i2,}, if\ Y_{i1} = 1\ and\ Y_{i2}^{*} > 0 \\ 0,\ \ if\ Y_{i2}^{*} \leq 0 \end{cases} \quad \ldots\ldots (2)$$

Where Y_{i1}^{*} is unobserved (latent) variable for the adoption decision of farmers,

Y_{i1} is the observed discrete decision of the farmer whether he/she has participated or not adoption decision of farmers,

The subscript i refer to the ith household,

The subscript 1 and 2 refers to the variable and parameters related with the adoption equation and the intensity of adoption decision of farmers, respectively.

X_1's are the index of explanatory variables determining adoption decision of farmers,

$ß_1's$ refers to the index of parameters related with explanatory variables determining adoption decision of farmers,

$\mathcal{E}_{i1}$ is the error term of the adoption equation which is normally distributed

$\mathcal{E}_{i1} \sim N(0, \delta_1^2)$ with zero mean and constant variance,

Y_{i2}^{*} is unobserved (latent) variable for the intensity of adoption decision of farmers,

Y_{i2} is the observed actual proportion of land allocated for Limu maize variety,

X_2's are the index of explanatory variables determining the intensity of adoption decision of farmers,

$ß_2's$ refers to the index of parameters related with explanatory variables determining intensity of adoption decision of farmers,

$\mathcal{E}_{i2}$ is the error term of the intensity of participation equation which is normally distributed

$\mathcal{E}_{i2,} \sim N(0, \delta_2^2)$= with zero mean and constant variance,

Analysis of marginal effects of adoption decision (probit part of double hurdle)

The marginal effects that would be determined from the estimation of probit part of double hurdle model in this particular study interest can be determined by using the formula of partial derivations/ partial effects based on Burke (2009).

The marginal effect, the effect of a unit change or discrete change in explanatory variables on the probability of participating in small-scale irrigated farming can be given as follows.

$$\frac{\partial p(y_{i1}=\frac{1}{x_i})}{\partial x_j} = ß_j \ \Phi(Xß) \ldots\ldots \text{(3)}$$

Where $ß_j$ is the coefficient on x_j and $\Phi(Xß)$ is the standard normal probability density function evaluated at $(ß_0 + ß_1X_1 + ß_2X_2 + ß_2X_2 + \cdots)$

Propensity score matching (PSM) specifications

In this study, propensity score matching has been used to analyze the impact of Limu maize variety adoption on rural households' food security. PSM constructs a statistical comparison group based on a model of the probability of adopting Limu maize variety, using observed characteristics. Then adopters were matched to the non-adopters group based on the probability of adopting Limu maize variety. Since matching adopters to non-adopters on each covariate was practically difficult, propensity score was predicted based on observed characteristics of adopters and non-adopters. Then, the average treatment effect of Limu maize variety was calculated as the mean difference in outcomes between these two groups (Rosenbaum and Rubin, 1983).

In order to estimate the average treatment effect on treated (ATT) by using PSM method the following steps such as estimation of the propensity scores, choosing a matching algorithm, checking on common support region, testing the matching balance and sensitivity analysis were followed.

The impact of Limu maize variety adoption on rural households' food security was explained as:

τi =Yi (Di=1)-Yi (Di=0) ……………………………………………………… (4)

Where τi effect because of Limu maize variety adoption, Yi is the outcome (the impact of Limu maize variety adoption on the rural household's food security) and Di is whether rural household i adopt Limu maize variety or not. However, Yi (Di=1) and Yi (Di=0) cannot be occurred simultaneously for the same individual at the same time. Based on this the condition household in the treatment either Yi (Di=1) or Yi (Di=0) is unobserved outcome. Hence, analyzing individual treatment effect τi is difficult. Therefore, estimating the average treatment effects of the population than the individual person was very important. Among the average treatment effect, average treatment effect on treated (ATT) was one of the most commonly used in impact assessment (Heckman *et al.,* 1998), and it was described as

τ_ATT=E (τ/D=1) =E[Y (1)/D=1]-E[Y (0)/D=1] …………………… (5)

Here the outcome variable of adopter households, E[Y (1)/D=1] is observed. However, the outcome variable of adopter households had they not adopted, E[Y (0)/D=1] is not observed. Hence, substituting the outcome (total Kcal/AE/day of adopter households had they not adopted) E[Y (0)/D=1], for outcome (total Kcal/AE/day of non-adopter households) is impossible in non-experimental impact assessment. This means that, the total Kcal/AE/day of households from adopter and non-adopter would differ even in absence participation, this leading to a self-selection bias. By deducting E (Y0/D=0 from the left and the right side of the equation we can specify the average treatment effect on treated as follow:

E[Y(1)/D=1]=E[Y(0)/D=1]-E[Y(0)/D=0]=τ_ ATT+ E[Y(0)/D=1]- E[Y(0)/D=0]……….(6)

In this case, the terms in the left side are observables and the average treatment effect on treated can determined if and only if E[Y(0)/D=1]- E[Y(0)/D=0] zero. This occurs when there is self-selection bias. In order to resolve the selection matter in non-experimental impact studies the following two assumptions are required.

Conditional independence assumption: It indicates the outcomes are independent of treatment and conditional on (Xi). This assumption shows that the selection is only depend on observable characteristics that affect both participation decision of households and the outcome variables simultaneously (Caliendo and Kopeinig, 2008).

Common support: Is refers to the area in which both participant and non-participant households have propensity score values in common. In other words, it is the area which contains the minimum and maximum propensity score of participant and non-participant groups, respectively. Those observations whose propensity scores is smaller than the minimum and larger than the maximum are discarded from the treatment and control groups (Caliendo and Kopeinig, 2008).

That is $0<P(D=1)/X<1$. Given these two assumptions, the propensity score matching algorithm to estimate ATT can be described as:

$E[Y(1)/D=1]=E[Y(0)/D=1]-E[Y(0)/D=0]=\tau\_ATT+E[Y(0)/D=1]-E[Y(0)/D=0]$ ………(7)

Where, P(X) is the propensity score calculated from covariate X. Equation is explained as; the PSM estimators is the difference between mean of outcomes over common support region.

4.6.Variables Selection, Definition and its Measurement

Dependent variable

Adoption decision

The dependent variable has dichotomous in nature representing farmer's adoption decision on improved maize varieties, taking values, 1 for household who adopt Limu maize variety and 0 otherwise. In this paper, a farmer household is categorized as an adopter if she/he used Limu improved maize variety in last three years from 2017 to 2019 production seasons and non-adopters are a household who have not used these seed in the last three years in the same period.

Intensity of LMV adoption by households

This variable is a continuous variable measured in terms of proportion of land under LMV. It represents the actual proportion of land under Limu maize seed by the households in 2018/2019. It takes zero value if the farmer is non-adopter and takes continuous value greater than zero if the farmer is adopter.

Outcome variable: Daily calorie intake per adult equivalent is the outcome variable of the study. To measure food security status of household in the study area, information concerning type and amount of food items consumed by each household in the seven days preceding the survey were collected from both adopter and non-adopter households. Then, the calorie content of food items consumed by sample households' was calculated using calorie conversion factor per adult equivalent. Finally, the amount of total calories consummation of each sample household was computed and divided to seven days and to Adult Equivalent (AE) of respective household (Hoddinott, 2001).

Independent variables

The literatures reviewed generally indicate that the number of independent variables can influence households' adoption decision and intensity of Limu maize variety adoption. These include; demographic, socio economic and institutional factors. The effects of some of these are defined and hypothesized as follows:

Gender of Household Head (GENDER): is a dummy variable which takes up a value of "1" if the household head is a male and "0" if the household head is female. In most cases male headed households are more likely to adopt new technologies than female headed households. This may be due to relatively better access of male-headed households to information and agricultural resources than females' household heads (Mulugeta *et al*., 2000; Adugna, 2002; Bayissa, 2010). Gender is, therefore, expected to positively influence adoption decision and intensity of Limu maize variety adoption.

Age of Household Head (AGE): This variable refers to the chronological age of household head at the time of the survey; it is continuous variable and is measured in years. There is negative relationship between age of the household head in years and the adoption of improved maize varieties. This may be due to the fact that, older farmers are more careful as they fear risk (Habtemariam, 2004). Therefore, age is expected to affect adoption decision and intensity of Limu maize variety adoption negatively.

Family size (FAMSZ): refers to the number of members who are currently living within the family. This variable is continuous variable measured in adult equivalent. Availability of labor in the household is one of the important resources in maize production. It is positively related with the speed of adoption of improved maize variety. This suggests that large family size provides more labor for farm operation and an increased incentive to produce more output on farm (Motuma *et al.*, 2010; Abadi *et al.*, 2015). Thus, family size is hypothesized to have positive effect on adoption decision and intensity of Limu maize variety adoption.

Level of education (EDULEVEL): is continuous variable measured in years of schooling. Farm households with more educated heads tend to adopt improved maize varieties. Farmers with higher levels of education, therefore, are more likely to adopt improved maize varieties than those who do not (Moti *et al.,* 2015). Education augments one's ability to receive, decode and understand information relevant to making innovative decisions (Wozniak, 1984). This creates an incentive to acquire more information. Farmers with more education have aware of more information sources and more efficient than those with less education in evaluating and interpreting information about new technologies (Gishu *et al.*, 2018). Therefore, education is expected to positively influence adoption decision and intensity of Limu maize variety adoption.

Livestock ownership (TLU): is continuous variable measured in Tropical Livestock Unit; where those who possess livestock will be expected to adopt IMVs' than those have not. In rural context, livestock holding is an important indicator of household's wealth position. Livestock serves as an important source of cash and insurance for risks (Yishak and Punjabi, 2011; Gishu *et al*., 2018). Therefore, livestock is expected to have positive effect on adoption decision and intensity of Limu maize variety adoption.

Total land size (FARMSIZE): is a continuous variable measured in hectare. It includes cultivated and uncultivated land for annual crops, permanent plants, grazing, and homestead in the cropping year. Land is an indicator of wealth and social status and influence within a community. This means that farmers who have relatively large land size would be more initiated to adopt the improved varieties (Yishak and Punjabi, 2011). Land size influences the adoption of improved maize varieties positively as those operating on larger farms tend to have greater financial resources, incentives and more land to allocate to the high yielding seed varieties (Wubeneh and Sanders, 2006; Beshir *et al.*, 2012). Hence, it expected that farm land holding size affects adoption decision and intensity of Limu maize variety adoption.

Cooperative membership (MCOOP): It is a dummy independent variable represented by 1 if the household head is a member in the farmers' cooperatives and 0, otherwise. Belonging to cooperative as member can influence farmers' decision to adopt improved maize varieties (Motuma *et al.* 2010). Thus, being a participant in famer associations is expected to affect adoption decision and intensity of Limu maize variety adoption.

Frequency of Extension Agents' contact (EXTENSION): it is a continuous variable that shows frequency of farmers visited by extension agents per year. Extension contact has the package such as advice, training, information, demonstration and distribution of agricultural input. Many adoption studies such as Feleke and Zegeye (2006) and Gishu *et al.*, 2018) have showed that frequency of extension contact increases farmers' adoption decision of improved maize varieties. This implies that respondents who highly contact with development agents have more chance to adopt the improved maize variety. Thus, frequency of extension contact is hypothesized to have positive influence on farmers' adoption decision and intensity of Limu maize variety adoption.

Credit utilization (CREDIT): It is a dummy variable, which takes a value 1 if the households are credit user or 0, otherwise. This variable is measured in terms of whether respondents are credit user or not. Farmers who are credit users may overcome their financial constraints and therefore be able to buy maize seeds and other farming inputs. Farmers without cash may find it very difficult to attain and adopt improved maize seeds (Taha, 2007; Sisay, 2016). Hence, using credit is hypothesized to positively influence farmers' adoption decision and intensity of Limu maize variety adoption

Off/non-farm income (INCOME): It is a dummy variable, which takes a value 1 if the farm households have off/non-farm income or 0, otherwise. It represents the activities other than the farm activities such as crops and livestock. The availability of non-farm income affect the probability of adoption positively since it can increase the farmer's financial capacity to pay for improved inputs (Getachew *et al.,* 2010; Dawit *et al.,* 2014). Therefore, availability source of household off/non-farm income is expected to increase probability of adoption decision and intensity of Limu maize variety adoption.

Distance to main markets (DISTANCE): It is a continuous variable measured as the walking distance in kilometer that the household travel to reach the main market. Farmers living nearby market are better adopters can easily buy improved seeds at lower transaction (Abadi *et al.,* 2015). Therefore, being far away from market is hypothesized to have a negative impact on the adoption decision and intensity of Limu maize variety adoption.

Lag price of maize grain (PRICE): It is a continuous variable measured in birr per quintal of maize grain that the household sold at the market in 2018 production year. High price of improved maize grain is hypothesized to be a positive contribution to the adoption decision and intensity of Limu maize variety adoption.

Table 2: Summary of Variables selection, definition and its measurement

No	**Variables**	**Type of Variable**	**Measurement & definition**	**Hypothesis**
I	Limu maize variety adoption	Dummy	1 if adopters otherwise 0	
	Intensity use of LMV adoption	Continuous		
II	Outcome variable	Continuous	HH daily calorie intake per AE	
1	Gender	Dummy	1 if male otherwise 0	+Ve
2	Age of HH	Continuous	Year	-Ve
3	Education of HH	Continuous	Year of schooling	+Ve
4	Family size	Continuous	Adult equivalent	+Ve
5	off/non-farm income	Dummy	1 for those have Non/Off farm income or 0 otherwise	+Ve
6	Cooperative membership	Dummy	1 if yes or otherwise 0	+Ve
7	Credit utilization	Dummy	1 if credit user otherwise 0	+Ve
8	Frequency of Extension contact	Continuous	Number per year	+Ve
9	Distance to the market	Continuous	Km	-Ve
10	Total livestock ownership	Continuous	TLU	+Ve
11	Total land size	Continuous	Hectare	+Ve
12	Lag Price of Maize Grain	Continuous	ETB	+Ve

Source: Author definition

5. RESULTS AND DISCUSSION

This section consists of four sub-sections. The first one is description of sample households' characteristics. The second sub-section is about the determinants of adoption. The third sub-section is about the determinants of use intensity of adoption. The fourth one is about estimation results of impact of Limu maize variety adoption on rural household security.

5.1.Descriptive Results

Table 3 presents the characteristics of respondents for continuous variables regarding household demographic characteristics. The average age of the household head was 41 years for adopters while, the mean age of non-adopters was 46 years. The t-test result shows that, the age of adopters is significantly lower (at 1% significance level) than that of non-adopters. The average family size of the household was about 5 adult equivalents for adopters and 4 for non-adopters of Limu maize variety. The t-test result indicated that there was a significant difference between the average family size of adopters and non-adopter households at 1% significance level. Similarly, adopter households have significantly more years of schooling (7.22 years) than non-adopter households (4.37 years) suggesting that there is a positive correlation between adoption and the number of years of formal education. The t-test indicated that, from sampled household the mean differences of year of schooling between adopter and non-adopter of Limu maize variety were found to be statistically significant at 1% probability level.

As depicted in table 3, adopters and non-adopters of Limu maize variety owned, 10.14 and 7.88 tropical livestock units (TLU). Meanwhile, the average farm size was 4.86ha and 2.07ha for adopters and non-adopters respectively. The t-test result revealed that the size of the livestock and farm size owned by adopters is significantly higher than that of the non-adopter households at 1% significance level.

In terms of social services, the average frequency of extension contact in a year was 3.97 for adopters and 3 for non-adopters of Limu maize variety. Meanwhile, the average distance to main market were 6.77 and 7.21 for adopter and non-adopter household respectively. The overall average walking distance to the main market for sampled household was about 6.9Km. The t-test indicated that, the mean difference for frequency of extension contact was significant between adopter and non-adopter of Limu maize variety at 1% significance level (Table 3).

Table 3 below revealed that, lagged price of maize grain (price of maize grain in 2018) for adopters household was 693.59 ETB, while that of non-adopters were 670.5 ETB. The result of the t-test confirmed that there is no significant difference between adopters and non-adopters selling price of maize grain.

Table 3: Description of households with continuous variables

Variable	Adopter		Non adopter		Overall		t-test
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. De v	
Age of the household head	41	10.59	46	13.61	44.2	12.5	4.09*
Family saize	4.86	1.7	3.64	1.6	4.24	1.7	6.6*
Education level of the household head	7.22	4.06	4.37	4.1	5.8	4.3	6.25*
Livestock ownership	10.14	2.9	7.88	3.52	8.9	3.42	6.26*
Farm size	2.78	0.8	2.07	1.08	2.4	1.03	6.42*
Frequency of extension contact	3.97	2.34	3	2.06	3.47	2.26	3.94*
Distance to main market	6.77	2.46	7.21	2.1	6.9	2.29	1.71
Lagged price of maize grain	693.59	146.5	670.5	143.5	681.8	145.2	1.42

Note: Std. Dev = standard deviation, **source**: Own survey, 2020

The descriptive and inferential statistics results of dummy variables are presented in Table 4 below. The result indicated that 71% of the respondents were male-headed households and 29 % were female-headed households. Out of adopter households, 35.42% were male-headed households and 13.48% were female-headed households. From non-adopter household, male-headed households were 35.74% and female-headed households were 15.36%. However, the Chi2- test reveals that these associations were not significant.

Table 4 below revealed that 69.28% of sampled household were members of the cooperatives farmers union while 30.72% were not a member of farmers cooperatives. Among the member households, 38.87% were adopters whereas 30.4% are not adopters. From non-member households, 10.03% were adopter and 20.69% were non-adopters. Meanwhile, about 76.81% and 23.19% of the sample households were credit user and non-user respectively. Among user households, 38.24% were adopter and 38.87% were non-adopter. From non-user households, 10.66% and 12.53% were adopter and non-adopter households respectively. Similarly, 53.3% of the sample household heads were under the category of having off/non-farm income while 46.7% of household heads did not have off/non-farm income. The proportion of the household heads having off/non-farm income under the adoption category was 26.96%. On the other hand, the proportion of the household heads that did not have their own off/non-farm income under the non-adoption category was 24.8%. However, according to the results of the Chi2- test, being a member of farmers' cooperatives was significant at 1% significance level.

Table 4: Descriptive and inferential statistics of sample HHs (for dummy variables)

Variable		Adopter		Non adopter		Total		chi^2
		N	%	N	%	N	%	
Gender of the house hold head	Male	113	35.42	114	35.74	227	71.16	0.242
	Female	43	13.48	49	15.36	92	28.84	
Cooperative membership	Members	124	38.87	97	30.4	221	69.28	14.95*
	Non members	32	10.03	66	20.69	98	30.72	
Credit utilization	Credit user	122	38.24	123	38.87	245	76.81	0.34
	Non-user	34	10.66	40	12.53	74	23.19	
Off/non-farm income	Yes	86	26.96	84	26.3	170	53.3	0.41
	No	70	21.94	79	24.8	149	46.7	

***** shows that significance level at 1%, **Source**: Own survey, 2020

5.1.1. Adoption status of Limu maize variety in the study area

Table (5) presents reported adoption of Limu maize variety based on the household survey. The result of the study shows that 48.9% of respondent farmers in the study area had adopted the

Limu maize variety. Comparing with previous varietal adoption studies in Ethiopia, this result shows that, increased generation and dissemination of improved maize technologies by government and non-government organization as well as utilization of improved maize seed by maize growers in the past years. For instance, according to a survey conducted in 2013 by the Ethiopian Institute of Agricultural Research (EIAR) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT) about 31% of the sampled farmers planted improved varieties (De Groot *et al.*, 2014). Further, study by Moti *et al.* (2018) revealed that the adoption status of improved maize varieties by households was 27% in 2016 in Ethiopia. The result of the current study was more than the previous study due to the study area is known in maize production potential even from Ethiopia.

Table 5: Adoption status of household

Adoption status by household	Frequency	Percentage
Adopter	156	48.9
Non-adopter	163	51.1

Source: From own survey, 2020

5.1.2. Land allocated for Limu maize variety and its productivity in the study area

The mean area under Limu maize variety was about 1.17 hectare with standard deviation of 1.46. The maximum area allocated land for Limu maize variety was 4 hectare and minimum land allocated for Limu maize varieties was 0.25 hectare (Table 6). In addition, average productivity of the Limu maize variety was 37.9 quintals per hectare with standard deviation of 3.9 and the maximum and minimum productivity was 55 and 34 quintals per hectare respectively (Table 6).

Table 6: Maize yield obtained and land allocated to Limu maize seed in the study area

Variable	Mean	Std. Dev.	Min	Max
Land under Limu maize variety	1.17	1.46	0.25	4
Productivity	37.9	3.9	34	55

Source: Own survey, 2020

5.1.3. Food security status of households

Table 7 shows that, the descriptive result of the outcome variable food security status of sample household measured in daily kilo calorie intake per AE.

The mean kilo calorie intake per adult equivalent of adopter and non-adopter is 2555.87 and 2082.67 Kcal respectively. This clearly shows that adopter household consumed on average 473.2 Kcal above that of non-adopters. This result showed that, there is a significant difference between adopter households and non-adopter households in terms of kilocalorie intake per AE (Table 5). This is raised from direct relationship of maize productivity and food security in maize based systems. Because of increased maize productivity, adopter rural households can consume more than non-adopter households.

Table 7: Descriptive result of the outcome variable

Variable	Adopter (n=156)		Non adopter (n=163)		Overall		Mean difference	t-test
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev		
Kilocalorie intake (Kcal)	2555.87	360.06	2082.67	250.94	2314.1	389.1	473.2	13.6*

Source: from own computation, 2020

4.2. Econometric Results

4.2.1. Multicollinearity tests

Before data analysis, variables were tested for multicollinearity. According to Gujarati (2004), it is essential to omit variable with VIF value exceeds 10 that happens and show high correlation between variables. Accordingly, data checked for the occurrence of multicollinearity problem for continuous variables using Variance Inflation Factor (VIF). If the value of VIF exceeds 10, it is used as a signal for existence of strong multicollinearity between continuous explanatory variables. But the value of VIF for continuous variable is less than 10 (Appendix Table 4). The presence of multicollinearity is also checked for dummy variables by using Contingency coefficient. As a rule of thumb variable with Contingency Coefficient below 0.75 shows weak association and a value above it indicates a strong association of variables. Accordingly, the value Contingency coefficient is below 0.75 (Appendix figure 1). This means that, there is no sign of the presence of multicollinearity among the explanatory variables included in the model.

4.2.2. Determinants of Limu maize variety adoption

The 1st Hurdle (Probit) model was used to examine the factors affecting the adoption of Limu maize variety using Maximum Likelihood Estimation (MLE) and the results are presented in Table 8. The estimated 1st Hurdle (Probit) model indicated that six (6) of the twelve (12) explanatory variables significantly influenced Limu maize variety adoption. Those are family size, education level of household head, livestock ownership, farm size, Membership in cooperative and the frequency of extension contact. The results in Table 8 reveal a number of significant and insignificant covariates of Limu maize variety adoption.

Table 8: Marginal effect estimates of 1st Hurdle (Probit) model.

Variable	Coef.	Std. Err.	z	P>z	dy/dx
Gender of the household head	0.2273	0.0707	1.27	0.203	0.0900
Age of the household head	-0.0062	0.0042	-0.60	0.550	-0.0025
Family size of the household	0.1989	0.0195	4.07	0.000	0.0792***
Education level of the household head	0.0784	0.0125	2.49	0.013	0.0312**
Livestock ownership	0.0897	0.0115	3.11	0.002	0.0357***
Total land size	0.1757	0.0356	1.99	0.047	0.0699**
Being membership in cooperative	0.5564	0.067	3.23	0.001	0.2163***
Frequency of extension contact	0.0834	0.0146	2.27	0.023	0.0332**
Credit utilization	0.0823	0.0779	0.42	0.674	0.0327
Off/on farm income	0.0576	0.0655	0.35	0.726	0.0229
Distance to main market	-0.0457	0.0145	-1.25	0.210	-0.0182
Lagged price of maize grain	0.0007	0.0002	1.33	0.183	0.0003
Number of observation	319	Prob > chi2	0.0000	Log likelihood	-161.33
LR chi2(12)	119.41	Pseudo R2	0.2701		

*** and ** means significant at the 1% and 5% respectively, **Source**: Own survey result, 2020

Family size: This variable significantly affects Limu maize variety adoption positively as expected at 1% significance level. This implies that adopters do have more labor than non-adopters and more family size will encourage use of the Limu maize variety. Marginal effects of the variable indicates that other factors being constant, Limu maize variety adoption increased by 7.9% as family size of household increase by one adult equivalent. This suggests that large family size provides more labor for farm operation such as planting, drilling and weeding and an increased incentive to produce more output on the farm. It is obvious that, the agriculture in the study area is labor intensive. This increases the importance of family size as a source of labor in adoption of Limu maize variety. This result is also in agreement with previous empirical findings such as (Arega *et al.,* 2000; Moti et al., 2015; Abadi *et al*., 2015).

Education level of household head: as expected, education level of the household head positively and significantly influences the adoption of Limu maize variety at 5% significance level. Marginal effects of the variable indicates that other factors constant, Limu maize variety adoption increased by 3.1% as the education level of household head increase by one year. Education creates awareness and helps the farmers to develop positive attitudes towards adoption of new technology (Limu maize variety) and ready to take the risk of new farming practices as well as helping farmers to understand and interpret different information. This result is in line with the finding of (Motuma *et al.*, 2010; Khonje *et al.*, 2015).

Livestock ownership: As hypothesized, this variable significantly and positively affects adoption of Limu maize variety at 1% significance level. Marginal effects revealed that at an increasing livestock ownership in TLU, adoption of Limu maize variety increased by 3.5%. This implies that, adopters have more access to financial capital by selling their livestock to purchase Limu maize variety from the suppliers. This means that, those farmers who owned more livestock have a better chance to adopt Limu maize variety. This might be due to fact that livestock is an important source of food and draft power as well as livestock represents an asset, which indicates the wealth and social status of the household and eases financial constraints. Livestock are also a source of additional income which supports farmers in buying the improved varieties and farm inputs. This is in line with the study by (Abadi *et al.,* 2015; Gishu *et al.,* 2018)

Total land size: The result is as expected, total land size has a positive and significant relationship at the 5% significant level and the result indicates that as land size increases by one hectare, the propensity of adopting Limu maize variety increases by 6.9%, holding other variables constant, confirming the expectation that owning more land is correlated with higher adoption rates. Land is one of the most important resources for agricultural production since the livelihood of rural people is highly dependent on it. This suggests that a farmer having more land size could lead to the higher possibility to use limu maize variety to increase production. This result is consistent with earlier findings (Yishak and Punjabi, 2011; Moti *et al.*, 2015; Khonje *et al.*, 2015; Musa *et al.* 2017).

Cooperative membership: as proposed, being a member of farmers' cooperatives positively and significantly influences the probability of Limu maize variety adoption at 1% significance level. Other things held constant, as a farmers becomes a member of farmers' cooperatives, Marginal effects in favor of adopting Limu maize variety increases by 21.6%. Membership to cooperative makes farmers to have more access to input and information. The result obtained from focus group discussion revealed that cooperatives are the major sources of Limu maize seed and other farm inputs. Member of FGD reported that they obtain seed from nearby local primary cooperatives. This implies that the importance of membership to the cooperatives is related to the access to inputs and information that cooperatives create for members. This finding is confirmed with (Motuma *et al.,* 2010).

Frequency of extension contacts: model output shows that the households' frequency of extension contact per year had positively and significantly influenced the likelihood of adoption of Limu maize variety at a 5% significance level. Extension contact is a necessary catalyst to technology adoption as it is the major source of agricultural information in Ethiopia. Marginal effects indicated in the model with regard to frequency of extension contact implies that, other thing being held constant, the favor of adopting Limu maize variety increases by 3.3% as farmers get contact with extension agents. Therefore, respondents who highly contact with extension agents have more chance to adopt the Limu maize variety in the area. The result obtained from key informants interview revealed that farmers' those have more contact with extension agents initiated to attend farmers' training; improved their knowledge and skills on farming practices as well as they improve their utilization of improved maize variety. This agreed with receiving training and advice from development agents and the perceived usefulness of development agents' advice are major factors that explain the likelihood of Limu maize variety adoption and rate of input use. The finding of this research result is also in lined with the research result reported by (Arega *et al.,* 2000).

4.2.3. Determinants of intensity of LMV adoption

The intensity of LMV adoption was one of the dependent variables in this study. Therefore, factors determining the intensity of LMV adoption in the study area were analyzed using the truncated part of double hurdle model. The result is presented on Table 9. The factors that were found to have significant determining power on the intensity of LMV adoption were four variables, out of 11 explanatory variables included in the model. These significant variables that determine the intensity of adoption were livestock ownership, being membership in cooperative, market distance and frequency of extension contact.

Table 9: Results of 2nd Hurdle (Truncated regression) model

Land under LMV in hectare	**Coef.**	**Std. Err.**	**Z**	**P>z**
Gender of the household head	0.2852	.2306	1.24	0.216
Age of the household head	-0.0001	.0131	-0.01	0.993
Family size of the household	0.0405	.0615	0.66	0.510
Education level of the household head	0.0115	.0354	0.32	0.745
Livestock ownership	0.0636	.0373	1.70	0.088*
Being membership in cooperative	0.6734	.2598	2.59	0.010**
Frequency of extension contact	0.0731	.0438	1.67	0.095*
Credit utilization	-0.0275	.2449	-0.11	0.911
Off/on farm income	0.2067	.2032	1.02	0.309
Distance to main market	-0.1585	.0437	-3.63	0.000***
Lagged price of maize grain	0.0007	.0007	1.04	0.297
Log likelihood	-226.95		Wald chi2(11)	33.79
Number of observation	156		Prob> chi2	0.0004

***, ** and * means significant at the 1%, 5% and 10% respectively, **Source**: Own survey result, 2020

Livestock ownership (TLU): This variable was found significantly and positively determined the intensity of adoption at 10% significance level. This implies that, all other factors being kept constant, the proportion of land under Limu maize variety increases by about 0.064ha, as the livestock owned by the household increases by one TLU. Implying that, farmers with more livestock holding are more likely to allot significant amount of land for LMV than those households with less livestock holding. The plausible reason for this is that a household with large livestock holding can obtain more cash income from the sales of animal products and then able to purchase farm inputs. This is consistent with the studies by Tesfaye *et al.* (2011), Hassen (2014); Aman and Tewodros (2019).

Being member of farmers' cooperative: also appears to positively influence the intensity improved maize adoption. It was statistically significant at 5% level. Being member of cooperative union increases land allocated for Limu maize variety by 0.67ha. This means that farmers who are cooperatives members allocate more hectare of land for Limu maize variety than farmers who are not members. This may be due to fact that, membership to cooperative makes farmers to have more access to input, information and better interpretation of available information related to new maize seed. Similar results were reported by Mmbando and Baiyegunhi (2016); Aman and Tewodros (2019).

Frequency of extension contact: found to be positive and significant at 10% significance Level, indicate that having more extension visits increases the land allocated for Limu maize variety by 0.07ha. This means that, the higher the extension contact, the higher the adoption of Limu maize variety. This is due to the fact that, frequency of contacts with extension agents increases the probability of acquiring up-to-date information on the new agricultural technologies. Further, the level of awareness and knowledge regarding the use of improved technologies for smallholder farmers associated with higher interaction between the farmer and extension agents. This result is in agreement with (Assefa and Gezahegn, 2009; Aman and Tewodros, 2019)

Distance to main market: was found negatively and significantly affected the intensity of adoption of Limu maize variety by the farmers at 1% significance level. Farmers closer to the main markets had allotting more land for Limu maize variety. These revealed that the one kilometer increase of the distance between farmers' home and the main market center would lower the land under Limu maize variety by 0.16ha.The implication of this negative relationship is that if the distance between farmers' living home and the market area is longer, the farmers will be discouraged from allotting more land for Limu maize variety. Proximity of farmers to main market center is essential in reduction of transport costs and to get market access for their output. This finding is consistent with the work of Solomon *et al.* (2012); Mariano *et al.* (2012) Dawit and Abduselam, (2018).

4.2.4. Impact of Limu maize variety adoption on households' food security

Estimation of Propensity Score

First each households' propensity score or probability of adoption has been estimated using binary logistic model where the dependent variable is the adoption status, which takes a value of 1 if a household is adopted of Limu maize variety and 0 otherwise.

The coefficients of binary logistic regression model have been used to generate propensity scores that can be further used for matching purposes. On the basis of the estimated propensity scores, 156 adopter households have been matched to 163 non-adopter households (control groups) that most resemble them. Twelve matching variables have been used in the model as explanatory variables. In doing so, the dependent variable was a binary variable taking a value of 1 for adopter household or 0 otherwise. Results presented in appendix table 7 shows the estimated model appears to perform well for the intended matching exercise. The rationale for PSM is help to compare households; those are adopters of Limu maize variety with non-adopter households. Besides, pseudo-R2 has been calculated. Pseudo-R2 indicates how well the regressors explain the participation probability. The pseudo-R2 should be low for a robust estimate of the model (Sianesi, 2004). Hence, the model is considered good since the estimated actual pseudo-R^2 is 0.2690 (appendix table 5).

Choosing matching algorithm

The next step in the calculation of the ATT is the choice of a matching algorithm. In matching Limu maize variety adopter with non-adopter households, different matching estimators were tried in the common support region. The choice of a matching estimator guided by different criteria such as equal means test (balancing test), low pseudo-R^2 for the overall balancing test and greater number of matched sample size are used to select the matching algorithm (Dehejia and Wahba, 2002). Balancing test refers number of explanatory variables with no statistically significant mean differences between the matched groups of treated and control households. Table 10 below shows that, the estimated results of tests of matching quality based on the above-mentioned performance criteria. When looking into the results, nearest neighbor matching bond width (2) is the best estimator for the data at hand based on the above criteria. Therefore, the following estimation results and discussion are the direct outcomes of the nearest neighbor matching band width (2).

Table 10: Performance criteria of matching algorithms

Matching estimators	Balancing test*	Pseudo-R2 after matching	Matched sample size
Nearest Neighbor (NN)			
Neighbor (1)	11	0.034	314
Neighbor (2)	12	0.024	314
Neighbor (3)	12	0.026	314
Neighbor (4)	12	0.026	314
Neighbor (5)	12	0.027	314
Caliper matching (CM)			
0.01	12	0.022	298
0.05	11	0.034	314
0.1	11	0.034	314
0.5	11	0.034	314
Kernel Matching (KM)			
With band width of (0.08)	11	0.028	314
With band width of (0.1)	12	0.028	314
With band width of (0.25)	11	0.039	314
With band width of (0.5)	7	0.071	314
Radius Matching			
With band width of (0.01)	5	0.261	314
With band width of (0.1)	5	0.261	314
With band width of (0.25)	5	0.261	314
With band width of (0.5)	5	0.261	314

Source: own compilation

Note: *Number of explanatory variables with no statistically significant mean differences between the matched groups of adopter and non-adopter households after matching.

Identifying common support condition

The common support region is the area which contains the minimum and maximum propensity scores of treatment and control group of households, respectively. Imposing a common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson *et al.*, 2002). Only the subset of the comparison group that is comparable to the treatment group should be used in the analysis, i.e., observations which lies outside this region are discarded from analysis (Caliendo and Kopeinig, 2008). According to the table 11 below Propensity Score for Limu maize variety adopter household is vary between 0.077 and 0.982 with mean score 0.655, whereas Score vary between 0.008 and 0.954 for non-adopter households with a mean of 0.329. Then the common support lies between 0.077 and 0.954. Accordingly, household with Propensity Score is less than 0.077 and greater than 0.954 is not considered for matching purposes. This is because no matches can be made to estimate the average treatment effects on the ATT parameter when there is no overlap between the treatment and non-treatment groups (Bryson *et al.*, 2002). For the sake of this restriction, 5 households all from adopter were discarded. This shows that the study does not have to drop many adopter households from the sample in computing the impact estimator.

Table 11: Distribution of Estimated propensity score of households

Group	Observation	Mean	SD	Min	Max
All households	319	0.489	0.287	0.008	0.982
Adopter households	156	0.655	0.227	0.077	0.982
Non-adopter Households	163	0.329	0.245	0.008	0.954

Source: own computation, 2020

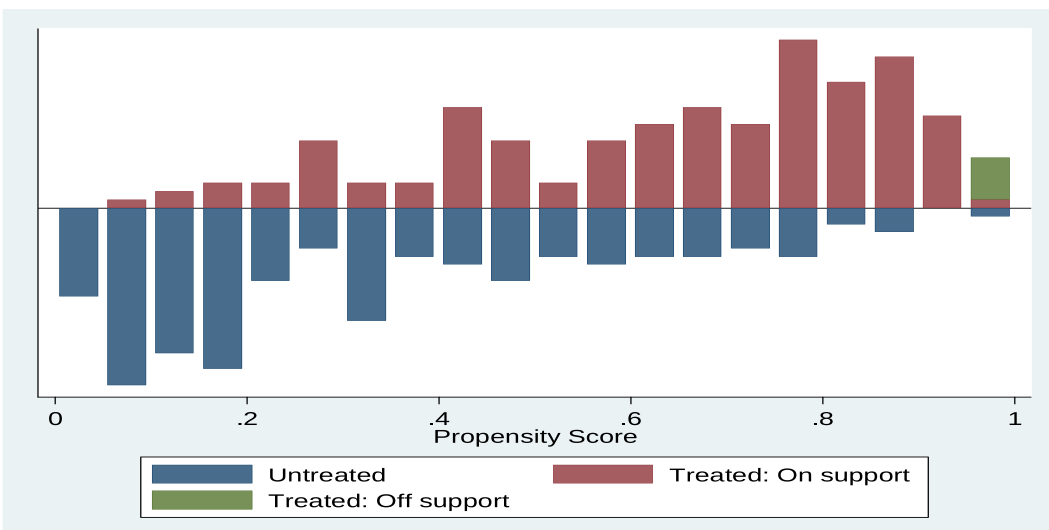
As shown in table 12, the total treated observation 5 households (1.57%) are off support, while 314 households (98.43%) are on support and all the control households are included in the common support region.

Table 12: Common Support region

Treatment assignment	Off support	On support	Total
Untreated	0	163	163
Treated	5	151	156
Total	5	314	319

Source: own computation

An important step in assessing the quality of matching is to perform tests that check whether the propensity score adequately balances characteristics between the treatment and comparison group units. Figure 3 below gives the histogram of the estimated propensity scores for adopter and non-adopters of Limu maize variety. A visual inspection of the density distributions of the estimated propensity scores for the two groups indicates that the common support condition is satisfied: there is substantial overlap in the distribution of the propensity scores of both adopter and non-adopter groups. The bottom half of the graph shows the propensity scores distribution for the non-adopters and the upper half refers to the adopters. The densities of the scores are on the y-axis.



Source: own compilation, 2020 **Figure 3:** Graph of common support region

Testing the balance of propensity score and covariates

After choosing the best performing matching algorithm and common support condition, the next step is checking the balancing of propensity score and covariate using different procedures by applying the selected matching algorithm. The balancing powers of the estimations are determined by considering different test methods such as the reduction in the mean standardized bias between the matched and unmatched households, equality of means using t-test and chi-square test for joint significance for the variables used.

Following Rosenbaum and Rubin (1985), the standardized difference has been calculated, that is, the size of the difference in means of conditioning variables (between the adopters and non-adopter). In the present matching models, the standardized difference in Z before matching is in the range of 5.5% and 73.9% in absolute value. Rosenbaum and Rubin (1985) recommend that a standardized difference after matching of 20% or more should be viewed as large. Accordingly, the remaining standardized difference of Z after matching for all covariates lies between 0.3% and 14.1% which is below the critical level of 20% (Table 13). In all cases, it is evident that sample differences in the unmatched data significantly exceed those in the samples of matched cases. The process of matching thus creates a high degree of covariate balance between the treatment and control samples that are ready to use in the estimation procedure.

In this study, nearest neighbor matching has been considered. The result indicates that before matching, several variables have exhibited statistically significant differences. However, after matching, the covariates in most cases have been balanced and no significant differences have been found. Since the mean difference for all covariates between treated and control group after matching has not been statistically significant (or if p-value computed after matching is >0.05) the matching has been considered valid match. Accordingly, using nearest neighbor matching has provided valid matching for all covariates.

Table 13: Propensity score and covariate balance

Variable	Unmatched	Mean		%bias	%reduct	t-test	
	Matched	Treated	Control		Bias	T	p>t
_pscore	U	0.655	0.329	137.8		12.29	0.000
	M	0.645	0.644	0.4	99.7	0.04	0.968
GENDER	U	0.724	0.699	5.5		0.49	0.624
	M	0.71523	0.668	10.2	-85.6	0.87	0.385

AGE	U	41.256	46.859	-45.9		-4.09	0.000
	M	41.397	39.983	11.6	74.8	1.16	0.248
FAMSZ	U	4.863	3.638	73.9		6.60	0.000
	M	4.807	4.691	7.0	90.5	0.60	0.548
EDULEVEL	U	7.224	4.3681	70.0		6.25	0.000
	M	7.053	7.0762	-0.6	99.2	-0.05	0.960
TLU	U	10.143	7.8803	70.2		6.26	0.000
	M	10.002	10.012	-0.3	99.6	-0.03	0.978
FARMSIZE	U	2.7804	2.072	72.2		6.43	0.000
	M	2.756	2.868	-11.4	84.2	-0.91	0.363
MCOOP	U	0.795	0.595	44.3		3.95	0.000
	M	0.78808	0.765	5.1	88.4	0.48	0.630
EXTENSION	U	3.974	3	44.1		3.94	0.000
	M	3.901	4.017	-5.2	88.1	-0.46	0.644
CREDIT	U	0.782	0.755	6.5		0.58	0.563
	M	0.788	0 .728	14.1	-117.1	1.21	0.228
INCOME	U	0.551	0.515	7.2		0.64	0.522
	M	0.543	0.523	4.0	44.7	0.34	0.730
DISTANCE	U	6.772	7.212	-19.2		-1.71	0.087
	M	6.818	7.002	-8.0	58.2	-0.69	0.492
PRICE	U	693.59	670.55	15.9		1.42	0.157
	M	694.37	08.94	-10.0	36.8	-0.84	0.404

Source: own compilation, 2020

As depicted in table 14 below, the standardized mean difference for overall covariates used in the propensity score (around 47.1% before matching) is reduced to about 6.8% after matching.

Furthermore, the p-values of the likelihood ratio tests shows that the joint significance of the covariates was always rejected after matching where as it was never rejected before matching. The bias substantially reduced, in the range of 33 to 22% through matching. The pseudo R2 was also dropped significantly from 27% before matching to about 2.4% after matching. This low pseudo R2, low standardized bias, high total bias reduction, and the insignificant p-values of the likelihood ratio test after matching suggest that the specification of the propensity is successful in terms of balancing the distribution of covariates between the treated and control groups.

Table 14: Propensity score matching: quality test

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.271	119.66	0.000	47.1	44.3	133.1*	0.75	33
Matched	0.024	10.17	0.680	6.8	7.0	37.0*	1.72	22

Source: own computation, 2020

Estimation of treatment effect on the treated

In order to attain the stated objectives of the study, this section evaluates the impact of the intervention (Limu maize variety) on the outcome variable (food security). After controlling for other characteristics, the propensity score matching model using the nearest neighborhood 2 indicates that, adopting Limu maize variety has brought significant and positive impact on rural household food security. Limu maize variety adopter got an average of 458.917Kcal per day per AE than non-adopter households (Table 15). This finding agrees with Menale *et al.* (2014); Moti *et al.* (2015). The average amount of calorie intake was higher for adopter than non-adopter households. The positive value of ATT shows that adopter households consume more calories as compared with their counterpart. Accordingly, it was found that adopting Limu maize variety has brought positive impact on rural household food security status.

Table 15: Treatment effect on the treated

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Kcal	Unmatched	2555.87	2082.67	473.199	34.626	13.67
	ATT	2563.73	2104.81	458.917	45.818	10.02

Source: author computation, 2020

The result of the study revealed that, adopters of Limu maize variety has been better off than non-adopter households in terms of their food consumption. This comes from cohesive relationships nature of maize productivity, incomes and food security. Limu maize variety has been widely distributed for farmers targeting the improvement of maize productivity in the study area. Increased maize productivity of farmers transform to enhancement in availability and access to food and marketable surplus for sale. In addition, household consumption can also be improved indirectly through purchase of other essential food stuffs from income obtained after selling surplus maize grain. This indicates that adoption of Limu maize variety has a direct and positive influence on household consumption ceteris paribus. Hence, adopters of Limu maize variety in the study area are better off in non-adopters terms of food consumption.

One of the participants of the FGD said that before five years he was under the yoke of famine. It was very hard for him even to get one piece of '*injera'* for his family. In order to feed his family, he need to borrow cash birr from his neighbors, which is locally known as '*Arata'*, or he need help from a friend or relatives, especially, during summer season. Meanwhile, one of the development agents of his Kebele told him that using improved maize technology can solve this serious problem. Then after, he decided to use improved maize varieties to pull out his self and his family from this ridiculous condition. He took Limu maize seed and started using this maize continously. Now he could produce eighteen (18) to twenty two (22) quintal of maize grain from a half hectare of land and he could be a model farmer in his Kebele. Step by step he is improving his livelihoods and now he could feed his family at least two times per day. His family consumed maize as an '*injera*.' Sometimes they also use "*kolo*" and "*Nefro*" as fast food and porridge as cultural food. Besides, its food value, he used leaf and stalk of maize for animal feed and also dried stack and cob as a source of energy for food preparations. In addition, they buy other food stuffs by selling maize grain. This qualitative information obtained from FGD participant is in line with the results computed from PSM model which indicated that adopters of Limu maize variety realized higher food security status than the non-adopters of the variety.

Sensitivity analysis

PSM controls for observable differences between treatment and control groups, but is vulnerable to unobservable differences (Smith and Todd, 2005; Becker and Caliendo, 2007). Different researchers become increasingly aware that it is important to test the robustness of results to departures from the identifying assumption. Since it is not possible to estimate the magnitude of selection bias with non-experimental data, the problem can be addressed by sensitivity analysis.

According to Dehejia (2005), sensitivity analysis is the final diagnostic that must be performed to check the sensitivity of the evaluated treatment effect to unobserved characteristics which affect both assignment in treatment and the outcome variable. Rosenbaum (2002) proposes that using Rosenbaum bounding approach in order to check the sensitivity of the estimated ATT with respect to deviation from the CIA. If a given study is not affected by unobserved characteristics, the effect of unobserved variables is zero. As a result, the participation probability determined only by observed characteristics. But, if there is unobserved bias, even if the two individuals with similar observed characteristics have different chance of receiving the treatment. Based on this concept the sensitivity analysis was conducted.

The result in appendix table 6 shows that, the Limu maize variety adoption on the rural households' food security was not altered even though adopter and non-adopter households have been allowed to differ in their odds of being treated up to gamma =3.25(100%) in terms of unobserved covariates. This implies that, for outcome variable computed at different level of critical value of gamma, the p-critical values were statistically significant. We couldn't get the critical value eγ where the estimated ATT is questioned even if we have set eγ largely up to 3.25 which is larger value. Thus, it can be concluded that impact estimate (ATT) of this study is insensitive to hidden bias and is a pure effect of adoption of Limu maize variety.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

This study was conducted on the impact of Limu maize variety adoption on rural households' food security in the Dale wabera district, which is located in the Kellem Wollega zone, the Oromia National Regional State of Ethiopia. In the study area, maize is one of the important cereal crops, which prioritized, as a means to improve rural household food security status and enhance the livelihood of the rural community. To improve rural households' food security status and livelihood, using maize technology was started before two decades in the study area. However, the impact of Limu maize variety adoption on households' food security is not analyzed in the area. Therefore, this study is initiated to analyze the impact of Limu maize variety adoption on household food security. Further, households' adoption status of Limu maize variety and the determinants of households' Limu maize variety adoption and its intensity use of LMV adoption in the study area were also examined.

The empirical analysis utilizes cross-sectional farm household level data collected from a randomly selected sample of 319 households in four (4) selected kebeles of the district by using structured questionnaires. Qualitative and quantitative data were collected from primary and secondary sources. Primary data were collected directly by interviewing selected households and to enrich primary data, focus group discussion and key informant interviews were held. Secondary data were collected from relevant documents to supplement the data obtained from the survey.

Both descriptive statistics and econometrics model were employed to analyze collected data. Descriptive statistics was used the mean, percentage and standard deviation as well as chi-square and t-test were also used to analyze the mean difference of the adopter and non-adopter households. On behalf of econometric model, double hurdle model and PSM model were employed to identify determinants of households' Limu maize variety adoption and its impacts respectively. According to descriptive statistics results, variables such as age of the household head, family size, education level of the household head, livestock ownership, farm size, frequency of extension contact and membership in farmers' cooperative of an adopter and non-adopter households show significant difference. Moreover, the study has also identified adoption status of Limu maize variety in the study area. Accordingly, from the sampled households 48.9% were adopters, whereas 51.1% were non-adopters of Limu maize variety.

According to the result of the first hurdle (probit model) , adoption of Limu maize variety in the study area was significantly and positively affected by factors such as family size, livestock ownership, total land size, education level, membership in cooperative and frequency of extension contact. Truncated regression part of double hurdle model was also revealed that factors such as livestock ownership, being membership in cooperative, market distance and frequency of extension contact was affected intensity use of LMV adoption. Further, based on the criteria of selecting matching algorithm the average treatment effect on treated is calculated using propensity score matching model. The result confirms that adopting Limu maize variety has a positive impact on household food security.

5.2. Conclusions

Agricultural technology development is important strategies, which is prioritized as a means to improve rural household food security and enhance the livelihood of the farmers. Due to the low adoption rate of the different agricultural technologies, low agricultural production and productivity is challenging the livelihoods of rural farmers. To combat this problem, priority is given to increase adoption of improved agricultural technologies. This paper analyzed the determinants and impact of adopting Limu maize variety as well as the adoption rate of Limu maize variety by rural households in the study area.

From the study, it is possible to understand that adoption of Limu maize variety is influenced by different factors. Family size, livestock ownership, land size, education level, membership in cooperative and frequency of extension contact have positively affected the decision to adopt Limu maize variety. Allocation of land for LMV in the study area was also affected by livestock ownership, being membership in cooperative, market distance and frequency of extension contact. This finding implies that creating conducive production environment for the farmers plays a vital role for the adoption of Limu maize variety.

In this study, adopters of Limu maize variety are significantly better than the non-adopters in terms of daily food consumption household level. The study also reveals that households who did not adopt had by far lower by their daily food consumption at the household level than the adopters. From the findings of the study, it is possible to conclude that, households with more family size, more livestock ownership, more farm size, more education level, membership in cooperative and have more frequency of extension contact tend to adopt Limu maize variety. Similarly, it was found out that households who could adopt Limu maize variety would improve their status of food consumption. Overall, adoption of Limu maize variety has a positive effect on food security of rural households.

5.3. Recommendations

Based on the result of empirical model the following recommendations are given.

The family size has a significant positive impact on adoption of Limu maize variety. This indicates that, in the study area labor force were used for farming activity. Therefore, introducing labor saving technology (use of horsepower tractor and herbicide chemical) at credit or subsidy base is recommended to increase the probability of adopting Limu maize variety in the study area.

The education level of household head positively affected the farmers' decision to adopt Limu maize variety. Therefore, enhancing the educational status of the rural farmer household through informal (training, demonstration, capacity building, experience sharing with model farmer and prepare farmer field days) is recommended.

Being a member of farmers' cooperatives has a significant and positive impact on adoption and intensty of Limu maize variety adoption. Farmers get farm inputs from these cooperatives and sell their products to the cooperative union. Hence, it is better if local government organizations encourage farmers' cooperatives which will help them to find markets for their products at a profitable rate in the study area.

The results of the study demonstrate the importance of extension contact as a source of information, on how to use Limu maize variety. Therefore, emphasis should be given to increase the farmers' contact with agricultural extension agents by creating awareness.

Having more livestock positively was affects adoption of Limu maize variety and intensity of Limu maize variety adoption in the study area. Hence, government is advised to strengthen the existing livestock production system through providing improved health services, better livestock feed (forage), credit services improved breeds and disseminating artificial insemination to improve adoption of Limu maize variety.

Household with less land size, less adopt Limu maize variety. Therefore, government organizations are advised to do on how farmers can access land through contract arrangement or any other means land acquisitions.

Distance to main market also discourages hectare of land allotted for limu maize variety in the study area. Hence, it is better if emphasis is given for investment of improved roads infrastructure in the study area.

The implications of the findings are straight forward that through the adoption of Limu maize variety, the food security status of the rural household can be improved. Therefore, it is recommended that wider supply and distribution of Limu maize variety has to be prioritized to improve food insecurity in the study areas. In addition, to sustain the positive impact of Limu maize variety adoption, emphasis should be given to remove the major obstacles hindering households' adoption of Limu maize variety in the study area.

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7. APPENDIX

Supportive and detail table containing results

Appendix table 1: Conversion factors used to compute adult equivalent (AE)

Age groups (years)	Male	Female
<10	0.6	0.6
10-13	0.9	0.8
14-16	1	0.75
17-50	1	0.75
>50	1	0.75

Source: Stock, *et al* (1991)

Appendix table 2: Conversion factors used to compute tropical livestock units

Animal category	Tropical Livestock Unit
Oxen	1.1
Cow	1
Bull	0.5
Heifer	0.6
Calves	0.2
Sheep	0.01
Goat	0.09
Donkey	0.5
Horse	0.8
Mule	0.7
Poultry	0.01

Source: Stork *et al.*,1991

Appendix table 3: Calorie value of food consumed by sample households

Food item	Unit	Kcals	Food item	Unit	Kcal
Teff	Kg	3589	Irish potato	Kg	1037
Wheat	Kg	3623	Sweet potato	Kg	1360
Sorghum	Kg	3805	Egg	Each	61
Maize	Kg	3751	Edible oil	Lt	8964
Barley	Kg	3723	Coffee	Kg	1103
Peas	Kg	3555	Sugar	Kg	3850
Lentils	Kg	3522	Spaghet/Macaroni	Kg	3550
Butter	Kg	7364	Kocho (bread)	Kg	2111
Milk	Lt	737	Kocho (powder)	Kg	2194
Cheese	Lt	3972	Kocho (porridge)	Kg	905
Meat	Kg	1148	Carrot	Kg	820
Onion	Kg	713	Tomato	Kg	300
Chickpea	Kg	3640	Anchote	Kg	1635.8
Millet	Kg	3781	Bean	Kg	1550

Source: EHNRI, 1998

Appendix table 4: VIF for all continues explanatory variables

Variable	VIF	1/VIF
EDULEVEL	2.66	0.376
AGE	2.49	0.401
TLU	1.46	0.686
FARMSIZE	1.38	0.723
FAMSZ	1.16	0.860
DISTANCE	1.08	0.929
EXTENSION	1.07	0.935
PRICE	1.06	0.947
Mean VIF	1.545	

Source: model results, 2020

. correlate GENDER MCOOP CREDIT INCOME
(obs=319)

	GENDER	MCOOP	CREDIT	INCOME
GENDER	1.0000			
MCOOP	-0.0039	1.0000		
CREDIT	0.0272	-0.0601	1.0000	
INCOME	0.0143	0.0712	0.0958	1.0000

Appendix figure 1: Contingency coefficient for dummy variables

Appendix table 5: Results of logit estimation of propensity scores

Variables	Coef.	Std. Err.	Z	P>z
Gender of household head	0.364	0.305	1.19	0.233
Age of household head	-0.011	0.018	0.64	0.521
Family size of household	0.326	0.083	3.92	0.000
Education level of household head	0.129	0.055	2.34	0.019
Livestock ownership	0.149	0.049	3.04	0.002
Total land size	0.318	0.153	2.07	0.038
Membership in cooperatives	0.915	0.308	2.97	0.003
Frequency of extension contact	0.142	0 .062	2.30	0.022
Credit utilization	0.134	0.338	0.40	0.691
Non-farm income	0.102	0.281	0.36	0.717
Distance to main market	-0.081	0.062	1.31	0.191
Lagged Price of maize grain	0.0012	0.0009	1.27	0.202
_cons	-5.638	1.431	3.94	0.000
Observations	319			
LR chi2(13)	118.93			
Prob > chi2	0.0000			
Pseudo R2	0.2690			

Appendix table 6: Result of sensitivity analysis using Rosenbaum bounding approach

rbounds KCal, gamma(1(.25)4)

Rosenbaum bounds for KCal (N = 319 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	2289.84	2289.84	2237.12	2342.91
1.25	0	0	2243.32	2337.19	2192.24	2388.51
1.5	0	0	2207.99	2372.35	2157.77	2425.47
1.75	0	0	2177.42	2403.83	2130.63	2456.23
2	0	0	2154.06	2429.78	2109.74	2482.94
2.25	0	0	2134.39	2451.58	2091.48	2505.97
2.5	0	0	2118.27	2471.97	2076.73	2525.98
2.75	0	0	2104.18	2489.3	2064.03	2542.58
3	0	0	2092.04	2505.21	2052.58	2558.07
3.25	0	0	2081.05	2519.62	2042.91	2571.98
3.5	1.1e-16	0	2072.35	2531.81	2034.42	2584.14
3.75	6.7e-16	0	2063.93	2542.82	2026.48	2595.63
4	5.0e-15	0	2056.21	2553.14	2019.23	2607.2

Gamma - log odds of differential assignment due to unobserved factors

Sig+ - upper bound significance level

Sig- - lower bound significance level

T-hat+ - upper bound Hodges-Lehmann point estimate

t-hat- - lower bound Hodges-Lehmann point estimate

CI+ - upper bound confidence interval (a= .95)

CI- - lower bound confidence interval (a= .95)

JIMMAUNIVERSITY

COLLEGE OF AGRICULTURE AND VETERINARY MEDICINE

DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS

<u>Household Interview Schedule</u>

Dear respondent:- I am a Post graduate student in Agricultural Economics and Agribusiness department, undertaking a research with the topic**: impact of limu maize variety a doption on rural household food security: the case of Dale Wabara District, Kellem Wollega Zone, Oromia National Regional state of Ethiopia.** You are selected to supply the required information towards addressing the specific objectives of the study. It therefore requests your co-operation to respond objectively as possible to the questions in the questionnaire. It is purely for academic purpose and all information supplied will be strictly confidential and for research purpose only.

Thank you for the anticipated cooperation.

Note: The respondent, to this interview, should be the HH head or his/her partner

Date of interview___/______/____

General information

Household ID ______________

Peasant administration/Kebele: ______________ Village: ___________________

Name of the enumerator: _______________ sign._______________

I. Household Personal, Demographic, Socioeconomic and Institutional Data

1. Full name of the respondent: ___________________________________

2. Sex of household head 1. Male 0. Female

3. Religion 0. Protestant 2. Orthodox 3. Muslim 4. Wakefata

4. Age of household head _________ years

5. Marital status 0. Single 1. Married 2. Widowed 3. Divorced

6. How many years of school have you completed? _______________years

7. How many family members do you have? Male _____ Female _______ Total ______

8. Household labor availability

Age category	Number (#)		*Activities participated in	Nature of participation		Other job for part-time participant
	Male	Female		Full time	Part-time	
Children<10 years						
Children 10-13 years						
Children 14-16years						
17-50 years						
>50years						

***Code:** 1) Land preparation 2) sowing 3) Weeding 4) Cultivating 5) Harvest 6) Transportation 7) Storage 8) Marketing 9) others (specify)

9. Do you have livestock? 1. Yes 0. No

1. If yes, indicate current number of livestock you have and number sold in last year's with its price?

S/n	Livestock holding	(Number)
1	Oxen	
2	Cow	
3	Bulls	
4	Calves	
5	Heifer	
6	Goat	
7	Sheep	
8	Poultry	
9	Donkey	
10	Horses	
11	Mule	
12	Chicken	

10. What is the size of your total farm land? ______*.

***Code** 1) Hectares 2) Sangaa 3) Keewwata

11. How much of the following cereals did you harvest in 2018/19 (2010 /2011 E.C) cropping season?

S/n	Type of crop	***Code 11a** L and size	Improved Seed used 1) yes 2) no	Fertilizer used 1) yes 2) no	***Code 11b** Amount Obtained
1	Maize				
2	Wheat				
3	Teff				
4	Sorghum				

5	Millet				
6	Barley				
7	Chickpea				
8	Beans				
9	Peas				
10	Lentil				
11	Potato				
12	Coffee				
13	Onion				
14	Garlic				
15	Other specify				

***code 11a**

1) Hectares 2) Sangaa 3) Keewwata

***code 19b**

1) Kilogram 2) Quintals 3) Quunnaa 4) Feresula

12. Do you have Non/off-farm activities? 1) Yes 0) No

13.1. If yes, please fill the following table

S/n	Operations involved	1) Yes 0) no	Total number of working days	Total income received in Birr per year
1	Daily laborer			
2	Petty trading			
3	Handicraft			
4	Firewood /charcoal selling			
5	Homemade drinks			
6	Selling grass and straw			
7	Selling stone & sand for construction			
8	Remittances/Gifts			
9	Government employee			
10	Other, specify			

13. Do you have access to extension service? 1)Yes 0) No

13.1. If yes, how many times you meet local extension agents during cropping season? ______ times per year*. ***Code:** 1. per month 2. Per year

13. Are you a member of farmers' cooperative? 1) Yes 0) No

15.1. If yes, what service did you get from the farmers' cooperative related to maize production?

i. Information supply **ii.** Input supply **iii.** Marketing services **iii.** Credit services **iv.** Other specify________

14. Have you taken credit in this production? 1) Yes 0) No

A) If yes, what was your reason for borrowing? 1) to buy production input 2) to buy food 3) medical bills 4) school fees 5) Other specify_______________

15. How far the nearest market from your residence? _____________(kilometers)

II. Maize production

16. Have you planted Limu maize variety from 2017 - 2019 production years?

1) Yes 0) No

16.1.If yes, please answer the following questions based on 2019 production year.

	Land size (ha)	Quantity of seed	Fertilizer use 1)Yes 0) no	Applied raw spacing 1)Yes 0) No	***code 18 b** Yield obtained	***code 18c** Amount consumed	**code 18d** Amount sold
Limu variety							
Local seed							

***code 18a, *code 18b, *code 18c and *code 18d:**

1) Quintals 2) Kilogram 3) Quunnaa 4) Feresula

17. What was a price of maize grain in 2018 production year? _____ Birr per quintal*.

III. Food security situations at household level

18. What type of food item your family consumed in last 7 (seven) days? Please list them accordi ngly

S/n	**Did your household consume any of these food items for the last seven days?**	**Quantity in Kg**	**Source**		
			Home produ ced in Kg	**Purchased in Kg**	**Gifts/remittances / wage in kind in Kg**
1	Maize				
2	Sorghum				
3	Wheat				
4	Barley				

5	Millet				
6	Teff				
7	Other specify				
8	Pulses				
9	Lentils				
10	Bean				
11	Peas				
12	Chick pea				
13	Cow milk in Littre				
14	Butter				
15	Cheese				
16	Anchote				
17	Enset *(kocho)*				
18	Spaghet/Macaroni				
19	Kocho (bread)				
20	Cattle meat				
21	Sheep meat				
22	Goat meat				
23	Egg in number				
24	Sugar				
25	Edible oil in litre				
26	Irish Potato				
27	Sweet potato				
28	Onion				
29	Carrot				
26	Tomato				
27	Edible salt				

28	Other , specify				

***code 22a, *code 22b, *code 22c and *code 22d**

1) Quintals 2) Kilogram 3) Quunnaa 4) Feresula

Part IV: Check List for Focus Group Discussion

1. Which one of the variety (local or improved) you prefer to produce maize?
   1.1.If you chose improved one, why you chose?
2. How the extension service approaches deliver information to you about importance of Limu maize variety?
3. What are the challenging factors which affect adoption of Limu maize Variety in the area?
4. Do you think that adopting Limu maize variety has an effect on your maize productivity and food security?

Part V: Questions for the Key Informants

1. What do you think about challenging factors in adoption of Limu maize variety?
2. Do you think that the maize production and productivity is enough to enhance food security status of household in the district?
3. In your opinion, what should be done to enhance household food security status in the district?
4. In your opinion, are there problems related to the adoption of Limu improved maize variety?
   4.1.If yes, please describe them, and suggest what could be done to overcome them.
5. Does strategies used by Agricultural and Rural development office of the ditsrict is enough to ensure the food security of the smallholder farmers?
6. Is there any capacity building initiatives in the area to ensure income and food security of smallholder farmers?
7. What methods did you apply for transferring knowledge and practice about Limu maize variety?
8. Is the farm inputs are accessible to farmers? If yes, how? If no, why?