

**IMPACT OF IMPROVED *TEFF* VARIETY (*Eragrostis Teff*) ADOPTION
ON FOOD SECURITY IN LASTA WOREDA, NORTH WOLLO ZONE
OF AMHARA NATIONAL REGIONAL STATE, ETHIOPIA**

MSc THESIS

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**Impact of Improved *Teff* variety (*Eragrostis Teff*) Adoption on Food
Security in Lasta Woreda, North Wollo Zone of Amhara Regional State,
Ethiopia**

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DEDICATION

I dedicate this thesis manuscript to my late grandfather Shimelash Tegegne who was our embodiment in coshering family members with love and patience.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my solely work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc. degree at the Haramaya University and is deposited at the University Library to be available to borrowers under rules of the library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

The author was born on August 14, 1988 in Lay-Gaynt Woreda, South Gonder zone of Amhara National Regional State from his father Ayen Tilaye and his mother Enaneye Shimelash. He attends his primary and secondary educational level in Nefas Mewucha primary and secondary schools respectively. After completion of secondary school, he joined Hawassa University in 2007, and graduated with B.Sc. degree in Agricultural Resource Economics and Management in July 2009. After his graduation, he joined Estie Woreda Office of Agriculture in 2010. In 2014 he joined Amhara Agricultural Research Institute (ARARI) and worked at Sekota Dry Land Agricultural Research Center in Socioeconomics Research Directorate. He had been working for the Institute until he joined the School of postgraduate Studies at Haramaya University to pursue his MSc. degree in Agricultural Economics program in October 2017.

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ACRONYMS AND ABBREVIATIONS

ANRS	Amhara National Regional State
ATA	Agricultural Transformation Agency
ATT	Average Treatment effect on Treated
ATU	Average treatment effect on untreated
CSA	Central Statistics Agent
ETB	Ethiopian Birr
ESR	Endogenous switching regression
FAO	Food and Agricultural Organization
Ha	Hectare
LWOA	Lasta Woreda Office of Agriculture
MASL	Meter Above Sea Level
PAE	Per adult equivalent
SDARC	Sekota Dry Land Agricultural Research Center
TLU	Tropical Livestock Unit
WFP	World Food Programme

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Impact of Improved Teff (*Eragrostis Teff*) Variety Adoption on Food Security in Lasta Woreda, North Wollo Zone of Amhara Region, Ethiopia.

ABSTRACT

Food insecurity is a recurrent phenomenon in Ethiopia. To reverse this phenomena investment on variety development and dissemination of improved teff varieties to farmers have been made by regional and national agricultural research institutes. Even though efforts on disseminating improve teff varieties have been made in the area, there is no empirical evidence those varieties that brings on food security. Moreover, previous studies employ propensity score matching which could not handle self-selection un observed endogeneity problem. To handle this problem ESR model was employed. This study was designed to analyze impact of adoption of improved teff variety on food security measured in terms of annual food consumption expenditure and daily calorie intake per adult equivalent in Lasta Woreda, North Wollo Zone, Ethiopia. This study uses cross sectional data which was collected from a total of 225 farm households which were randomly and proportionately selected from 3 teff producer Kebeles in Lasta Woreda using multi-stage sampling technique. To analyze the data descriptive inferential statistics and Endogenous switching regression model were employed for data analysis. The results from probit model shows that family size, off-farm and farm income(log), variety information from research center and development agents, number of seed traders known by respondents and distance from agricultural extension office were factors that significantly determine farmer's decision to adopt improved teff variety. The outputs from endogenous switching regression model asserts that had the adopter households decided not to adopt, their average daily calorie intake and food consumption expenditure per adult equivalent would have decreased by 417.908 kilocalorie and 1096.509 ETB, respectively which is significant at 1% probability level. On the other hand, if non-adopter households would have adopted improved teff variety, their average daily calorie intake and annual food consumption expenditure per adult equivalent would have increased by 512.581 kilocalorie and 1323.987 ETB, respectively. Thus, facilitating adoption of improved teff varieties and institutional support are recommended to improve food security of smallholder teff growers in the study area.

Keywords: Adoption, ESR, Impact, Improved Teff, Lasta Woreda, Ethiopia

1. INTRODUCTION

1.1. Background of the Study

Despite some improvement in recent years, food insecurity in Ethiopia is a prolonged challenge that derives directly from low application of inputs and low productivity of agriculture. Ethiopian farmers do not produce enough food even in good rainfall condition to meet consumption requirements (Beddington, 2010). To minimize this recurrent problem of food insecurity agricultural production and productivity development policy has been developed. This has been achieved by research and extension endeavors particularly on improving the production and productivity of major staple crops widely grown by resource poor smallholder farmers (Moti *et al.*, 2015).

In Ethiopia out of the total grain crop area, 80.71% was under cereals. *Teff* [*Eragrostis teff*] is a small cereal grain which is indigenous to Ethiopia. It accounts 23.85% of the grain crop area and in terms of quantity of production Cereals contributed 87.48% of the grain production and *teff* account 17.26 % of the total grain production. Economic indicators show that *teff* is being the most dominant cereal crop in Ethiopian agriculture. About 5.28 million tons of *teff* was produced from 3.02 million hectare of land in the main Meher season (CSA, 2018).

Teff [*Eragrostis teff*] is one of strategic food security cereal crop which plays a paramount role in achieving food security and enhancing income of households in most parts of Ethiopia (Regassa *et al.*, 2018; Etsehiwot, 2018). It is the most preferred staple food by the majority of Ethiopian population and is key contributor to food security (Haftamu *et al.*, 2009).

Ethiopian rural smallholder farmers grow *teff* for a number of merits which is mainly attributed to the socioeconomic, cultural and agronomic benefits. *Teff* has special merit such as special values in the national diet, provides major feed source, well adapted to different agro-ecologies, the crops ability to tolerant extreme environmental conditions which performs better both under low moisture stress and high moisture conditions (Assefa *et al.*, 2011).

Teff is the leading crop among cereals and even among other annual crops (CSA, 2017). Even if the economic importance of *teff* is high, its productivity still remains very low which is at 16.64 qt/ha, 16.99qt/ha, 13.31qt/ha in Ethiopia, Amhara region, North Wollo zone, respectively. In North Wollo Zone, *teff* accounts 58% area coverage among cereal crops and is the dominant crop in area coverage (CSA, 2017). To increase this low productivity of *teff*, agricultural research and technological improvements are very important to realize food security to meet the demands for food at reasonable prices without irreversible degradation of the natural resource base. It is the agenda of policymakers that research should focus on food insecurity reduction objectives when setting priorities and making resource allocations (Assefa *et al.*, 2013). In Ethiopia Research endeavors has been done on generating new crop varieties and *teff* is one of stable crops which is one of the research agenda in Ethiopia to increase its lower productivity in order to alleviate food insecurity in the country. To increase the productivity of *teff* 42 improved varieties were developed by federal and regional research centers by different breeding mechanism (Misgana, 2018).

To this effect, in Amhara region different improved *teff* varieties have been released and popularized. Among those, Lasta woreda is the one which improved *teff* technologies had been scaled up. *Teff* is the dominant crop grown by smallholder farmers which accounts 24 % of the total cultivated land in the study area. Different improved *teff* varieties have been disseminated to smallholder farmers in the past six years so as to reverse the low productivity of *teff* and to alleviate food insecurity situation in the study area. However, the impact of those improved *teff* varieties on food security in the woreda is not studied yet. Thus, to better inform future research and policy, this study attempt to evaluate the impact of improved *teff* variety adoption on food security.

1.2. Statements of the Problem

Ethiopia is one of the countries in which recurrent food insecurity is a problem. To troubleshoot this recurrent problem specifically in Lasta woreda, extensive efforts have been undertaken to enhance agricultural production and productivity. This has been achieved by improving the production and productivity of major staple crops widely grown by smallholder famers through research and extension endeavors (Moti *et al.*, 2015).

To alleviate low productivity of local varieties of *teff*, Sekota Dry Land Agricultural Research Center and other national and regional research centers have been pursuing variety development through variety development and adaptation trials with their agronomic practices to recommend best technology packages. For this purpose, Sekota Dry Land Agricultural Research center (SDARC) has organized farmers into farmers' research extension group to select the best performing technologies through participatory evaluation of the different improved *teff* varieties. In this regard different improved *teff* varieties such as Kuncho, Zoble, Dz-01-1285 and Worekiyu in collaboration with other research centers based farmer's preference have been selected and recommended by the researchers so as to boost crop productivity and to alleviate food insecurity (SDARC, 2013).

Beside to technology generation, efforts have been made to popularize the improved *teff* varieties in collaboration with woreda office of agriculture. Accordingly, different improved *teff* varieties especially Kuncho *teff* have been widely adopted by small holder farmers in different Kebeles where agro-ecology is found to be suitable for *teff* production (LWOA, 2018).

Despite considerable efforts and investment to generate and disseminate improved *teff* variety towards rural farm households in the country in general and in Lasta Woreda in particular, the impacts of these improved variety that brings on food security is not studied yet. There is no empirical study regarding the impact of improved *teff* variety to the household food security status in the area. Others studies were conducted on impact of improved *teff* variety in different part of the country for example (Debelo, 2015; Etsehiwot, 2018; Regassa *et al.*, 2018).

However, all of these studies measure the impact of improved *teff* variety limited to crop productivity and crop income (supply side of food security dimension). Because adequate supply of food at the national or international level does not by itself guarantee for household level food security. Concerns about insufficient food access have resulted in a greater policy focus on expenditure in achieving food security objectives (FAO, 2008).

While conducting the welfare impact of improved technologies most researchers use only standard measures or objective measurement of food security indicators or monetary indicators of food security example (Zenaye, 2016; Tsegaye and Bekele, 2012; Debelo, 2015).

To fill this gap both standardized food security indicators and subjective food security indicators were used. Because the data were collected at specific time it may under or overestimate the status of food security (Bekele *et al.*, 2014; Moti *et al.*, 2015).

Moreover, most researchers in their studies employ only Propensity Score Matching (PSM) method for example (Regassa *et al.*, 2018; Debelo, 2015); to evaluate the impact of adoption of improved *teff* variety on productivity and crop income. But the result of PSM could not show the real adoption impact since the adoption decision have self-selection unobserved endogeneity problem which PSM could not handle (Khandker *et al.*, 2010). Therefore, ESR model was used.

Therefore, to fill the above stated gaps, this study was designed to evaluate impact of improved *teff* variety adoption on food security measured in terms of food consumption expenditure per adult equivalent per year in Ethiopia birr and daily kilo calorie intake per adult equivalent.

1.3. Research Questions

This study was conducted to addresses the following research questions:

1. Does adoption of improved *teff* variety has impact on daily calorie intake of smallholder farmers?
2. Does adoption of improved *teff* variety has impact on consumption expenditure per adult equivalent of small holder farmers?

1.4. Objectives of the Study

The general objective of this study was to evaluate the impact of improved *teff* variety on smallholder farm household's food security in the Woreda.

The specific objectives of the study were:

1. To analyze the impact of improved *teff* variety on daily calorie intake per adult equivalent of smallholder farmers.
2. To analyze the impact of improved *teff* variety on food consumption expenditure per adult equivalent of smallholder farmers.

1.5. Significance of the study

The finding of this study is pertinent in evaluating the performance of the prevailing efforts in disseminating improved *teff* variety in the study area. Investigating the impact of adopting improved *teff* varieties disseminated towards smallholder farmers is imperative for policy makers to design future policy and strategies. Moreover, the information generated from this study is expected to help for academicians, researchers, governmental and non-governmental organizations and other different development practitioners engaged on the sector for future intervention targeting to realize food security.

1.6. Scope and Limitation of the Study

This study was delimited to evaluate the impact of improved *teff* variety on smallholder farm household's food security which is limited only in three Kebeles of Lasta woreda . This study also focuses on only one dimension or pillars of food security among the four dimension or pillars of food security on two indicators. Food access dimension using food consumption expenditure per adult-equivalent and average daily calorie intake per adult-equivalent were used as an outcome variable to measure the impact of improved *teff* varieties on food security. This study employs cross-sectional data and thus doesn't explore the dynamic effect of adoption of improved *teff* variety on food security.

1.7. Organization of the Thesis

The thesis is organized into five main chapters. Chapter two depicts literature review including definition of adoption and food security, definition of impact evaluation, empirical studies on adoption of improved technologies and impact of improved technologies on different indicators of food security. Chapter three provides description of the study area, the methods of data collection and data sources, the sampling procedures and methods of data analysis techniques employed to analyze the data to meet the stated objectives. Moreover, chapter four comprises results and discussion part of the study. The final chapter focuses on summary, conclusions and recommendation part of the study.

2. LITERATURE REVIEW

In this topic, the conceptual definitions and theoretical descriptions, empirical evidences on factors affecting adoption of improved *teff*, impacts of improved varieties on food security has been reviewed.

2.1. Concepts and Operational Definitions

2.1.1. Adoption

Understanding the concepts of adoption is very important to evaluate the welfare impact of agricultural technologies. Because impact evaluation is possible particularly for this study if farm households were adopting agricultural technologies particularly improved *teff* varieties and the concepts also helps to analyze factors affecting adoption of improved *teff* varieties to estimate propensity score.

According to Feder *et al.* (1985) adoption was defined as the extent use of new biological, mechanical, managerial and institutional innovation by a farmer when producers avail full information regarding the new innovation and its potentials. The author classified adoption of new technology into two as individual and aggregate adoptions. Moreover, they defined Individual adoption as the farmer's decisions to apply a new technology into the production process and the aggregate adoption as the aggregate level of use of a particular technology among one specific group of farmers or within one particular area. Therefore, aggregate adoption is the process of diffusion of a new technology within a region or population. Furthermore, Rogers and Shoemaker (1971) defined technology adoption as the decision made by a farmer to use a new technology as best course of action he or she ever practiced. Adoption of new technology in agriculture which occurs due to behavioral changes like desirable changes in knowledge, understanding and ability to apply technological information, changes in feeling behavior such as changes in interest, attitudes, aspirations, values and the like; and changes in overt abilities and skills, is determined by many socio-economic factors.

Adoption is not a simple and an overnight activity which can't be implemented immediately overnight but it is a mental process which an individual farm decision-maker or group of

decision maker's family members so as to make decision to apply a given technology. To ensure adoption of new innovation the fulfillment of specific economic, technical and institutional conditions is required. From the farmers' perspective, the new technology should be economically more profitable than the existing alternatives. Moreover, the new technology should also be technically easily manageable by small holders and adaptable to the surrounding socio-cultural situations and availability of the new technology and all other necessary inputs to small holders at the right time and place and in the right quantity and quality are necessary conditions (Ehui *et al.*, 2004). In general adoption is a function of five characteristics of the technology which are relative advantage or profitability, compatibility or riskiness, complexity, triability /divisibility, or initial capital requirements, and observability or availability (Rogers, 1981).

2.1.2. Impact Evaluation

Impact analysis refers to the analysis of the distributional impact or change due to adoption of new technology on the well-being or welfare or income of the beneficiary (Khandker *et al.*, 2010). Impact evaluations are part of a broader agenda of evidence-based policy making which assesses the changes in the well-being of individuals that can be attributed to a particular implementation of project, program, or policy in a given area. This focus on attribution is the hallmark of impact evaluations. Correspondingly, the central challenge in carrying out effective impact evaluations is to identify the causal relationship between the program or policy implemented and the outcomes of interest.

According to (Imas and Rist, 2009) evaluations can address three types of questions. Descriptive questions ask about what is taking place. They are concerned with processes, conditions, organizational relationships, and stakeholder views. Normative questions compare what is taking place to what should be taking place based on value judgment. They assess activities based on whether or not target out comes are accomplished. Normative questions can apply to inputs, activities, and outputs. Cause-and-effect questions focus on attribution. They ask about what difference the intervention makes to outcomes of interest.

Impact evaluations can be divided into two categories: prospective and retrospective. Prospective evaluations are developed at the same time as the program is being designed and

are built into program implementation. Baseline data are collected before the program is implemented for both the group receiving the intervention (known as the treatment group) and the group used for comparison that is not receiving the intervention (known as the comparison group). Retrospective evaluations assess program impact after the program has been implemented, looking for treatment and comparison groups (Gertler *et al.*, 2016).

Agricultural research can contribute to food security reduction by generating yield increasing technologies which play an indispensable role in increasing the supply of food on which the poor spend a considerable share of their income. The development of high-yielding varieties which boost food production both by increasing yields per unit of land per cropping season and by facilitating multiple cropping (Bekele *et al.*, 2014).

2.1.3. Food Security

“Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.” (FAO, 1996) points out the four key dimensions of food security:

Food availability: This is supply side of food security dimension and is defined as availability of sufficient quantities of food consistently with appropriate quality, supplied through domestic production, purchasing, imports and food aid.

Food access: The access to adequate resources or entitlements to acquire appropriate foods for a nutritious diet. Entitlements are defined here as the set of all commodity bundles over which a person can establish command, given the legal, political, economic and social arrangements of the community in which he or she lives. food access refers to having sufficient economic and physical resources for acquiring appropriate food for a nutritious diet.

Food utilization: The utilization of food through adequate diet, clean water, sanitation, and health care, to achieve a state of nutritional well-being in which all physiological needs are met. This highlights the importance of non-food inputs in food security. For example, it is insufficient for an individual to receive an adequate quantity of food, if he or she is unable to make use of the food due to illnesses resulting from inadequate sanitation or poor sanitary practices.

Food stability: The stability of availability and accessibility of adequate food at all times, independent of shocks such as economic, climate related crises and cyclical patterns. This includes issues of seasonal food insecurity such as food shortage before production periods of crops.

This study focuses on food access dimension of food security which is measured by consumption expenditure per adult equivalent and average daily calorie intake per adult equivalent following Magrini and Vigani (2014) and Bekele *et al.* (2014) using Ethiopian food consumption table.

2.2. Importance of *Teff* production in Ethiopia

According to Tamiru (2013) about two thirds of cereal production is consumed by the producing households themselves, with only just over 16% that farm households produced is being supplied to the market. *Teff* and wheat have relatively higher marketable surplus shares at 29% and 20% of total production, respectively. Mostly *Teff* is produced by smallholder farmers at the central, eastern and northern highlands of the country on fragmented lands with rain fed conditions in both, Meher and Belg, seasons (Engdawork, 2009).

Teff is relatively resistant to many biotic and abiotic stresses and can be grown under different agro-ecological conditions ranging from lowland to highland areas (FAO, 2015). *Teff* is mostly concentrated in the center and the northwest of the country. East Gojjam, East Shewa, West Shewa, South and North Wollo, North Shewa etc. are *teff* producing zones all in Amhara and Oromia regional states (Yihenew *et al.*, 2013).

Teff has the largest value in terms of both production and consumption in Ethiopia and the value of commercial surplus of *teff* is second only to coffee (Minten *et al.*, 2013). It is also the main source of income and employment for the majority of rural households. The crop accounts for approximately 12.7% of all calories consumed (Kaleab, 2014). *Teff* is nutritionally rich with high levels of iron and calcium and has the highest amount of protein among cereals consumed in Ethiopia. It ranks low on the glycemic index (making it suitable for consumption by Type II diabetics), gluten free, and high in fiber (FAO, 2015).

The major yield-limiting factors to *teff* production are the lack of cultivars tolerant to lodging and to prolonged drought (Assefa *et al.*, 2011). According to Assefa *et al.* (2013) the low productivity is also related to the widespread use of landraces and cultivars lacking desirable agronomic traits. Lodging (permanent displacement of the stem from the upright position) is the major production constraint in *teff*.

2.3. Empirical Evidence

2.3.1. Adoption of improved crop technologies

This empirical evidences which affect adoption of Improved crop technologies is important in analyzing the impact of adoption of improved *teff* varieties on food security.

The study by Debelo (2015) identified the determinant factors to adopt kuncho *teff* variety in Wayu Tuqa district of Ethiopia. The result indicates that family labor availability, participation of farmers in agricultural trainings, education level of the household head, livestock holding (TLU), farmer's ability of meeting family food consumption and frequency of extension contact were the determinant factors which positively affect decision to adopt kuncho *teff*. On the contrary age of household head, owning oxen and distance from household residence to market center were found adversely influence adoption of kuncho *teff*.

A study by Tsibuk (2015) identified factors affecting adoption of kuncho *teff* variety using logistic regression model in Medebayzana Woreda of Tigray Region, Ethiopia. The result asserts that family labor, access to credit service, frequency of contacts with extension agents, participation in training and mass media exposure positively and significantly influence whereas market distance and perception towards cost of input influenced the adoption of kuncho *teff* variety negatively

Susie (2017) by his study identified determinants of adoption of improved *teff* technologies using double hurdle model in Kobo Woreda of Amhara National Regional State. The result indicates that educational level of the household head, off/non-farm income, proportion of cultivated land allocated for *teff* production, livestock holding in TLU, frequency of extension contact, participation on demonstration, improved *teff* seed availability, distance from the

nearest market and farmers' perception on yielding capacity are the determinant factor for adoption of improved *teff* technologies.

Tsegaye and Bekele (2012) in their study identified the determinants of adoption of improved wheat technologies in in South Eastern part of Oromia National Regional State, Ethiopia. The results of the Econometric models using probit model confirm that age, education, farm experience, participation in off-farm activities, access to credit, extension contact, and livestock holding are important factors that determine farmers' adoption decision of wheat technologies.

A study by Bayissa (2014) examined factors affecting adoption of improved *teff* technology in Diga District of Oromia National Regional State, Ethiopia by employing Double-Hurdle approach. The result revealed that farming experience, participation on crop production training, education level, distance to nearest marketing center and the characteristics of new technologies like yield superior and maturity positively affects farmer's decision to adopt, whereas distance to market(negatively) determine adoption and intensity of improved *teff* technologies.

A study conducted by Daniel (2008) examined determinants of adoption and intensity use of *teff* technology in in Yilmana Densa Woreda of Amhara National Regional State, Ethiopia using tobit regression model. The result indicates that annual income, access to research service, access to extension service, perception of improved varieties were the determinant factors which influence adoption decision and intensity use of *teff* improved technologies positively and distance to market affect negatively the decision to adopt.

A study by Bekele *et al.* (2014) identified determinant factors affecting adoption impact of improved wheat varieties in Ethiopia. The finding revealed that education, access to input and output market, variety information, agro-ecology, input access, extension contact positively whereas price of competing crops negatively affects the decision to adopt improved wheat variety using probit model.

The study by Tesfaye *et al.* (2016) examined the determinant factors affecting adoption of improved wheat technology in Ethiopia using probit model. The finding indicates that Education (negatively) and gender, livestock ownership, wheat disease(dummy) positively affects the decision of farm households to adopt improved wheat variety.

A study conducted by Regasa *et al.* (2018) examined determinants of improved *teff* varieties adoption in the Case of non-traditional *teff* growing areas of Western Ethiopia using tobit model. The result shows that dependent dependency ratio, land allocated to cereal crops other than *teff* and horticultural crops had negative and significantly whereas livestock ownership (heifer and poultry), access to training and information on *teff*, status of the household heads (being progressive farmer) and being improved *teff* cultivars of friends, relatives and neighbors have contributed positively and significantly to *teff* adoption in the study areas.

A study conducted by Estehiwot (2018) entitled on the determinants of agricultural technology adoption and its' impact On *teff* productivity in the Case of Amhara and Oromia National Regional State using multinomial logit model. The result indicates that technology adoption is positively determined by sex, education, soil fertility, contact with an extension and development agents visit whereas age, distance to main road, distance to the input and output market, parcel ownership and farm size influences negatively and significantly.

2.3.2. Impact of improved varieties on food security

Evaluating the impact of adoption of agricultural technology has a great advantage for Ethiopia where the agriculture sectors the engine of development which drives the entire economy. Applying new agricultural technologies has positive impact on the economic development of a country. Different studies on the impact of adoption of improved crop varieties and other accompanying technologies shows positive contribution for small holder farmers towards, income improvement, household expenditure, daily calorie intake generally on food security of farm households. The following reviews of literature reveals the positive impact of adoption of agricultural technologies and food security of households measured by different indicators.

The study by Estehiwot (2018) on the determinants of agricultural technology adoption and its' impact on *teff* productivity in the Case of Amhara and Oromia National Regional State using multinomial endogenous regression model. The result found that adoption of improved *teff* have a positive and significant impact on *teff* productivity.

The study by Regasa *et al.* (2018) on determinants of improved *teff* varieties adoption and its impact on productivity in the Case of non-traditional *teff* growing areas of Western Ethiopia

using PSM revealed that adoption of improved *teff* have a positive and significant impact on *teff* productivity.

Bekele *et al.* (2014) on their study on impact of improved wheat variety on food security using both propensity score matching and endogenous switching regression methods of impact evaluation in Ethiopia. The result indicate that adoption of improved wheat varieties increases the probability of food security, per capita food consumption, and the probability of attaining the food breakeven and food surplus status. On the other hand, it decreases the probability of chronic and transitory food insecurity. Similarly, households that did not adopt have more per capita food consumption expenditure if they had adopted the technology which means that non adopters would have higher levels of consumption from switching to improved wheat production under the given conditions.

A study conducted by Tsegaye and Bekele (2012) on the impact of improved wheat varieties on food consumption in Eastern Ethiopia and results of the finding using PSM revealed that the food consumption per adult equivalent per day for adopters of improved wheat variety was higher for adopters than non-adopters of the improved variety. The result also shows that adopters were better than non-adopters by about 17% in terms of food consumption and the difference is statistically significant.

A study conducted by Debelo (2015) on impact of adoption of kuncho *teff* on farmers' crops income using propensity score matching method the result revealed that the crops net income (one indicator of food security) of the farmers who were adopter of kuncho *teff* was much greater than non- adopters, which clearly shows that the average treatment effect on the treated (ATT) of crops net income is high for adopters and the difference is significant. So it is concluded, in this analysis that, the kuncho *teff* adoption has positive income effect on the farm households.

Tesfaye *et al.* (2016) on their study on impact of improved wheat technology adoption on productivity and income which are among the indicators of food security, in Ethiopia using propensity score matching. The finding indicates that the average treatment effect on the treated (ATT) estimate that improved wheat variety adoption significantly increase the wheat productivity.

The study by Misgana (2018) on impact of adoption of improved wheat varieties on crop productivity in Ethiopia using propensity score matching asserts that adoption of improved wheat varieties increases crop productivity and the mean difference is statistically significant.

The study by Moti *et al.* (2014) evaluate the impact of improved varieties on food consumption using endogenous switching regression model in Ethiopia and the results of the finding revealed that the food consumption per adult equivalent per day for adopters of improved variety was higher for adopters than the non-adopters of the improved variety and the difference is statistically significant.

The study by Tesfaye *et al.* (2018) on impact of improved wheat variety on crop productivity using propensity score matching in Oromia Region affirms that improved wheat variety has a positive and significant difference in crop productivity in small holder farm household farmers.

2.4. Conceptual Framework of the Study

For this study the conceptual frame work had been developed based on previous literature and empirical evidences done before which affect adoption decision of smallholder farm households which may affect negatively or positively and the interrelationship between adoption of improved technologies. It also shows how adoption of improved *teff* variety enhance food security status of smallholder *teff* producers.

Adoption of improved *teff* varieties is expected to have a considerable advantage in terms of increase in *teff* productivity there by increased output. Then an increased output is expected to increase consumption pattern of farm households and in turn improve the food security status of smallholder *teff* producer farm households.

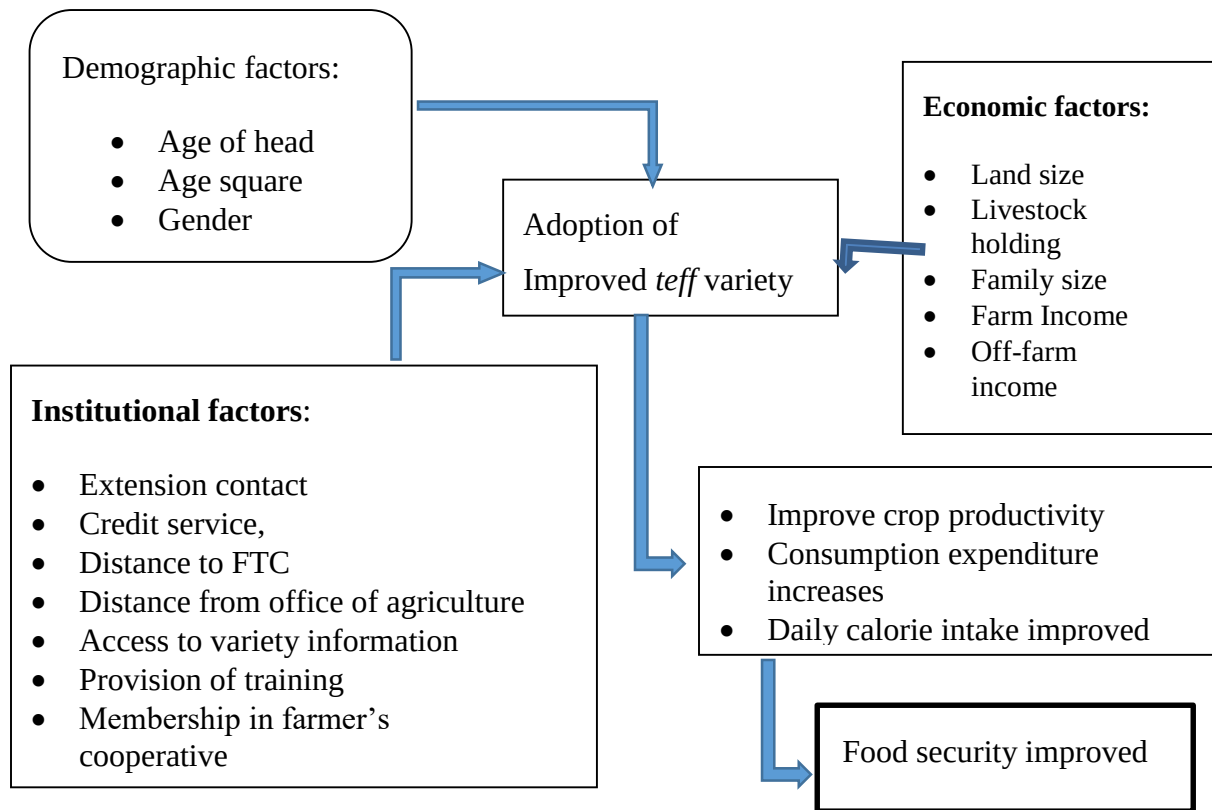


Figure 1. Conceptual Framework of the study

Source: Zenaye, 2016 with some modification

2.5. Analytical Framework of Impact Studies

The quantitative methods for evaluating any social programs have been critically reviewed by Ravallion (2005), who concluded that no single method dominates, and that rigorous policy relevant evaluations should be open-minded about methodology, adapting to the problem, the setting, and data constraints. Estimating the impact of a program or project requires separating its effect from intervening factors which may be correlated with the outcomes, but not caused by the program. 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 comparison group of individuals or households who did not participate in the program, but have similar characteristics as those participants who are known as the treatment groups. Identifying these groups correctly is key to identifying what would have occurred in the absence of the program or project (Ezemenari *et*

al., 1999). There are two main methods in establishing control and treatment groups: randomization/pure experimental design and non-experimental design/quasi-experimental design. The choice of a particular approach depends on availability of data and cost.

2.5.1. Experimental method of impact evaluation

Experimental method is randomized method, where the treatment and control samples are randomly drawn from the same population. In other words, in a randomized experiment, individuals are randomly placed into two groups, namely, those that involve in the program or those that do not involve in the program. This allows the researcher to determine the participation impact by comparing means of outcome variable for the two groups. In the contrary, non-experimental approach is used in cases where program placement is intentionally located. Non-experimental methods are frequently used in practice either because program administrators are not too keen to randomly exclude certain parts of the population from an intervention or because a randomized approach is out of context for a rapid-action project with no time to conduct an experiment.

Generally, randomized evaluations seek to identify a program's effect by identifying a group of subjects sharing similar observed characteristics for example across incomes and earning opportunities and assigning the treatment randomly to a subset of this group.

The non-treated subjects then act as a comparison group to mimic counterfactual outcomes. This method avoids the problem of selection bias from unobserved characteristics. However, the quality of impact analysis depends ultimately on how it is designed and implemented. Often the problems of compliance, spillovers, and unobserved sample bias hamper clean identification of program effects from randomization. In such cases, researchers then turn to non-experimental methods. The basic problem with a non-experimental design is that for the most part individuals are not randomly assigned to programs, and as a result, selection bias occurs in assessing the program impact (Shahidur *et al.*, 2010).

The essential idea of the before and after estimator of an impact evaluation approach is to compare the outcome of interest variable for a group of individuals after participating in a program with outcome of the same variable for the same group or a broadly equivalent group

before participating in the program and to view the difference between the two outcomes as the estimate of average treatment effect on the treated. Cross-section estimators use non-participants to derive the counterfactual for participants in which case it becomes quasi-experimental method.

2.5.2.A quasi-experimental/non-experimental method

A quasi-experimental method is the only alternative when neither a baseline survey nor randomizations are feasible options (Jalan and Ravallion, 2003). The main benefit of quasi-experimental design is that they can draw on existing data sources and are thus often quicker and cheaper to implement, and they can be performed after a project has been implemented, given sufficient existing data. The principal disadvantages of quasi-experimental techniques are that the reliability of the results is often reduced as the methodology is less robust statistically; the methods can be statistically complex and data demanding; and there is a problem of selection bias. There are different methods of quasi-experimental impact evaluation.

Double difference or difference-in-differences (DID) methods, in which one compares a treatment and comparison group (first difference) before and after a program (second difference). Comparators should be dropped when propensity scores are used and if they have scores outside the range observed for the treatment group. In this case potential participants are identified and data are collected from them. However, only a random sub sample of these individuals is actually allowed to participate in a certain program. The identified participants who do not actually participate in the program form the counterfactual (Jalan and Ravallion, 2003). This method can be used to reduce the potential selection bias (when unobservable individual characteristics are assumed to be time invariant) and the impact of other factors exogenous to the program on observable characteristics. It accomplishes this by looking at the difference in outcome of participants relative to the difference in outcome of non-participants. Equivalently, it looks at the difference in indicators for the two groups at the end of the program relative to the difference in indicators at the beginning.

Instrumental variable is one of the econometric techniques that can be used to compare program participants and non-participants correcting for selection bias. In this method one uses one or more variables that matter to participation but not to outcomes given participation. This

identifies the exogenous variation in impact attributable to the program, recognizing that its placement is not random but purposive. The instrumental variables are first used to predict program participation; then one sees how the outcome indicator varies with the predicted values (Baker, 2000). Endogenous switching regression is one of the one of the instrumental econometric methods which catches both observed unobserved biased which was used for this study.

Propensity score matching is one of the quasi-experimental methods that have been employed if we don't have baseline data. Rosenbaum and Rubin (1983) were the first to develop the propensity score matching (PSM) statistical tool. PSM is preferred to the traditional regression method in several ways. Among others, PSM compares outcomes for observations who share similar observable characteristics although they differ in treatment status. Moreover, PSM compares only those households who lie in the common support region by excluding those others outside the overlapping region from the analysis. According to Bernard *et al.* (2010), there are three potential sources of bias. The first is that participant households may significantly differ from non-participant households due to observable characteristics (such as geographic remoteness or a household's physical and human capital stock) which may have a direct effect upon the outcome of interest. Secondly, the difference arises due to unobservable community level characteristics. For instance, the existence of a project may be in part driven by particularly dynamic local leaders at community level. At the household level, a household's expected benefits, its entrepreneurial spirit, or its relationship with other programs/projects may significantly influence behavior. Thirdly, externalities (or spillover effect) are sometimes exerted by the project on nonparticipants. As a result of the above problems, differences between program participants and nonparticipants may either totally or partially reflect initial differences between the two groups, rather than the effects of program.

PSM controls the households' observable characteristics by comparing the outcomes of participants with those of matched non-participants based on similarity in observed characteristics; this minimizes the first bias. If not feasible to control for these characteristics, PSM estimation becomes biased. Having control households from the same communities as program beneficiaries helps to reduce the risks of such bias (Bernard *et al.*, 2010). According to Caliendo and Kopeinig (2008), there are progressive steps to be taken when implementing PSM:

these are estimations of the propensity scores using binary model, choosing a matching algorithm, checking common support conditions and testing the matching quality. Initially, the propensity score can be obtained using either logit or probit models to predict the probability of participation of a household.

The logit model used to estimate propensity scores and determinant factors for adoption of improve varieties using household's pre-intervention characteristics (Rosenbaum and Robin, 1983); matching could then be performed using propensity scores of each observable characteristics, which of course must be unaffected by the intervention. These characteristics include covariate variables which influence participation decisions and the outcome of interest. The coefficients are used to calculate a propensity score, and participants are matched with nonparticipants based on having similar propensity score.

Even though matching procedures can be applied in many settings, they have several serious shortcomings. they require large samples, Treated and control groups should have substantial overlap and matching can only be performed based on observed characteristics (Gertler *et al.*, 2016). Because of PSM has several limitations, endogenous switching regression complemented was employed to evaluate the impact of adoption of improved *teff* variety on the food security of farm household to check the consistency of the estimate. To examine the impact of a given technology adoption on outcome variables. the result of PSM could not show the real adoption impact since the adoption decision may have self-selection unobserved endogeneity problem which PSM could not handle (Khandker *et al.*, 2010). Therefore, full information maximum likelihood endogenous switching regression models was employed (Di Falco *et al.*, 2011; Solomon *et al.*, 2012; Bekele *et al.*, 2014) to handle heterogeneity effect among sample households.

2. RESEARCH METHODOLOGY

This chapter provides research methodology used in the study in order to achieve desired objectives.

3.1. Description of the Study Area

This study was conducted in Lasta woreda, one of the districts of North Wollo Zone which is found inside Tekeze basin growth corridor of Amhara National Regional State, Ethiopia. The district is located in northeastern part of ANRS at 13°20' N' latitude and 38°58' E' longitude. the Woreda is bordered by Wagehemira zone in the North Meket Woreda in South, Bugna Woreda in the West and Gidan Woreda in the East (LWOA, 2018).

The altitude of the Woreda ranges from 1400 to 4200 m.a.s.l. The Woreda has four agro-ecological zones essentially based on altitude, namely extreme highlands (above 3000 m.a.s.l), highland (2400 to 3000m.a.s. l), midland (1600 to 2400 m.a.s.l), and lowland (below 1600 m.a.s.l) covering 0.6%, 15.4%, 48.5%, and 36.3% of the Woreda respectively. The topography of the area includes plain land, plateaus, hills and undulating landform. The area receives an average annual rainfall of 533-880mm and minimum and maximum temperature of 16°C and 27°C, respectively. Total area of the Woreda is about 1,197,330,000 square meter (119733 ha). 24,071 hectare of land is arable land under crop production, whereas 24.3% is grazing land, 41.5% covered with forest, and the remaining 24% of the zone is under other land use forms (LWOA, 2018). Lasta woreda has a total population of 117,777, of whom 58,451 are men and 59,326 women. The highland parts of the woreda uses bimodal rainfall pattern and hence suitable for agriculture. About 4,000 ha of land in the Woreda is cultivated during *Belg* season while 24,071 ha of land cultivated during *Meher* season and about 3105 ha of land is cultivated in irrigation. The Woreda has 23 administrative Kebeles among those *teff* is grown in 18 kebeles. Wheat, *teff*, barley and sorghum are the dominant crops grown by smallholder farm households in the Woreda (LWOA, 2018).

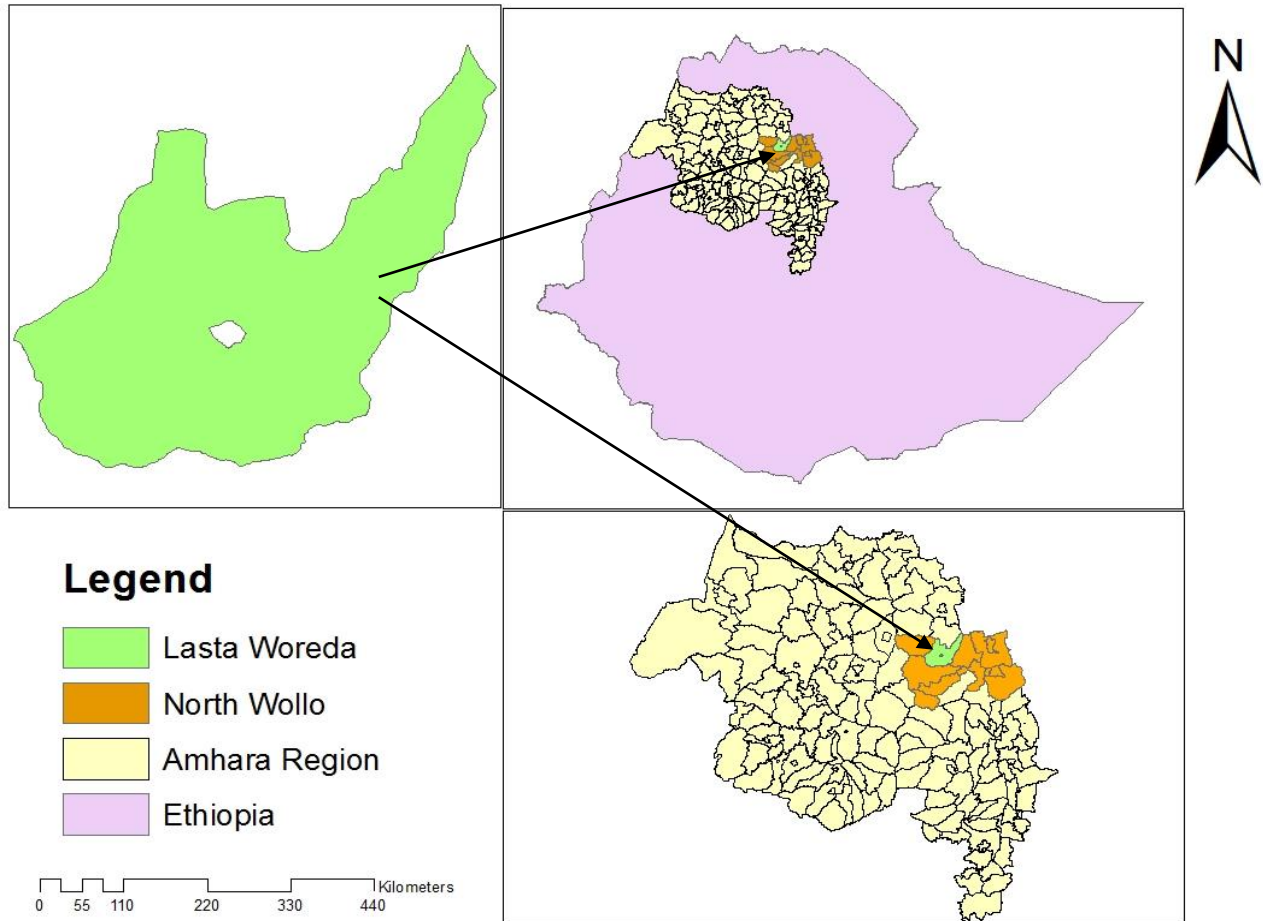


Figure 2. Map of the study area

Source: Own drawing, 2018

3.2. Data Type, Sources and Methods of Data Collection

To gather necessary data that are relevant for maintaining/meeting the stated objective of the study; quantitative and qualitative data were collected from primary and secondary data sources. Primary data were collected through formal interview of sample households using semi-structured questionnaire. Before conducting formal survey, the prepared questionnaire was tested so as to incorporate important parameters into the questionnaires. The primary data were collected by well-trained enumerators under the supervision and coordination of the researcher. Secondary data were also collected from secondary data source by reviewing different published and unpublished articles, proceedings, books, Woreda office of Agriculture reports and the like.

3.3. Sampling procedures and Sample Size Determination

Multi-stage sampling procedure was employed to select representative sample households for this study. In the first stage 13 major *teff* producer Kebeles were selected purposively where improved *teff* variety is introduced among 23 Kebeles of Lasta Woreda. In the second stage, three kebeles were randomly selected from 13 *teff* producing Kebeles. In the third stage, households in the selected three Kebeles were stratified into two groups of adopters and non-adopters of improved *teff* variety. Finally, using simple random sampling technique from each Kebele in each category proportional to the total number of sample households 225 sample households were selected randomly (119 from adopters and 106 non-adopters).

Table 1. Distribution of sample households by kebele

Name of the kebeles	Total households	Sample households		
		Adopters	Non-Adopters	Total sample households
Shumshiha	1133	48	50	98
Debre Loza	838	25	34	59
Medagie	847	46	22	68
Total	2818	119	107	225

Source: own sample survey (2019)

3.4. Methods of Data Analysis

The collected data were analyzed using both descriptive statistics and econometric models.

3.4.1. Descriptive and inferential statistics

The data which was collected from sample households was analyzed by using descriptive statistics such mean, minimum, maximum, standard deviation and percentages. Moreover, test statistics such as t-test was applied for discrete and continuous variables and chi-square (χ^2) test was also applied for dummy and categorical variables to check the significance of variables between adopters and non-adopters of improved *teff* variety.

3.4.2. Econometric analysis

To evaluate the impact of improve *teff* variety on food security full information maximum likelihood endogenous switching regression model was employed.

3.4.2.1. Endogenous switching regression(ESR)

The decision to adopt improved *teff* variety and its implication on food security can be modeled in a two-stage treatment framework. In the first stage of ESR, farmers' choice of improved *teff* variety is modeled and estimated using a probit model. Following De Janvery *et al.* (2010) the observed outcome of adoption of improved *teff* variety can be modeled following a random utility formulation. Consider the i^{th} farm household facing a decision on whether or not to adopt improved *teff* varieties. Let U_0 represent the benefits to the farmer from adoption of traditional/local *teff* variety, and let U_k represent the benefit stream from adoption of improved variety/varieties. The farmer will adopt improved varieties if $I_i^* = U_k - U_0 > 0$. The net benefit (I_i^*) that the farmer derives from the adoption of improved varieties is a latent variable determined by observed characteristics (z_i) and the error term (ε_i):

$$I_i^* = z_i \alpha + \varepsilon_i \text{ with } I_i = \begin{cases} 1 & \text{if } I_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where I_i is a binary indicator variable that equals 1 if a farmer adopts an improved variety and zero otherwise and α is a vector of parameters to be estimated. In this study, adoption is defined if farmers used any of the improved *teff* varieties, either newly purchased from different seed source, recycled improved varieties. Recycling of seed is very common in sampled smallholder farmers growing improved *teff* varieties in the study area. About 81.5% of the adopter famers recycle seed either by saving from the previous production or by exchanging the improved seed with other commodities and purchasing the improved *teff* variety with other neighboring farmers.

The outcome functions, conditional on adoption, can be written as an endogenous switching regime model following (Lokshin and Sajaia, 2004):

$$\text{Regime 1: } y_{1i} = x_{1i}\beta_1 + \eta_{1i}, \text{ if } I = 1 \quad (2a)$$

$$\text{Regime 2: } y_{2i} = x_{2i}\beta_2 + \eta_{2i}, \text{ if } I = 0 \quad (2b)$$

where y_1 and y_2 are outcome variables, representing food consumption expenditure per year and daily calorie intake per adult equivalent and binary food security status, X represents a vector of covariates, and α is a vector of parameters to be estimated.

For the ESR model to be identified it requires to use as exclusion restrictions, thus as selection instruments, not only those automatically generated by the nonlinearity of the selection model of adoption but also other variables that directly affect the selection variable but not the outcome variable. For this study number of seed traders known by farmers and access to different sources of improved *teff* variety information [development agents(1=yes) and research center (1=yes)] are the instrumental variables used for the identification of the impact of adoption on the food security of outcome variables for this study.

Adoption behavior of farmers can be greatly influenced by access to different information sources are used as a tool for the diffusion process and content of information gained regarding the technology may differ by access to variety information sources Similarly, number of seed traders influence local availability of seed which in turn affects the incentive to adopt and the intensity of adoption (Bekele *et al.*, 2014; Moti *et al.*, 2014). We consider that these variables

are likely to be correlated with the adoption of *teff* variety but are unlikely to influence the outcome variable directly or correlated with the unobserved errors of equations 12a and 12b. Number of traders known by farmers has been used as an instrument that address adoption impact on household food consumption expenditure PAE (Bekele *et al.*, 2014; Di Falco *et al.*, 2011) used different information sources and number of seed dealers known by respondent farmers used as instrument in their analysis of the impact evaluation studies in Ethiopia.

A simple falsification test following Di Falco *et al.* (2011) had been implemented to test the validity of the instruments. In a simple falsification test: if a variable is a valid selection instrument, it will affect the selection equation but it will not affect the outcome variables among farm households that did not adopt. As presented in the Appendix Table 9,10 and 11 indicates that access to variety information and number of seed traders known by farmers are used as valid selection instruments for different outcome variables: they are jointly statistically significant selection equation ($\chi^2 = 102.85$; $p = 0.00$) but not of the outcome variables by the farm households that did not adopt F-stat. =1.79 , $p = 0.1542$ and F-stat. = 0.5, $p = 0.6833$ when taking daily calorie intake per adult equivalent and annual food consumption expenditure per adult equivalent as an outcome variable respectively, when binary food security is used as an outcome variable. [$\chi^2 = 1.23$ ($p=0.3023$) which verify the validity of the instruments used for this study.

The error terms in equations (11) and (12) are assumed to have a trivariate normal distribution with mean zero and covariance matrix specified as:

$$\text{cov}(\varepsilon, \eta_1, \eta_2) = \begin{bmatrix} \sigma_\varepsilon^2 & \sigma_{\varepsilon 1} & \sigma_{\varepsilon 2} \\ \sigma_{1\varepsilon} & \sigma_1^2 & . \\ \sigma_{2\varepsilon} & . & \sigma_2^2 \end{bmatrix}, \quad (3)$$

where $\sigma_\varepsilon^2 = \text{var}(\varepsilon)$, $\sigma_1^2 = \text{var}(\eta_1)$, $\sigma_2^2 = \text{var}(\eta_2)$, $\sigma_{\varepsilon 1} = \text{cov}(\varepsilon, \eta_1)$, and $\sigma_{\varepsilon 2} = \text{cov}(\varepsilon, \eta_2)$. The variance of σ_ε^2 can be assumed to be equal to 1 since the β coefficients in the selection model are estimable up to a scale factor. The covariance between η_1 and η_2 is not defined since y_1 and y_2 are not observed simultaneously (Maddala, 1983). The expected values of η_1 and η_2

conditional on the sample selection is non-zero because the error term in the selection equation (11) is correlated with the error terms of the food security functions. (η_1 and η_2)

$$E(\eta_{i1}|I_i = 1) = \sigma_{1\epsilon} \frac{\phi(z_i\alpha)}{\Phi(z_i\alpha)} = \sigma_{1\epsilon} \lambda_{i1} \quad \text{and}$$

$$E(\eta_{i2}|I_i = 0) = -\sigma_{2\epsilon} \frac{\phi(z_i\alpha)}{1 - \Phi(z_i\alpha)} = \sigma_{2\epsilon} \lambda_{i2}$$

Where $\phi(\cdot)$ is the standard normal probability density function, $\Phi(\cdot)$ is the standard normal

cumulative density function, $\lambda_{i1} = \frac{\phi(z_i\alpha)}{\Phi(z_i\alpha)}$ and $\lambda_{i2} = \frac{\phi(z_i\alpha)}{1 - \Phi(z_i\alpha)}$. Where λ_{i1} and λ_{i2} are the Inverse Mills Ratios (IMR) computed from the selection equation and will be included in 12a and 12b to correct for selection bias in a two-step estimation procedure i.e., endogenous switching regression. If the estimated covariance $\sigma_{1\eta}$ and $\sigma_{2\eta}$ are statistically significant, then the adoption decision and outcome variables of the household are correlated, implying the presence of endogenous switching and suggesting to reject the null hypothesis that there is no sample selection bias (Di Falco *et al.*, 2011). An efficient method to estimate endogenous switching regression model is by full information maximum likelihood estimation following Lokshin and Sajaia (2004).

Conditional expectations, treatment and heterogeneity effects

The above framework can be used to estimate the average treatment effect on the treated (ATT) and untreated (ATU) by comparing the expected values of the outcomes of adopters and non-adopters in actual and counterfactual scenarios. Following (Di Falco *et al.*, 2011) and the wage decomposition literature, we compute the ATT and ATU in the actual and counterfactual conditions. The estimates from ESR allow computing the expected values in the real and hypothetical scenarios as presented in Table 5 and 6 and is defined below:

Adopters with adoption (observed in the sample)

$$E(y_{i1}|I = 1; x) = x_{i1}\beta_1 + \sigma_{1\epsilon}\lambda_{i1} \tag{4a}$$

Non-adopters without adoption (observed in the sample)

$$E(y_{i2}|I = 0; x) = x_{i2}\beta_2 + \sigma_{2\varepsilon}\lambda_{i2} \quad (4b)$$

Non-adopters had they decided to adopt (counterfactual)

$$E(y_{i2}|I = 1; x) = x_{i1}\beta_2 + \sigma_{2\varepsilon}\lambda_{i1} \quad (4c)$$

Adopters had they decided not adopt (counterfactual)

$$E(y_{i1}|I = 0; x) = x_{i2}\beta_1 + \sigma_{1\varepsilon}\lambda_{i2} \quad (4d)$$

Equations (14a) and (14b) represent the actual expectations observed from the sample, while equations (14c) and (14d) are the counterfactual expected outcomes. Using these conditional expectations, the following mean food security outcome difference can be computed.

The expected change in adopter's food security, the effect of treatment on the treated (ATT) is computed as the difference between (4a) and (4c)

$$ATT = E(y_{i1}|I = 1, x) - E(y_{i2}|I = 1, x) = x_{i1}(\beta_1 - \beta_2) + \lambda_{i1}(\sigma_{1\varepsilon} - \sigma_{2\varepsilon}) \quad (5)$$

Similarly, the expected change in non-adopter's food security, the effect of the treatment on the untreated (ATU) is given as the difference between (4d) and (4b)

$$ATU = E(y_{i1}|I = 0, x) - E(y_{i2}|I = 0, x) = x_{i2}(\beta_1 - \beta_2) + \lambda_{i2}(\sigma_{1\varepsilon} - \sigma_{2\varepsilon}) \quad (6)$$

The first term on the right hand side of equation (5) represents the expected change in adopter's mean outcome, if adopters' characteristics had same return as non-adopters, or if adopters had similar characteristics as non-adopters. The second term (λ) is the selection term that captures all potential effects of difference in unobserved variables. For the effect of treatment on the untreated, Equation (6) can be interpreted in the same way.

We can use the expected outcomes described in equations (4a)–(4d) to calculate also the heterogeneity effects. For example, farm households that adapted may have produced more than farm households that did not adopt regardless of the fact that they decided to adopt but because of unobservable characteristics such as their skills. Following Carter and Milon (2005) and define as “the effect of base heterogeneity” for the group of farm households that decided to adopt as the difference between (4a) and (4d),

$$\begin{aligned} BH_1 &= E(y_{1i}|A_i = 1) - E(y_{1i}|A_i = 0) \\ &= (X_{1i} - X_{2i})\beta_{1i} + \sigma_{1\varepsilon}(\lambda_{1i} - \lambda_{2i}). \end{aligned} \quad (7)$$

Similarly, for the group of farm households that decided not to adopt the improved variety, “the effect of base heterogeneity” is the difference between (4c) and (4b),

$$\begin{aligned} BH_2 &= E(y_{2i}|A_i = 1) - E(y_{2i}|A_i = 0) \\ &= (X_{1i} - X_{2i})\beta_{2i} + \sigma_2\eta(\lambda_{1i} - \lambda_{2i}). \end{aligned} \tag{8}$$

Finally, as shown the mathematical representation in the appendix table 12 we investigate the “transitional heterogeneity” (TH), which shows whether the effect of adopting improved *teff* variety is larger or smaller for farm households that actually adopted or for farm households that actually did not adopt in the counterfactual case that they did adopt, that is the difference between equations (5) and (6) that is the difference between average treatment effect on treated (ATT) and average treatment effect on untreated (ATU).

3.5. Definition of Variables and Working Hypotheses

Dependent (treated) Variable

The dependent variable is adoption decision which is a dummy dependent variable that takes a value of 1 if the households adopted improved *teff* variety and 0, otherwise. Adopters are farm households who use any of improved *teff* variety either newly purchased from different seed sources or saved from previous planting in the past five consecutive years. And non-adopters sampled households are farm households who did not use any of improved *teff* variety but grow local *teff* varieties.

Outcome Variables:

Daily Calorie intake per adult equivalent: it is the daily food available for consumption for all household members in kilocalories per adult equivalent.

Consumption expenditure per adult equivalent: it is the total amount of money the household spent on consumables items (food and beverage) in Ethiopian birr per year per adult equivalent.

Food security status: this is a dummy outcome variable (subjective food security indicator) based on farmers own self-assessment on their own food security status (taking value 1 if farmers say food secure and 0, if farm households are food insecure) in the past 12 months.

Covariates (Explanatory variables): The following explanatory variables have been hypothesized which influence the adoption of improved *teff* variety based on empirical studies.

Age of the household head: this is a discrete variable which indicates age of household head measured in year. Previous studies conducted by (Debelo, 2015; Zenaye, 2016; Solomon *et al.*, 2012) indicates that as the accumulated experience of older farmers is expected to help them make adoption decision rather younger farmers. However, as the age of household head reaches at a certain age limit where the farmer become older and older and unable to contribute in farming activities, decisions on adopting improved technologies might be very slow and will have turning point. Therefore, a quadratic relationship was expected between adoption decision and age. Thus, this variable is hypothesized to have positive effect on adoption decision of improved *teff* technologies of the household head.

Education level (year of schooling): this is a discrete explanatory variable which indicates formal education level of the household head, which indicates the total number of years of schooling of the household head. Education creates awareness and helps the farmers to develop positive attitude towards using new technologies (improved *teff* varieties) and helps to take risk of new farming practices (Bayissa, 2014). Thus, this variable is expected to influence the adoption decision of *teff* grower farm households positively.

Family size: This is a continuous variable refers to number of family members who are currently living with in the family which is measured in adult equivalent. Previous studies affirm that family size is important factor for agricultural production especially for such type of(*teff*) labor-intensive production (Debelo, 2015; Tsibuk, 2015). Therefore, a farm household with higher number labor is hypothesized to affect adoption of improved *teff* varieties positively.

Farm size in hectare: it is a continuous variable that the total size of land that the farm household own. Farmers with larger land size can afford the expenses on new agricultural technologies. This means that farmers who have relatively larger farm size will be more initiated to adopt improved technologies and the reverse is true for farmers with less land (Zenaye, 2016). Therefore, this explanatory variable is expected positively affect the decision to adopt improved *teff* varieties.

Livestock holding: this is a continuous explanatory variable measured in terms of Tropical Livestock Units (TLU), indicating the number of livestock owned by the household. Previous study indicates that an increase in livestock number minimizes the liquidity problem of farm households by selling the livestock when the need (Debelo, 2015). This variable is hypothesized that ownership of livestock increases the adoption of improved *teff* technologies.

Access to credit: This is a dummy variable 1 if respondents get credit and 0, other wise and this access to credit improves farmers' purchasing power of new production technologies like improved varieties, fertilizer and other agricultural inputs. Access to credit hypothesized affect the adoption of improved *teff* variety positively by improving the liquidity status of the farm household (Tsibuk, 2015). Thus, this variable is expected positively influence decision to adopt.

Distance of farmer resident from agricultural extension office: This is a continuous variables and measures the distance in kilometer from the household residence to respective kebele agricultural extension office. Previous studies show that increase in distance of farmer's resident from Kebele office of agriculture limits accessibility of information on new technologies (Solomon *et al*, 2012; Asmiro *et al.*, 2017). Thus, this explanatory variable is hypothesized to affect the adoption decisions negatively.

Off-farm income: this is a continuous variable that farm households generate from off-farm activities such as trading, remittance etc. in Ethiopia birr. Previous study indicates that an increase in off-farm income facilitate adoption of improved *teff* technology because it minimizes liquidity problems of farmers to purchase inputs required for improved *teff* production (Daniel, 2008). Therefore, this variable is hypothesized positively affect adoption decision of farmers to adopt improved *teff*.

Provision of training: this is a dummy variable which takes 1 if the respondents got training by different governmental and non-governmental organization on improved *teff* technologies and 0, otherwise. Previous studies indicate that provision of training is very crucial for smallholder farmers to acquire knowledge and skill on the theoretical and practical aspect of the variety and motivate to adopt (Debelo, 2015; Tsibuk, 2015). Thus, this variable is hypothesized positively affect adoption decision of improved *teff* technologies

Access to variety information from development agent: This is a dummy variable if farmers get variety information from development agents (1 if yes otherwise 0). Previous studies indicate that if farmers get sufficient information regarding the variety from development agents they motivate to adopt the variety (Di Falco *et al.*, 2011; Bekele *et al.*, 2014; and Etsehiwot, 2018). This, this variable is hypothesized positively influence the likelihood to adopt.

Access to variety information from research center: This is a dummy variable if farmers get variety information from research center (1 = if yes otherwise 0). Previous studies indicate that if farmers get sufficient information regarding the variety they motivate to adopt the variety (Bekele *et al.*, 2014). Therefore, this variable is hypothesized positively influence decision to adopt. is expected to determine adoption of improved *teff* positively

Frequency of extension contact: This is a discrete variable which is frequency of extension visit undertaken by development agents in the past 12 months for *teff* producer smallholder farmers. Previous studies indicate that frequency of contacts with extension agents increases the likelihood of acquiring up-to-date information on the new agricultural technologies (Daniel, 2008; Tsibuk, 2015; and Etsehiwot, 2018). Thus. this variable is hypothesized to have a positive effect on farmer's adoption decision of improved *teff* variety.

Membership in farmer's primary cooperatives: it is a dummy explanatory variable that takes a value of 1 if the household head is a member of farmer's primary cooperative and 0 otherwise. Membership to agricultural cooperative positively influences adoption of improved agricultural technology by providing members access to inputs and better markets (Zenaye, 2016). Membership to primary agricultural cooperatives is hypothesized to have a positive relationship with adoption of improved *teff* varieties.

Number of seed traders known by farmers: this is a discrete variable which shows number of improved *teff* sellers(traders) known by farm households. Number of seed traders influence local availability of seed which in turn affects the incentive to adopt and the intensity of adoption (Bekele *et al.*, 2014). This variable is hypothesized to influence adoption of improved variety positively.

Farm income: this is a continuous variable which is the amount of income that farm households generate from farm activities mainly from livestock and crop product in one-year in Ethiopia birr. Previous study indicate that the income generated from these farm activities solves liquidity problems of farmers and will be motivated to adopt improved *teff* variety (Daniel, 2008). This variable is hypothesized to influence adoption of improved *teff* variety positively.

Sex of the household head: is a dummy variable that takes a value of 1 if the household head is male and 0 otherwise. Sex difference is found to be one of the factors influencing adoption of new technologies. Due to many socio-cultural values and norms, males have freedom of mobility and participation in different extension programs as a result they have greater access to updated information (Tsibuk, 2015). Therefore, it is hypothesized that male farmers are more likely to adopt new technology.

Table 2. Explanatory variables and expected sign which affect adoption.

variable	measurements	Expected effect
Age	Discrete , age of the household head in years	+
Age square	Discrete, age square of household age	+
sex	Dummy, Sex of household head(1=male)	+
Education:	Discrete, year of schooling	+
Family size	Continuous, total family members in adult equivalent	+
Farm size in hectare	Continuous, farm size that households own	+
TLU(log)	Continuous, total livestock owned in TLU	+
Access to credit	Dummy, Status of credit access 1 yes 0,otherwise	+
Distance from kebele office	Continuous, distance in kilometer	-
Off-farm income	Continuous, income from off-farm activities	+
Extension service	Discrete, frequency of extension visit	+
Provision of training	Dummy, Training provided for farmers(1=yes)	+
Variety information 1	Dummy, Access to variety information from development agents (1=yes)	+
Variety information 2	Dummy, access to variety information from research center(1=yes)	+
Farm income(log)	Continuous, income from farm activities	+
Seed traders	discrete, number of seed traders known by respondents.	+
Membership	Dummy, membership in farmers primary cooperative	+

4.RESULTS AND DISCUSSIONS

This parts of the study presents the descriptive result, econometric result on factors affecting adoption decision of improved *teff* variety and average treatment effect on treated on outcome variables using full information maximum likelihood endogenous switching regression and propensity score matching with brief discussions of the result of the cross-sectional data collected from 2017/2018 production year from sampled households.

4.1. Descriptive Results

From a total 225 sampled households 119(53%) are adopters and the remaining 106(47%) sample households are non-adopters of improved *teff* variety. The proportion of male-headed and female-headed sample respondents are 96% and 4% respectively. The mean land area allocated for improved *teff* is 0.31ha and it is higher than the mean area of 0.22 ha land allocated for local *teff* varieties. Moreover, the mean productivity of improved *teff* variety (994kg/ha) is higher than local-variety (590kg/ha). Kuncho and worekiyu are the two improved *teff* varieties mainly used by sampled adopters with the former constituting the higher proportion of 94.3%. The remaining 6.7% of adopters use both varieties. Saving from previous year and exchange with neighbor farmers are the two major sources of improved *teff* varieties for sampled adopters.

The result indicates that among the total adopters 98.3% were male headed households and remaining 1.7% were female headed. Among the total non-adopters 92.4% were male headed households and the remaining were female headed. The mean total family size measured in adult equivalent for adopters was 4.345 while it was 3.885 for non-adopters and the result shows significant mean difference between adopters and non-adopters. Concerning total livestock owned (TLU in log), the mean livestock owned in TLU by adopters was 1.431 whereas the mean livestock holding for non-adopters was 1.243 TLU and the mean difference is significant at 5% probability level. On average, adopters of improved *teff* varieties generated 9.778 ETB (log) farm income compared to 9.36 ETB (log) by non-adopters. The difference in farm income is significant at 1% significance level. Moreover, the sampled adopters generated a higher off-farm income (2,647 ETB) than non-adopters (1193 ETB) and the mean difference is statistically significant (Table 3).

The t-test shows that there was a significant difference in frequency of extension visit and distance of farmer's residence from office of agriculture between adopters and non-adopters. The chi-square test result indicates that there is a positive and significant of access to credit service, access to variety information from development agents and from research center, membership in farmer's primary cooperative with improved teff varieties adoption decision (Table 3).

The average annual food consumption expenditure per adult equivalent of adopters (4973.018 ETB) is significantly higher than that of non-adopters (3735.863 ETB) and the mean difference is significant at 1% probability level. The daily calorie intake per adult equivalent by adopters (2026.911 kilo calorie) is higher than non-adopters (1614.125 kilocalorie) and mean difference significant at 1% significant level (Table 3).

Table 3.t-test and χ^2 test of variables compared between adopters and non-adopters

Explanatory Variables	Mean			χ^2 /t-value
	Adopters	Non-adopters	Total sample	
Sex(%)of household head male	0.983	0.924	0.953	4.54**
Age of household head	48.915	47.433	48.217	-1.047
Age square of household head	2479.151	2336.96	2412.16	-1.029
Year of schooling	2.579	2.084	2.346	-1.225
Membership in farmers cooperatives(%yes)	0.605	0.377	0.492	11.62***
Total family size in adult equivalent	4.345	3.885	4.128	-2.96***
Total farm land	0.759	0.696	.7299	-1.252
Log livestock owned in TLU	1.431	1.243	1.342	-2.96***
Log farm income	9.778	9.360	9.581	-5.04***
Off-farm income	2646.637	1192.972	4390.18	-2.82***
Frequency of extension visit	2.815	1.669	2.275	-4.57***
Provision of training(%yes)	0.714	0.594	0.654	3.58*
Access and need of credit service(%yes)	0.058	0.009	0.021	3.988**
Number of seed traders known by respondents	3.176	1.009	2.155	-7.55***
Variety information from development agents(%yes)	0.907	0.547	0.737	37.638** *
Variety information from research center(%yes)	0.336	0.132	0.212	12.78***
Distance from Kebele office of agriculture	1.968	2.748	2.336	4.57***
Daily calorie intake PAE	2026.911	1614.125	1832.443	4.372***
Food consumption expenditure PAE	4973.018	3735.863	4390.181	3.709***
Mean productivity (k.g./ha	improved	994	Local	590
Mean area allocated(ha)	improved	0.31	local	0.22

*, ** and *** denotes significance level at 10%,5% and 1% probability level respectively.

Source: Own survey result (2019)

4.2. Adoption of Improved *Teff* Variety

To identify the factors which affect adoption decision of improved *teff* varieties, a binary probit model was employed. The result of binary probit model indicate that the selected covariates provide a good estimate of adoption decision of improved *teff* varieties. The Wald chi² test statistic (87.36) indicates that explanatory variables are jointly statistically significant ($P < 0.00$).

The result indicates that total family size measured in adult equivalent, log of farm income, off-farm income, number of traders known by farmers, variety information from development agent and research center influences adoption decision of improved *teff* varieties of sampled respondents positively, distance of farmer's residence from Kebele office of agriculture is negative and significant (Table 4).

Family size in adult equivalent is one of the factor which determine the adoption decision of improved *teff* variety by smallholder farm households. As expected family size positively affected the adoption of improved *teff* varieties. The possible reason is labor-intensive nature of improved *teff* varieties during critical times to perform basic agronomic practices such as plowing, sowing, weeding and harvesting. The marginal effect of the probit model affirms that a unit increase in family size measured in adult equivalent the likelihood of adopting improved *teff* variety increase by 11.19%. This result is consistent with that of Etsehiwot (2018).

Access of variety information from development agents is the determinant factors which positively influences sampled respondent's adoption decision of improved *teff* varieties at 1% probability level. Availability of information on improved *teff* variety production and variety information such as productivity, earliness and other variety traits had a positive effect on adoption decision of improved *teff* variety. Access to information is supposed to make sure confidence on the nature of the improved variety and to have better understanding of the variety trait. The result of the marginal effect indicates that, those farm households who have access to information on improved *teff* varieties are 60.47% more likely to adopt than those without access to this information. This result is consistent with the results of Etsehiwot (2018), and Regassa *et al.* (2018).

Similarly, access to variety information from research center positively and significantly affect sampled respondent farmer's decision to adopt improved *teff* variety. The result of the marginal effect indicates that, those farm households who have access to information on improved *teff* varieties are 25.12% more likely to adopt than those without access to this information. This result is consistent with the result of Etsehiwot (2018) and Regassa *et al.* (2018).

Different income sources generated from off-farm activities and farm income (in log form) are other determinant factors which positively influence the adoption decision of farm households. The output of the marginal effect indicates that a one percent increase in farm income and a unit increase in off-farm income increases the adoption of improved *teff* by 26.97 % and 0.0038 % respectively at 1% and 5% probability level respectively by keeping other variables constant. Because as farmers get more income they motive to adopt improved varieties because it solves liquidity problems that farmers faced to purchase necessary inputs for improved *teff* production. This result is in agreement with the findings by Susie (2017), Regasa *et al.* (2015), and Daniel (2008).

Distance of farmer's residence from Kebele office agriculture is the limiting factor which negatively influence adoption decision of improved *teff* variety as hypothesized. The result of marginal effect indicates that as the distance of farmer residence from Kebeles office of agriculture increase by one kilometer the probability to adopt improved *teff* variety decrease by 7.63% at 1% probability level. This might be due to limited access to information on improved varieties for those who are far from Kebele office of agriculture. This result is consistent with the findings of Asmiro *et al.* (2017) and Solomon *et al.* (2012).

Number of seed traders known by the respondents' influences decision to adopt positively. The marginal effect indicates that keeping other variables constant as the number of seed traders' increases by one the likelihood to adopt improved *teff* varieties by 10.94%. The possible reason is as the number of local seed traders increases the local availability of improved seed for farmers increases and they motivate to adopt. This result coincides the result of Bekele *et al.* (2014).

Table 4. Decision to adopt improved *teff* variety, probit model

Explanatory variable	coefficient	Robust St. error	Marginal effect
Sex of household head	0.9114	0.5928	0.3325
Age of household head	-0.0886	0.1067	-0.0352
Age square of household head	0.0010	0.0010	0.0004
Year of schooling	0.0322	0.0418	0.0128
Membership in farmers cooperatives	0.0374	0.2372	0.0149
Total family size in adult equivalent	0.2812***	0.1009	0.1119
Total farm land	-0.4349	0.3393	-0.1730
Log Livestock ownership in TLU	0.2366	0.3190	0.0941
Log total farm income	0.6779***	0.2472	0.2697
Off-farm income	0.00009**	0.00004	0.00003
Frequency of extension visit	0.0973	0.0681	0.0387
Provision of training	0.0338	0.2494	0.0134
Access and need of credit service	-0.7912	0.7141	-0.2950
Number of seed traders known by respondents	0.2749***	0.0593	0.1094
Variety information from development agents	1.811895***	0.3298	0.6047
Variety information from research center	0.6597***	0.2486	0.2512
Distance from kebele office of agriculture	-0.1919**	0.0946	-0.0763
Number of observations	225		
Wald chi2	87.36		
Prob > chi2	.000		
Pseudo R2	0.4876		
log likelihood	-79.721		

*, ** and *** denotes significance level at 10%,5% and 1% probability level respectively.

Source: Own survey result (2019)

4.3. Impact of Adoption of Improved *Teff* Variety on Food Security

4.3.1. Endogenous switching regression model(ESR)

The result from endogenous switching regression model estimated by full information maximum likelihood shows that the estimated error correlation between selection equation and outcome equations for adopters for each outcome variables is negative for both groups and are significantly different from zero for correlation between selection equation and for both outcome equations for adopters ρ_1 . The results indicate that both observed and unobserved factors influence the decision to adopt improved *teff* varieties and outcome variables given the adoption decision. The significance of the coefficient of correlation between the adoption equation and the outcome variables indicates that the presence of sample selectivity bias in the adoption of improved *teff* variety and illustrates the presence of heterogeneity in the sampled as presented in the Appendix Table 4,5 and 6 for daily calorie intake per adult equivalent, food consumption expenditure per year in ETB and binary food security status respectively.

The likelihood-ratio test for joint independence of the three equations are reported in the last lines of Appendix Table 4 (LR $\chi^2 = 3.73$, $p = 0.0536$) and in Appendix Table 5 (LR $\chi^2 = 6.07$, $p = 0.013$) for daily calorie intake and food consumption expenditure per adult equivalent respectively. The tests indicate that the error term of the selection equation (1), the error terms of equations outcome equations (2a) and (2b), are correlated and ignoring them leads to biased results.

Full information maximum likelihood endogenous switching regression model results as depicted in Table 5 below shows that adoption of improved *teff* variety had significant effect on food security measured by daily kilocalorie intake and food consumption expenditure per adult equivalent. Had the adopter households decided not to adopt, their average daily calorie intake per adult equivalent would have decreased by 417.908 kilocalorie which is significant at 1% probability level. On the other hand, if non-adopter households would have adopted improved *teff* variety, their daily calorie intake per adult equivalent would have increased by 512.581 kilocalorie which is higher than the benefit adopters would have lost due to non-adoption (switching from adoption to non-adoption).

The additional average daily calorie intake per adult equivalent for adopters at household level due to adoption is about 1815.810 ($4.345 * 417.908$) where 4.345 is the average adult equivalent for adopters. Similarly, households that did not adopt, would have daily calorie intake per adult equivalent of about 1991.377 ($512.581 * 3.885$) kilocalorie at household level more if they had adopted the improved *teff* variety, implying that current non-adopters would have achieved higher levels of daily calorie intake switching from non-adopting to adopting improved *teff* under the given conditions (Table 5).

Base heterogeneity (BH_1) is negative for daily calorie intake per adult equivalent indicates that if the current non-adopters had been adopted, they would have got significantly higher daily kilocalorie intake per adult equivalent (about 100.293 kilocalorie (4.949%) more) than the actual adopters of improved *teff* variety. Base heterogeneity effect (BH_2) is negative which indicates that adopters would have got less daily calorie intake per adult equivalent than the actual non-adopters if they had not been adopted. The transitional heterogeneity effect (TH) also shows whether the effect of adopting improved *teff* variety is larger or smaller for farm households that actually adopted or for farm households that actually did not adopt had they did adopt the improved *teff* variety. The result of transitional heterogeneity effect for daily calorie intakes per adult equivalent is negative which implies that non-adopters would have benefited more if they decide to adopt the improved *teff* variety than the actual impact of adopters generated by adopting the improved *teff* variety. Which means the average effect of adopters is significantly smaller for actual adopters as compared to actual non-adopters if non-adopters had been adopters (Table 5).

Table 5. ATT of daily calorie intake PAE using endogenous switching regression

a) Daily caloric intake PAE	Decision stage		Treatment effect
	Adopted	Not to adopt	
Adopters	2026.420 (53.418)	1608.512 (50.565)	417.908*** (73.555)
Non-adopters	2126.713 (61.167)	1614.132 (45.033)	512.581*** (75.957)
Heterogeneity effects	$BH_1 = -100.293$	$BH_2 = -5.620$	$TH = -94.673$

Standard error in parenthesis; ***, denotes significance level at 1% probability level.

Source: Own survey result (2019)

The endogenous switching model result indicates that adoption of improved *teff* variety had a positive and significant impact on food consumption expenditure per adult equivalent per year measured in Ethiopia birr. Had the adopter households decided not to adopt the improved *teff* variety, their average food consumption expenditure per adult equivalent per year would have decreased by 1096.509 ETB. Moreover, if non-adopter households would have adopted improved *teff* variety, their food consumption expenditure per adult equivalent would have increased by 1323.987 ETB. Accordingly, non-adopter farm households would be more benefited than adopter households if they switch to adopt the improved *teff* variety (Table 6).

The additional average food consumption expenditure per adult equivalent gain for adopters at household level due to adoption is about 4863.017 ETB ($4.345 * 1096.509$) where 4.345 is the average adult equivalent for adopters. In similar manner, households that did not adopt, would have food consumption expenditure per adult equivalent of about 5143.689 ETB ($1323.987 * 3.885$) at household level more if they had adopted the improved *teff* variety, implying that current non-adopters would have realized higher levels of food consumption expenditure PAE switching from non-adopting to adopting improved *teff* under the given condition (Table 6).

Base heterogeneity (BH_1) for annual food consumption expenditure per adult equivalent is positive which indicates that if the current non-adopters had been adopted, they would have got significantly less food consumption expenditure (about 226.856 ETB less) than the actual adopters of improved *teff* variety. Base heterogeneity effect (BH_2) is positive indicates that adopters would have got more annual food consumption expenditure per adult equivalent than the actual non-adopters. This means adopters are better off even if they had not been adopted and this indicates some heterogeneity that makes adopters better expenditure than non-adopters. The result of transitional heterogeneity effect (TH) for annual food consumption expenditure per adult equivalent is negative which implies that non-adopters would have benefited more if they decide to adopt the improved *teff* variety than the actual impact of adopters generated by adopting the improved *teff* variety. Which means the average effect of adopters is significantly smaller for actual adopters as compared to actual non-adopters if non-adopters had been adopters (Table 6).

Table 6. ATT of food consumption expenditure PAE using endogenous switching regression

	Decision stage		Treatment effect
	Adopted	Not to adopt	
b) Food consumption expenditure PAE			
Adopters	4929.360 (195.123)	3832.850 (94.819)	1096.509*** (216.942)
Non-adopters	4732.527 (310.711)	3408.540 (81.775)	1323.987*** (321.292)
Heterogeneity effects	BH1=226.856	BH2=468.682	TH=-241.826

***denotes significance level at 1% probability level.

Source: Own survey (2019)

Furthermore, when we look the binary food security variable as depicted in table 13 the average probability of being food secure decreases by 20.1 percentage points for adopters of improved *teff* variety had they decided not to adopt the improved *teff* variety. In the same way, the average probability of food security increases by 30.3 % point for non-adopters had they adopted improved *teff* variety (Table 7).

Table 7. Average treatment effect on the probability of food security

	Decision stage		Treatment effect
	Adopted	Not to adopt	
c) Probability of food security			
Adopters	0. 697	0.496	0. 201***
Non-adopters	0.642	0.338	0.303***

***, denotes significance level at 1% probability level

Source: Own survey result (2019)

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

Improved varieties play an indispensable role in realizing food security. In this regard, different *teff* varieties have been developed by regional and national research Institutes and disseminated to small holder farmers. This study was conducted in Lasta woreda, North Wollo Zone of Amhara Region, Ethiopia aimed at investigating impact of improved *teff* variety adoption on food security. The study uses cross-sectional survey data collected in 2019 from randomly selected 225 sample households from three Kebeles in Lasta Woreda. Primary and secondary data were used for this study. The primary data were collected using semi-structured survey, whereas secondary data were collected from different published and un-published articles, books and reports.

To analyze the objective of this study both descriptive statistics and econometric model were employed. From descriptive statistics mean, percentage, chi2 test and t-test were used to check the relationship between covariates with adoption of improved *teff* variety. From econometric models full information maximum likelihood endogenous switching regression approach was employed to analyze the data to meet the objective of the study. This methodology was used to reduce the potential effect of self-selection bias due to both observable and unobservable household and farm characteristics.

The result from descriptive statistics shows 96% were male headed and the remaining 4 % were female head households. Among the total sample households 47 % were adopters and the remaining 54% were non-adopters. In addition, the proportion of farm households who got variety information from development agents and research center, access to extension service for adopters is higher for adopters as compared to non-adopters.

The results from probit show that family size measured in adult equivalent, off-farm income, log of farm income, access to variety information from research center and development agents, positively affected farmer's decision of adopting improved *teff* variety. However, distance of farmer's residence from kebele office of agriculture negatively determine farmer's decision to adopt improved *teff* variety.

The result from full information maximum likelihood endogenous switching regression asserts that impacts of improved *teff* variety adoption on daily calorie intake per adult equivalent is significantly high for adopter households compared to their counterfactuals that is when adopters had not adopted improved *teff* variety. The daily calorie intake of impact of improved *teff* variety adoption is higher for non-adopters had they adopted improved *teff* variety. This implies non-adopter would have better benefited than adopters if non-adopters had adopted the improved variety.

When we observe the households status of food security, adoption of improved *teff* variety significantly affects the probabilities of being food secure not only for adopter but also for non-adopter households if non-adopters would have adopted the improved *teff* variety. When we look the dummy outcome variable, adoption of improved *teff* variety also increases the probability of being food security by for adopters and had non-adopters decided to adopt the probability of being food secure increase by 31% point.

Further more, the impacts of improved *teff* variety adoption on food consumption expenditure per adult equivalent is also significantly high for adopter households compared to their counterfactuals (had they not adopted improved *teff* variety/ies).

5.2. Conclusion and Recommendations

From the result of this study adoption of improved *teff* varieties is affected by family size, off-farm income, farm income, variety information from research center and development agents positively and distance of farmer's residence from kebele office of agriculture negatively. The result from full information maximum likelihood endogenous switching regression model result indicates that adoption of improved *teff* variety have a positive and significant impact on food security measured by food consumption expenditure per adult equivalent per year in ETB and daily calorie intake per adult equivalent in the study area. The result of ESR also shows that non-adopters would be more benefited if non-adopters switch to adopt. Therefore, based on the result the following recommendations were drawn:

The results of probit model shows that farmers adoption decision of improved *teff* variety is significantly and positively influenced by family size, variety information from development agents and research centers, farm income and off-farm income whereas distance of farmer's resident from kebele office of agriculture negatively affect decision to adopt. The significant and positive effects of family size, access to variety information from development agents and research center, farm income and off-farm income on adoption decision of improved *teff* variety indicate the need to focus on providing adequate information on variety trait to have clear insight on it. Family size is a limiting factor which calls the need to introduce labor saving technologies. Moreover, encouraging smallholder farmers to involve on income generating activities during off- season need to give due attention. The negative effect of farmer's residence from kebele office of agriculture shows the need to consider smallholder farmers who are far from kebele office of agriculture to facilitate adoption of improved *teff*.

To enhance food security status of smallholder farmers, agricultural policies and strategies designed to realize food security in the study area should facilitate and further strengthen the process of disseminating improved *teff* varieties among smallholder *teff* producer farm households.

Research center incollaboration of woreda office of agriculture should give attension on multiplication of basic improved *teff* seeds which are already released befor and developing new varieties to support rural farm households so as to extricate from food insecurity . Because the result confirms that possitive impact of improved *teff* variety on food security in the study area.

Due attension to establish new private seed cooperatives and strengthening the existing once have to be made so as to multiply basic seeds in order to boost production and productivity of *teff* inturn to realize food security of smallholder farmhouseholds in the Study area.

Further study on dynamic impact of improved *teff* variety need to be conducted. Because this study is on cross-sectional data collected from farm households.

6. REFERENCES

- Asmiro Abeje, Kindye Ayen, Mulugeta Awoke and Lijalem Abebaw. 2017. Adoption and intensity use of modern beehive in Wagehemira and North Wollo Zone, Ethiopia. *Ethiopian journal of economics*, 26 (2):1-24.
- Assefa Kebebew, Sherif Aliye, Getachew Belay, Gizaw Metaferia, Hailu Tefera and Sorrells, M.E. 2011. kuncho: The first popular *teff* variety in Ethiopia. *International Journal of Agricultural Sustainability*, 9(1):25-34.
- Assefa Kebebew, Chanyalew Solomon and Tadele Zerihun. 2013. Achievements and Prospects of *Teff* Improvement. *Proceedings of the Second International Workshop*, November 7-9, 2011, Debre Zeit, Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland.
- Baker, J.L. 2000. Evaluating the impact of development projects on poverty: A handbook for Practitioners. Washington D.C. World Bank.
- Bayissa Gedefa. 2014. A Double-Hurdle Approach to Modeling of Improved *Teff* Technologies Adoption and Intensity Use in Case of Diga District of East Wollega Zone: *Global Journal of Environmental Research*, 8 (3): 41-49.
- Becker, S. and Ichino, A. 2002. Estimation of average treatment effects based on propensity scores. *The Stata Journal*, 2(4):358 -377.
- Becker, S.O. and Caliendo, M. 2007. Sensitivity Analysis for Average Treatment Effects. *The Stata Journal*, 7 (1): 71-83.
- Beddington, J. 2010. Food Security: Contributions from Science to a new and greener revolution. *Philos T Roy Soc B*. 365:61-71.
- Bekabil Fufa, Befekadu Behute, Rupert S. and Tareke Berhe. 2011. Strengthening the *teff* Value Chain in Ethiopia.
- Bekele Shiferaw, Menale Kassie, Moti Jaleta and Chilot Yirga. 2014. Adoption of improved wheat varieties and impacts on household food security in Ethiopia, *Food Policy*, 44 (2014): 272–284.

- Bernard, T., Spileman, D.J., Alemayehu Seyoum and Eleni Gabre-Madhin. 2010. Cooperatives for staple crop marketing: evidence from Ethiopia. IFPRI research monograph; 164.
- Bryson, A., Dorsett, R. and Purdon, S. 2002. The Use of Propensity Score Matching in the Evaluation of Labor Market Policies, Working Paper No. 4, Department for Work and Pensions.
- Caliendo, M., and Kopeinig, S. 2005. Some Practical Guidance for the Implementation of Propensity Score Matching. IZA Discussion Paper, no. 1588. Bonn, Germany.
- Caliendo, M., and Kopeinig, S. 2008. Some practical guidance for the implementation of propensity score matching. *Journal of Economic Survey*, 22(1): 31–72.
- Carter, D. W., and Milon, J.W. 2005. Price Knowledge in Household Demand for Utility Services. *Land Economics*, 81(2):265–283.
- CSA (Central statistics agency). 2018. Agricultural Sample Survey: Area Planned and Production of Major Crops, Meher Season. Volume I, Addis Abeba, Ethiopia
- CSA (Central statistics agency). 2017. Agricultural Sample Survey: Area Planned and Production of Major Crops, Meher Season. Volume I, Addis Abeba, Ethiopia
- Cochran, W. G. 1977. *Sampling techniques*, 3rd edition. New York, John Wiley & Sons.
- CTA/ECSA (Technical Centre for Agricultural and Rural Cooperation/ East, Central, and Southern Africa Food and Nutrition Cooperation), 1987. Food composition table.
- Daniel Tilahun. 2008. Adoption and Intensity of use of *teff* Technology Package in Yilmana Densa District, West Gojjam zone in Amhara Region, MSc Thesis, Haramaya University, Haramaya, Ethiopia.
- David, P. 2011. Using Propensity Scores to Adjust for Group Differences. *Stata journal*, 9(2):1-12.
- Debelo Duressa. 2015. Analysis of Factors Influencing Adoption of Kuncho Teff: The Case of Wayu Tuqa District. *International Journal of African and Asian Studies*, 6(27):20-35.
- Dehejia, R. H. and Wahba, S. 2002. Propensity score matching methods for non- experimental causal studies. *The Review of Economics and Statistics*, 84 (1):151-161.

- De Janvery, A., Dustan, A. and Sadoulet, E. 2010. Recent advances in impact analysis methods for ex-post impact assessments of agricultural technology: options for the CGIAR. Paper prepared for the workshop “Increasing the rigor of ex-post impact assessment of agricultural research: a discussion on estimating treatment effects”, the CGIAR Standing Panel on Impact Assessment, SPIA, Berkeley.
- Di Falco, S., Veronesi, M. and Yusuf, M. 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American Journal of Agricultural Economics*, 93(3): 829-846.
- Dixon, J., Nalley, L., Kosina, P., La Rovere, R., Hellin, J. and Aquino, P. 2006. Adoption and Economic Impact of Improved Wheat Varieties in the Developing World. *Journal of Agricultural Science*, 144 (489): 489-502.
- EHNRI (Ethiopian Health and Nutrition Research Institute). 1998. Food composition table for use in Ethiopia. Part III, from 1968-1997. A research project sponsored by Government of Ethiopia through former ENI and EHNRI.
- Ehui, S.K., Lynam, J. and Okike, I. 2004. Adapting Social Science to the Changing Focus of International Agricultural Research. *Proceedings of a Rockefeller Foundation. ILCA Social Science Research Fellows Workshop Held at ILCA*, 14-18 November 1994, 189-203. Addis Ababa,
- Engdawork Tesfa. 2009. Understanding *Teff*: A Review of Supply and Marketing Issues. Ethiopia Commodity Exchange Authority
- Etsehiwot Semreab. 2018. The determinants of agricultural technology adoption and its’ impact on teff productivity in the case of Amhara and Oromia national Regional state, MSc thesis, Addis Abeba University, Addis Abeba, Ethiopia.
- Ezemenari, K. Rudqvist, A. and Subbarao K. 1999. *Impact Evaluation: A Note on Concepts and Methods, Poverty Reduction and Economic Management Network*, World Bank.
- FAO (Food and Agriculture Organization of the United Nations). 1996. The State of Food and Agriculture, Rome.
- FAO (Food and Agriculture Organization of the United Nations). 2008. Food Security Information for Action Practical Guides, food security programme, Rome.

- FAO (Food and Agriculture Organization of the United Nations). 2015. Analysis of price incentives for *teff* in Ethiopia, Technical notes series, Monitoring and Analyzing Food and Agricultural Policies (MAFAP) programme, Rome
- Feder, G., Just, R.E. and Zilberman, D. 1985. Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2): 255-298.
- Gertler, J., Sebastian, M., Patrick P., Laura B. R., Christel, M. and Vermeersch, J. 2016. *Impact Evaluation in Practice, second edition*. Washington, DC: Inter-American Development Bank and World Bank.
- Grilli, L., and Rampichini, C. 2011. Stata module on Propensity scores for the estimation of average treatment effects in observational studies, Bristol.
- Haftamu Gebretsadik, Mitiku Haile and Charles F.Y. 2009. Tillage Frequency, Soil Compaction and N-Fertilizer Rate Effects on Yield of Teff (*Eragrostis Teff* (Zucc) Trotter) in Central Zone of Tigray, Northern Ethiopia. *MEJS*, 1 (1): 82 – 94,
- Hailu Beyene. 2008. Adoption of improved *teff* and wheat production technologies in crop and livestock mixed systems in Northern and Western Shewa Zones of Ethiopia. Doctoral Dissertation, University of Pretoria, South Africa.
- Imas, L., Linda G. M. and Ray C. R. 2009. *The Road to Results: Designing and Conducting Effective Development Evaluations*. Washington, DC: World Bank.
- Heckman, J., Ichimura, H., Smith, J., and Todd, P. 1998. Characterizing selection bias using experimental data. *Econometric a*, 66(22): 1017–1098.
- Jalan, J. and Ravallion, M. 2003. Estimating the benefit incidence of an antipoverty program by propensity-score matching. *Journal of Business and Economics Statistics*, 21 (1): 19- 30.
- Kaleab Baye. 2014. *Teff* Nutrient Composition and Health Benefits. ESSP II working paper. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.
- Khandker, G., Gayatri, B. Koolwal, F., and Hussain A. S. 2010. *Handbook on Impact Evaluation: Quantitative Methods and Practices*. Washington, DC: World Bank

- Lokshin, M. and Sajaia, Z. 2004. Maximum Likelihood Estimation of Endogenous Switching Regression Models. *Stata Journal*, 4(3): 282-289.
- Maddala, G.S. 1983. Limited dependent and qualitative variables in econometrics, Cambridge University, Cambridge, UK.
- Magrini, E. and Vigani M. 2014 Technology adoption and the multiple dimensions of food security: the case of maize in Tanzania, Discussion Paper 352/2014. using experimental data.
- Mendola, M. 2007. Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh. *Food Policy*, 32(4):372-393.
- Minten, B., Seneshaw Tamru, Ermias Engida and Tadesse Kuma. 2013. Ethiopia's Value Chains on the Move: The Case of *Teff*. ESSP II Working Paper 52. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia
- Misgana Merga. 2018. Progress, Achievements and Challenges of *Teff* Breeding in Ethiopia, *Journal of Agricultural Science and Food Research*, 9(1):1-8.
- Moti Jaleta, Menale Kassie, and Paswel Marennya. 2015. Impact of improved maize variety adoption on household food security in Ethiopia: An endogenous switching regression approach. *Agriculture in an interconnected World*. Milan, Italy: International Conference of Agricultural Economics.
- Ravallion, M. 2008. "Evaluating Anti-Poverty Programs." In *Handbook of Development Economics*, vol. 4, ed..T.Paul Schultz and John Strauss." Amsterdam: North-Holland.
- Regasa Dibaba, Afework Hagos and Chilot Yirga. 2018. Determinants of Improved *Teff* Varieties Adoption and Its Impact on Productivity: The Case of Non-Traditional *Teff* Growing Areas of Western Ethiopia, *Journal of Natural Sciences Research*, 8(22):55-67
- Rogers, E.M., and Shoemaker, F.F. 1971. *Communication of Innovation: A Cross-Cultural Approach*, 2nd Edition, the Free Press, New York
- Rogers, E.M. 1983. *Diffusion of Innovations*, 3rd edition. New York. Macmillan Publishing Co.Inc.

- Rosenbaum, P. R., and Rubin, D.B. 1983. Assessing Sensitivity to an Unobserved Binary Covariate in an Observational Study with Binary Outcome. *Journal of the Royal Statistical Society*, 2(45): 212-218.
- Rosenbaum, P.R. and Rubin, D.B. 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70(1): 41-55.
- Rosenbaum, P. R. 2002. *Observational Studies*. 2nd edition. New York: Springer.
- Rubin, D. 2006. *Matched Sampling for Causal Effects*. Cambridge University Press, New York.
- Shahidur, R. Khandker, G., Gayatri, B. Koolwal, B. Hussain A. S. 2010. *Handbook on Impact Evaluation*. Quantitative Methods and Practices. The World Bank Washington DC.
- Sekhon, J. 2011. Multivariate and Propensity Score Matching Software with Automated Balance Optimization: The Matching Package for R. *Journal of Statistical Software*, 42(7):1-52.
- Sekota Dry Land Agricultural Research Center. 2013. Progress report, Amhara Agricultural Research Institute, Ethiopia.
- Solomon Asfaw, Bekele Shiferaw, Simtowe, F. and Lipper L. 2012. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, 37 (2012):283-295.
- Tamiru Seneshaw., Bart, M., Ermiyas Engida and Tadesse Kuma. 2013. Africa's value chains on the move: The case of *teff* in Ethiopia. IFPRI.
- Tesfaye Zegeye, Bedada Tadesse and Mesay Yami. 2016. Impact of Improved wheat technology adoption on productivity and income in Ethiopia. *African Crop Science Journal*, 24(5) :127-135.
- Tsibuk Berhe. 2015. Factors Affecting Adoption of Kuncho *Teff* variety: the case of Medebayzana Woreda, North-Western Administrative zone of Tigray Region, MSc thesis, Haramaya university, Haramaya Ethiopia.
- Storck, H. Bezabih Emanu, Berhanu Adenew, A. Borowiecki and Shimelis W/Hawariat; 1991. Farming Systems and Farm Management Practices of Small holders in the Hararghe

- Highlands. *Farming Systems and resource Economics in the Tropics*, Vol. 11, Wissenschaftsverlag Vauk, Kiel KG, Germany.
- Susie Teshome. 2017. Determinants of Adoption of Improved *teff* varieties by Smallholder Farmers: the case of kobo district, north Wollo zone, Amhara region, Ethiopia. MSc thesis, Haramaya University, Ethiopia.
- Tsegaye Mulugeta and Bekele Hundie. 2012. Impacts of Adoption of Improved Wheat Technologies on Households' Food Consumption in Southeastern Ethiopia. Selected Poster prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24
- Verónica, G., Ibarrarán, P., Maffioli, A., and Rozo S. 2009. "The Impact of Technology Adoption on Agricultural Productivity: The Case of the Dominican Republic." Washington, D.C.
- WHO (World Health Organization) and FAO. 1985. Energy and protein requirements. Technical Report Series 724. Geneva.
- Yang, G., Stemkowski, S. and Saunders, W. 2008. A Review of Propensity Score Application in Healthcare Outcome and Epidemiology. *Journal of statistics*, 12(4):5-19.
- Yihenew Zewdie, Amdissa Teshome and Kassahun Berhanu. 2013. Drivers' of Success for CAADP Implementation Ethiopia Case Study.
- Zenaye Degefu. 2016 Adoption and Welfare Impact of Improved Food legume Technologies in Bale highlands of Ethiopia: Intra and Inter-Household Empirical Analysis, MSc thesis, Haramaya University, Haramaya, Ethiopia.

7. APPENDICES

Appendix Table 1. Conversion factor used to calculate TLU

Livestock Category	TLU
Calf	0.34
Heifer	0.75
Cow and Ox	1.0
Horse	1.1
Donkey	0.7
Sheep and goat	0.13
Chicken	0.013

Source: Storck *et al.*, 1991

Appendix Table 2. Conversion factors to compute adult equivalents

Age year	Male	Female
Under 1	0.33	0.33
1-1.99	0.46	0.46
2-2.99	0.54	0.54
3-4.99	0.62	0.62
5-6.99	0.74	0.7
7-9.99	0.84	0.72
10-11.99	0.88	0.78
12-13.99	0.96	0.84
14-15.99	1.06	0.86
16-17.99	1.14	0.86
18-29.99	1.04	0.8
30-59.99	.99	0.82
60+	0.84	0.74

Source: WHO and FAO (1985)

Appendix Table 3. Conversion factors for kilocalories per gram of different food items

Food items	Kcal/gram	Food items	Kcal/gram
Tea	1.19	Teff	3.589
Soft Drink	0.38	Maize	3.751
Juice	0.6	Green Maize	1.66
Beer In Ml	4.3	Wheat	3.623
Coffee Been	1.103	Barely	3.540
Orange	0.47	Sorghum	3.805
Mango	0.6	Potato	0.77
Banana	0.89	Bean	3.29
Avocado	1.6	Tomato	0.373
Beef	2.5	Onion	0.713
Goat	1.43	Head Cabbage	0.25
Sheep	2.94	Leaf Cabbage	0.37
Chicken	2.39	Beetroot	0.43
Eggs(Unit)	61	Carrot	0.41
Milk	0.42	Pepper	1.493
Cheese	0.98	Garlic	1.49
Butter	7.17	cooking Oil	8.964
Yogurt	0.59	Biscuit	3.53
		Sugar	3.87
		salt	1.70

Source: CTA/ECSA (1987) and Ethiopian Health and Nutrition Research Institute, 1998

Appendix Table 4. Endogenous switching regression estimate for daily calorie intake

Variables	Adopters		Non-Adopters	
	Coef.	St. error	Coef.	St. error
Sex of household head	231.696**	367.197	-185.423	183.002
Age of household head	-394.35***	46.193	16.764	15.287
Age square of household head	56.925	0.444	-0.156	0.144
Year of schooling	467.323***	16.579	1.059	18.047
Membership in farmers cooperatives	-121.992	100.951	80.458	98.969
family size in adult equivalent	0.0176*	41.563	-396.72***	50.064
Land holding size	-30.169	137.258	111.437	138.952
Log of farm income	5.418	128.962	104.273	75.416
Log of tropical livestock holding	-181.976	127.992	148.224	126.008
Off-farm income	-12.422	0.010	0.0008	0.022
Frequency of extension visit	43.113	25.719	63.085**	28.271
Provision of training	231.696**	117.127	93.902	100.990
Access to credit service	-394.35***	202.145	4.672	493.918
Distance from kebele office	56.925	44.788	-68.0780**	34.609
constant	467.32***	1651.387	1625.823**	810.585
Sigma(σ_i)	493.7979	34.753	454.154	31.766
Rho(ρ_j)	-0.0429*	0.198	-0.1401	0.3645
Wald Chi2	163.28			
Log likelihood	-1780.6223			
Number of observations	225			
LR test of independency	chi2 = 3.73 Prob > chi2 = 0.0536			

*, ** and *** denotes significance level at 10%, 5% and 1% respectively

Appendix Table 5. Endogenous switching regression estimate of food consumption

Food consumption Expenditure per adult equivalent				
Variables	Adopters		Non-Adopters	
	Coef.	St. error	Coef.	St. error
Sex of household head	512.702	1298.38	720.221	408.69
Age of household head	-71.785	163.386	-0.393	34.53
Age square of household head	0.677	1.571	0.088	0.32
Year of schooling	-28.264	58.825	-92.520	40.57
Membership in farmers cooperatives	135.041	357.705	-321.88	223.42
Total family size in AE	-1446.43***	147.27	-326.6***	111.41
Land holding size	-507.385	486.62	678.978**	314.06
Log TLU	-74.696	452.99	92.398	280.60
Log of farm income	3316.56***	454.006	433.046**	170.54
Off-farm income	0.059	0.037	-0.048	0.049
Frequency of extension visit	-148.788*	89.878	43.370	63.57
Provision of training	-256.100	414.599	367.721	227.32
Access to credit service	-556.440	717.810	2820.071**	1102.9
Distance from kebele office of agriculture	-350.759**	156.99	-179.212**	76.30
constant	-17929.38	5776.79	--220.1829	1811.1
Sigma	1756.741	123.08	1025.42	71.095
Rho(ρ_j)	-0.4694***	.15307	.1198	0.296
Wald Chi ²	168.890			
Log likelihood	-2016.347			
Number of observations	225			
LR test of independency: chi2 =	6.07	Prob > chi2 = 0.013		

*, ** and *** denotes significance level at 10%, 5% and 1% respectively.

Appendix Table 6. Endogenous switching regression estimate of food security status

Variables	Food security status			
	Adopters		Non-Adopters	
	Coef.	St. error	Coef.	St. error
Sex of household head	-0.370	0.288	0.107	0.181
Age of household head	0.082**	0.036	0.009	0.015
Age square of household head	-0.001**	.0003	-0.0001	0.0001
Year of schooling	0.025 *	0.012	-0.0112	-0.011
Membership in farmers cooperatives	0.201**	0.080	0.009	0.009
Total family size in adult equivalent	-0.096***	0.032	-0.109**	0.047
Land holding size	0.047	0.106	0.160	0.136
Log TLU	0.096	0.099	0.076	0.121
Log of farm income	0.230**	0.100	-0.010	0.073
Off-farm income	2.31e-06	8.19e-06	-.00001	0.0001
Frequency of extension visit	-0.0258	0.020	.035	0.027
Provision of training	0.011	0.091	-.033	.0989
Access to credit service	0.050	0.156	0.240	0.466
Distance from kebele office	-0.0349	0.037	-.022	0.033
constant	-2.838**	1.309	0.234	0.784
Sigma	0.378	0.0252	0.453	0.035
Rho(ρ_j)	-0.191*	0.290	-0.447	0.282
Wald Chi2	52.74			
Log likelihood	-197.644			
Number of observations	225			

LR test of independency.: $\chi^2(1) = 2.82$ Prob > $\chi^2 = 0.0930$

*, ** and *** denotes significance level at 10%, 5% and 1% respectively.

Appendix Table 7. Expected conditional and average treatment effects

	Decision stage		Treatment effect
	To adopt	Not to adopt	
Adopters	(a) $E(y1i Ai = 1)$	(c) $E(y2i Ai = 1)$	ATT
Non-adopters	(d) $E(y1i Ai = 0)$	(b) $E(y2i Ai = 0)$	ATU
Heterogeneity effects	BHi=	BHi=	TH=

Note: (a) and (b) represent observed expected outcome variables; (c) and (d) represent counterfactual expected outcome variables.

$Ai = 1$ if farm households adopted to Improved teff variety; $Ai = 0$ if farm households did not adopt;

$Y1i$: outcome variables if farm households adopted;

$Y2i$: outcome variables if farm households did not adopt;

ATT: the effect of the treatment on the treated (i.e., farm households that adopted);

ATU: the effect of the treatment on the untreated (i.e., farm households that did not adopt);

BHi: the effect of base heterogeneity for farm households that adopted ($i = 1$), and did not adopt ($i = 2$);

TH = (TT - TU), i.e., transitional heterogeneity

Appendix Table 8. Test on the validity of the Selected Instruments for daily calorie intake

Instrumental variable	Adoption decision (1=yes)	For Non-adopters
Variety information from development agents	1.519342*** (0 .2568)	-33.04568 (128.8983)
Variety information from research center	0.68285 *** (.24002)	23.44533 (184.330)
Number of seed traders known by farmers	0.3049704 *** (.0446124)	64.60632 ** (29.75484)
test	$\chi^2 = 102.85^{***}$	F-stat. = 1.79
sample	225	106

Note: for adoption decision: Probit model; for outcome variable: ordinary least squares. Standard errors in parenthesis; **, and *** denotes significance level at 5% and 1% respectively.

Appendix Table 9. Test on the Validity of the Selected Instruments for consumption expenditure

Instrumental variable	Adoption decision (1=yes)	For non-adopters
Information from development agents	1.519342*** (0 .25682)	-131.7869 (268.5898)
Variety information from research center	0.68285 *** (0.24002)	343.8283 (384.0959)
Number of seed traders known by farmers	0.30497 *** (0.0446)	-50.1026 (62.00117)
test	$\chi^2 = 102.85^{***}$	F-stat. = 0.5
sample	225	106

Standard errors in parenthesis; *** denotes significance level at 1% probability level

Appendix Table 10. Test on the validity of the selected Instruments for probability of food security

Instrumental variable	Adoption decision (1=yes)	For non-adopters
Information from development agents	1.519342*** (0 .2568289)	0.0004819 (0 .0951993)
Variety information from research center	0.6828588 *** (.2400274)	0.1802987 (0.1361394)
Number of seed traders known by farmers	0.3049704 *** (0.0446124)	-0.290804 *** (.0219758)
Wald test	$\chi^2 = 102.85$ ***	F-stat. = 1.23
sample	125	106

Standard errors in parenthesis; *** denotes significance level at 1% probability level

Appendix Table 11. Questionnaire on impact of improved *teff* variety on food security.

I. General information

2. District -----

3. Kebele_____Agro Ecology 1. Woyna Dega 2. Kola

4. Name of respondent -----

5. Age of respondent _____ sex 1=male 0=female

6. Marital status?1=single 2=married 3= Divorced 4. Widowed

7. Religion? 1= Orthodox Christian, 2=Muslim, 3=Other (specify)

8. Education level (___ year of schooling)

9. farming experience particularly in *teff* production -----(years).

10.Social capital

10.1. Are you a member of community organizations? 1. Yes 2. No

10.2.If yes, on which community organizations do you participate? 1.*Edir* 2. *Mahiber*
(religious association) 3. *Senbete* (religious association) 4. Debo 5. other

10.3.What do you get from community participation? -----

10.4. Do you participate in formal institutions? 1. Yes 2. No

10.5.If yes, on which formal institutions?

1. Government groups (administrative units) 2. Service cooperative 3. Rural credit association 4. Bee cooperatives 5. other specify-----

10.6.What do you get from formal institution participation? -----

11. Type of houses you own and live in? 1=grass roofed 2=corrugated iron roofed
3=both types

II. Demographic characteristics of the household

12. Household members including the respondent and who presently live in the house

N o	Na me	Sex (Male=1 Female =0)	Age	Education al level	*Occupation	
					Main	Secondary
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

*A=Farming B= Salaried employment, C= Self-employed off-farm, D=Casual laborer on-farm, E=Casual laborer off-farm, F= Herding G= Household chores H=School child I=Non-school child, J=other, specify_____

III. Land holding and crops grown

13. Land owned and allocation

Land allocation	m2/timad/ha
Rain fed Farm land	
Irrigated Farm land	
Permanent tree and fruits(mango, avocado ,papaya etc.)	
Grazing land (Private)	
Total land	

14. How many plots of farm land do you have in 2017/2018 _____and indicate the area and each plot characteristics

Plot	Area (ha)	Fertility(Rank: 1=low 2=Medium 3=high)

15. Did you practice contract/shared/rent in or contract/shared/rent out in last year 2017/2018) to grow crops? 1=Yes 0=No,

16. Indicate the area allocated for each of the following practices

Practices	Area (ha/timad)	Remark
Rented in		
Shared in		
Rented out		
Shared out		
Other		

19. Income from sale of livestock products and off -farm activities

Products	Produced	Sold	Unit price(Birr	Total income(Birr)
Milk (lit)				
Butter (kg)				
Yoghurt (kg)				
Egg (No)				
Honey & wax in k.g				
Hide and skin				
Off-farm income				
Sales of labor				
Land rent				
Petty trading				
Land renting				
House renting				
Aid from GOs and NGOs				
remittance				
salary				
other				

V. Use of local and improved *teff* varieties

20. Have you ever planted any improved *teff* varieties in 2010/2018? 1=Yes 0 = No

21. If question no.20.is yes, do you remember when did you plant improved *teff* varieties for the first time? 1 = Yes, 0 = No when did you start using improved *teff*? _____

22.If question no. 20 is no, give reason 1.not available 2. finance problem 3. lack of awareness 4.the seed is not productive 5. Other-----

23.If question 20 is yes, have you been growing improved *teff* continuously since you start to grow 1 = Yes 0 = No

Have you purchased any seed of <i>teff</i> for the 2017/2018 cropping season? 1. Yes 0. No					
Please tell us about the seed of all <i>teff</i> varieties you purchased for the 2017/2018 cropping season					
Variety name	Quantity (Kg)	Is it improved? 1 = yes 0 = no	Which market did you buy it from?	How much did it cost (Birr/kg)?	Will you recycle/replant the seed? 1 = yes 0 = n

24. Land allocated & Names of improved and local *teff* varieties grown in the last 2 years

2017/2018			2018/2019			*The first Seed Source of the variety	**Preferred trait
Name	Area(ha)	Yield	Name	Area (ha)	Yield		
Improved							
Local variety							

*A=other farmer, B=office of agriculture/Extension agent, C=NGOs, D=Research Centers, E=Other**1= high yields 2=droughts tolerant 3=early mature 4. marketability

VI. Seed and fertilizer source

25. What are your improved *teff* variety seed sources for the last cropping season (2017/2018)? 1= Saved from last planting, 2= Seed exchange with farmers, 3= Purchased from local market, 4=Farmers' Cooperative 5=Office of Agriculture / Research centers 6=other

25.1. Distance of your residence from seed market in walking minute-----

25.2. Number of improved seed dealers you know in your village and outside your village-

26. what is the cost of inputs/quintal 1. improved *teff* seed-----DAP/NPS-----Urea-----

27. Do you know where to get improved *teff* seed 1=yes 0=No

28. What is/are the problem/s associated with improved *teff* seed access in your area

1=not available when needed 2=too expensive 3=Poor quality 3=others (specify)

29. Do you know where to get fertilizer 1=yes 0=No

VII. Plot characteristics

30. In How many plots of land did you grow *teff* in 2017/2018.-----plots and fill description of each plot as shown below in the table accordingly.

31. Total land allocated for improved *teff* variety ----ha. 33. Total land allocated for local *teff* variety----ha. Total land-----ha

Plot description		Plot 1	Plot2	Plot 3	Plot 4
Size of plot (timad)					
Form of ownership? Code A					
Who manages the plot? Code B					
How far is it from your residence in kilo meter					
How fertile is the soil? Code C					
Code A 1.Own 2.Rented in 3.Sharecropped 4.Gift	Code B 1.Husband 2.Wife 3. All households	Code C 1.Very fertile 2.Fertile 3.Infertile 4.Very poor fertile			
Input used(NPS) for <i>teff</i> (k.g.) variety.	improved				
	Local				
Input used(UREA) for <i>teff</i>	improved				
	Local				
Chemical (pesticide)	improved				
	Local				
Improved <i>teff</i> varieties grown					
Yield of improved <i>teff</i> variety					
Local <i>teff</i> varieties grown on the plot(ha)					
Yield of local <i>teff</i> variety (kg) on the plot					

VIII. Access to information about improved *teff* seed

32. From whom do you usually get information about improved *teff* variety? 1=DA/agricultural development expert 2=Another neighboring farmer 3=Research center 4. Farmers' cooperative 5=NGOS 6. Other----

33. Do you own radio or television? 1=Yes 0=No.

34. If **yes**, do you listen/watch to any agricultural education program on the radio? 1=Yes 0=No.

35. If **yes**, have you ever got advice on the use of improved *teff* varieties? 1=Yes 0=No.

36. if question no 32 answer is from 2 how many relatives you support to grow improve *teff*? -

IX. Extension service

37. Distance to the nearest development agents' office------(walking minutes).

38. Did you get any extension service from Development agents in last year 2017/2018)? 1=Yes 0=No If no, why-----

39. How frequent you meet with extension agents to get advice? -----times per year

40. Did you get any advice on *teff* production and use of improved *teff* varieties from any source? 1=Yes 0=No.

41. If the answer is **YES** from whom did you get the advice? 1=Another farmer 2=NGOs 3= Research Centers 4=Other specify

42. Have you involved in agricultural extension tools concerning improved *teff* production in the last years.

Agricultural Programs	Yes=1, No	If yes, Freque	Specify the content of training if you get
Field day/visit			
Training			
On farm research(PVS)			

X. Access to credit

43. Have you received credit for agricultural input purchase in the (2017/2018)? 1= Yes 0= No

44. If **no**, what are the main reasons? 1=No credit service in the area 2= high interest rate 3=need collateral 4 =long procedures to get credit 5=I didn't repay last time credit 6=My religion doesn't allow 7=I don't need credit 8=Other _____

If yes, from whom you get credit-----for what purpose? 1.for improved seed 2. fertilizer 3. other specify----- And credit amount for input purchase-----Ethiopian birr

45. What are the requirements associated with getting credit in the area?__

46. If you get cash shortage for input purchase, from whom you can get credit? -----

XI. Institutional support

47. Is there any government, private, NGO etc. working on improved *teff* seed supply in your area?1=yes 0=No

48. If **yes**, have you ever received any support from any of these organizations to improve your *teff* production? 1=yes 0=No

49. If yes, Name of organizations or institution and type of support you received

No	Name	*Type of support
1		
2		
3		

*1=Seed 2=Fertilizer 3=Farm implement 4=Advice on agronomic management practices 5=other specify

50. Are you a member of any farmer cooperative/groups which provide inputs for food crops production? 1=yes 0=N

51. If **YES**, which inputs they provide?1=Fertilizer 2=improved *teff* seed 3=Other

1. Beans dry	k.g									k.g	
2. Beans fresh	k.g									k.g	
3.pea fresh/dry	k.g									k.g	
4.chickpea	k.g									k.g	
5.lentile	k.g									k.g	
6.Vetch	k.g									k.g	
Drinks										k.g	
1. Tea (leaves)	k.g									k.g	
2. Coffee leaves)	k.g									k.g	
3.Soft drinks	k.g									k.g	
4. Juices	k.g									k.g	
5. Local beer	k.g									k.g	
6. Bottled beer	k.g									k.g	
7. Wine	k.g									k.g	
8. Drinking water	k.g									k.g	

Fruits	k.g									k.g	
1. Oranges	k.g									k.g	
2. Mangoes	k.g									k.g	
3.Avocado	k.g									k.g	
4. Pineapple	k.g									k.g	
5. Bananas (ripe)	k.g									k.g	
6. Apple	k.g									k.g	
7. Guava	k.g									k.g	
8. Sugar cane	k.g									k.g	
9. potato	k.g									k.g	
10.sweet potato	k.g									k.g	
Meat and other animal products											
1. Beef	k.g									k.g	
2. Goat meat	No									k.g	
3. Sheep meat	No									k.g	
4. Chicken	No									k.g	
5. Eggs	No									k.g	
For family health care	ET B										
For family education											
Animal health care											
For family cloth											
Electric ,tax, soap, ceremony ,church contribution and other expense											

Note that:1litter of water=1kilo gram and 1iter of oil =0.9 kilo gram

xiv. Coping with food insecurity and status of food security

74. Have you faced any food shortage in the last 12 months for your family?

1 = Yes 0 = NO

75. If there is food shortage in which month 1. throughout the year list Months- 2. During the transition (around harvesting time of crop list months-----

76. why did they happen? 1 = Drought 2 = Poor harvest 3 = absence of job 4 = Death in the family 5 = Unreliable income 6 = Inflation 7 = Theft 8 = Other, specify

77. How did the household recover from this? 1 = Relied on neighbors

2 = Relied on family to send food 3 = Took credit 4 = Remittances from abroad

78. if Question no. 74 is no, is there any surplus crop product left after fulfilling your yearly consumption 1. yes, 0, .no

79. Food security status of farm household 1. food surplus 2. at breakeven 3. transitory food insecure 4, chronic food insecure.

Thank you very much for your cooperation