



IMPROVED FORAGE TECHNOLOGIES ADOPTION AND ITS
IMPACT ON SMALLHOLDER DAIRY PRODUCTIVITY: THE CASE
OF DEBRELIBANOSE, WOREDA, OROMIA REGION, ETHIOPIA

BY

MAMARU TEFAYE TEGEGNE

ADDIS ABABA, ETHIOPIA

OCTOBER, 2021



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A THESIS SUBMITTED TO CENTER FOR RURAL DEVELOPMENT
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COLLEGE OF DEVELOPMENTAL STUDIES
CENTER FOR RURAL DEVELOPMENT

DECLARATION

I, the undersigned, declare that this thesis is my own original work and that all sources of materials used for this thesis have been duly acknowledged. This thesis is submitted in partial fulfillment of for a Masters of Arts in Development Studies (Rural Livelihood and Development) at Addis Ababa University. I solemnly declare that this thesis has not been submitted to any other institutions anywhere for the award of any academic degree, diploma, or certificate. The thesis should be made available at the University's Library under the rules of the Library.

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As a major advisor of this thesis, I certify that I have read and evaluated the thesis by Mamaru Tesfaye Tegegne entitled ‘Improved Forage Technologies Adoption and Its Impact on Smallholder Dairy Productivity: The Case of Debre Libanos Woreda, Oromia Region, Ethiopia’ and recommended for open defense as fulfilling the requirements for the degree of Master of Art in Rural Livelihoods and development.

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DEDICATION

This thesis manuscript is especially dedicated to my family who fulfilled my desire and uplifting me to this level.

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ACRONYMS /ABBREVIATIONS

AEZs:	Agro Ecological Zones
ATT:	Average Treatment Effect
CIMMIYT:	The International Maize and Wheat Improvement Center
CSA	Central Statistics Agency
EARO	Ethiopian Agricultural Research Organization
FAO:	Food and agriculture Organization
FGD:	Focus Group Discussion
FLDP	Fourth Livestock Development Project
GDP:	Gross Domestic Product
IBC:	Institute of Biodiversity
IFAD:	International Fund for Agricultural Development
IFPRI:	International Food Policy Research Institute
IGAD:	Inter-Governmental Authority on Development
ILRI:	International Livestock Research Institute
IVOMD:	in vitro organic matter digestibility
KAs:	Kebeles
KBM	Kernel Based Matching
KII:	Key Informant Interview
MOFED:	Ministry of Finance and Economic Development
MPT:	Multipurpose Tree
NGO:	Non-Governmental Organization
NNM	Nearest Neighbor Matching
ONRS	Oromia National Regional state
PADETES:	Participatory Demonstration and Training Extension System
PSM:	Propensity Score Matching
RM	Radius Matching
SSA:	Sub Saharan Africa
TLU:	Total Livestock Unit
VIF:	Variable Inflation Factor

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ABSTRACT

Adoption of improved forage technologies is one in every of the measures presumed to boost dairy productivity and farm income given potential promotions of the crops. In light of this premise, the objective of the research is to examine factors affecting improved forage technology adoption and impact on smallholder dairy productivity in Ethiopia evidence from Debre Libanose woreda, North Shoa zone, Oromia regional state. The study used cross-sectional design. A multistage stratified sampling procedure was employed to draw 319 sample households from one woreda and three kebeles. Within the selected kebeles sample respondent households were categorized into two groups using a random sampling approach (adopters and non-adopters). In this particular study, both primary and secondary data were gathered. Primary data was collected using KI interview, focus group discussions and cross-sectional survey from sample households (128 adopters and 191 non-adopters). Descriptive statistics and econometric models were employed to analyze the collected data. The statistical models namely, binary logistic regression, Tobit and propensity score matching were used to determine factors affecting the decision of farm households who participate (adopt) improved forage technologies, extents of improved forage technology adoption and impact of technology adoption on household income respectively. The binary logistic regression result revealed that age, education, market distance, extension contact, participation in training; field day and improved cattle ownership were significant factors affecting the likelihood of adoption of improved forage technology positively and significantly. Similarly, results from Tobit model estimates revealed that education, distance to market, extension contact, field day and improved cattle ownership were positively and significantly affect the intensity use on improved forage technology while age of the household head had negatively and significant influence on the intensity use of improved forage technologies. The result from PSM estimation revealed that adoption of improved forage technology had significant impact on milk yield and farm income of the treated households compared to the control groups. The estimated ATT revealed that, improved forage technology adoption has increased dairy productivity (milk yield) and farm income of household (in line with farm income, keeping other farm income constant for both the treated and controls) by 29.32 % and 19.56 %, respectively, and the result is statistically significant at 5% (t-value =2.49; P=0.05 for yield) and (t=2.02; P=0.05 for farm income).The study concludes that improved forage technology adoption has remarkable effect on the dairy productivity and livelihood of smallholder farmers' status. Finding of this study suggests that improved forage technology is one of the viable solutions to improve the livelihood of smallholder farmers in the study area by increasing income from livestock. Therefore, policy interventions giving priority to the variables mentioned above that stimulate improved forage technology adoption thereby improve their livelihood are recommended.

Keywords: Adoption, Debre Libanose, Forage technology, Impact, yield, Income, PSM

CHAPTER ONE: INRODUCTION

1.1. Background of the study

In Ethiopia, agriculture is a dominant economic sector which makes a lion share contribution to the Gross Domestic Product, employment and foreign exchange earnings. Agriculture is still believed to remain a sector that plays an important role in stimulating the overall economic development of the country in the years to come (CSA, 2016). Livestock husbandry is an important aspect of farming systems, particularly in the country's agricultural districts. Ethiopia has large livestock population in Africa's, with 56.71 million cattle, 29.33 million sheep, 29.11 million goats, 7.43 million donkeys, 2.03 million horses, 0.4 million mules, 1.16 million camels, 56.87 million poultry, and 5.89 million beehives, according to estimates (CSA, 2015). The subsector is mainly of smallholder farming system having multipurpose use and contributes about 16.5% of the national Gross Domestic Product (GDP), 35.6% of the agricultural GDP, 15% of export earnings and 30% of agricultural employment. Furthermore to direct income benefits, livestock delivers secondary benefits, like fuel, transportation services and fertilizer from animal manure and draught power for farm production, which could double the overall contribution of the arena to the livelihoods.

In spite of its large numbers, the country's livestock productivity is low. Besides animal health problems, lack of adequate quantity and substandard of feed is additionally a heavy challenge to low livestock productivity. The utilization of improved feed is restricted (0.3%) in rural areas of Ethiopia (CSA, 2015). Natural pasture grass (56.23%) is that the foremost important feed resource followed by crop residue (30.06%) (CSA, 2015). Animal feeds made up of hay and crop by-products account for 7.44 percent and 1.21 percent of total feeds, respectively (CSA, 2015). However, because these resources are in short supply and of poor quality, animal feed shortages continue to be the most significant barrier to output in both the lowlands and the highlands.

The dairy sub-sector in Ethiopia has not been effectively developed and promoted, and milk output in the country has fallen far short of expectations. The dairy herd's

productivity is low, with an average milk yield of 1.3L–1.54L per day in indigenous cattle and 10L per day in crossbred cattle during mean lactation duration of 180–210 days (Belete et al., 2010; Land O'Lakes, 2010). When compared to the average for the geographic region and the world, this is reflected in the country's low per capita milk consumption. This per capita milk and meat consumption is 16 liters per year and 13.9 kilograms per year, respectively, falling short of African and thus worldwide per capita milk and meat consumption of 27 kilograms per year and 100 kilograms per year, respectively (FAO, 2009).

Ethiopia's dairy output is limited by a number of interconnected challenges classified as technical and non-technical restrictions. Non-technical constraints include the policy environment, socioeconomic problems, and institutional issues. Land availability, financing availability, and other incentives, as well as extension services, infrastructural setups, and overall coordination, are all influenced by these factors. This, in turn, has a direct or indirect impact on the production of dairy products. Ethiopian cattle policies, according to Degefe and Nega (1999), are inefficient in terms of finance, extension, marketing, and infrastructure.

On the other hand, the key technical obstacles limiting dairy production are insufficient feed and nutrition, the presence of numerous diseases and poor health services, and the genetic make-up of indigenous breeds. For biological and economic reasons, the most important barrier is a lack of feed supplies, both in terms of quantity and quality. From a biological aspect, nutrition is often responsible for roughly two-thirds of the cost of increasing dairy output. Feed expenses account for around 60 to 70% of overall dairy production costs, meaning that the dairy enterprise's viability is determined by the type of feed and feeding system used (Adebabay, 2009). Dairy cattle productivity is sometimes limited by inadequate nutrition caused by poor quality feeds and inconsistent feed supply, especially in resource-constrained smallholder systems in the country.

The highlands of Ethiopia are recognized for their mixed farming methods, which benefit from ideal climatic conditions for both crop production and cattle rearing. In this strategy, livestock and crops are handled as complimentary businesses. With the exception of camels, this farming system has all of the major farm animal species. Livestock is an

essential aspect of the entire agricultural system, accounting for up to 87 percent of smallholders' cash revenue and encompassing all major farm species (NABC, 2010). Despite the fact that cereal crops dominate the economy, cereals, vegetables, meat, and milk make up the majority of the population's diet (IBC, 2004).

In Ethiopia, in the 1970s, improved forage crops (legume and grass), as well as multipurpose tree (MPT) forages, were introduced, promoted, and used in the mixed crop-livestock system to supplement roughage feed supplies (EARO, 2002). The most suited preserved forage for small scale fattening or dairy production in Ethiopia is hay made from natural grasses, enhanced forage legumes, and browse legumes (Alemayehu, 2002).

The production of fodder has been improved by a number of public and commercial groups. The International Livestock Research Institute (ILRI) has promoted access to forage seeds to boost the use of forages in sustainable agricultural systems in Sub-Saharan Africa. ILRI has been the region's leading supplier of forage seeds since 1990, providing over 7000 samples of 60 best-bet lines of forage legumes, grasses, and fodder trees to development workers, ministries, NGOs, and farmers, as well as attempting to collaborate with national programs on disease-resistant Napier grass varieties to support the scaling up of smallholder dairy activities across East Africa (ILRI, 2009).

Livestock feeding is primarily based on natural pasture and crop residues, with crude estimates of available feed in various parts of the country indicating a deficit of 35–57 percent even for maintenance. It is unlikely that livestock productivity will improve through commercialization of the production system without concurrent intensification in feed production (ILRI, 2009). Milk yields can be increased by up to 50% when forages are used (ILRI, 2009). Improved forages also reduce stress on natural pastures, increase soil fertility and reduce erosion on marginal lands, encourage carbon sequestration to combat climate change, support system sustainability, and increase natural assets and system resilience (ILRI, 2009).

Ethiopia has a total annual biomass available for animal feeding of 144.5 million tones, with ME and CP values of 890 x 109 MJ and 7.49 million tones, respectively. With 5.8 million tons of stubble biomass, 57.09 million tons of grazing fodder, and 46.9 million tons of crop residues (primarily straw and Stover), the total annual potential availability of forage (in million tons of dry matter (DM)) is around 110. (FAO 2017). With the exception of the Harari region, where it accounts for 1.68 percent of the diet, hay and crop residues plus natural grass account for more than 90% of animal diets in all regions. Improved forages account for less than 0.35 percent of the diet in all regions. Improved fodder species and types are minor in terms of use and relevance now, but they will be crucial in the near future if animal production is to be sustained (FAO 2017).

Ethiopia's most abundant feed source is natural pastures, which are most plentiful during the crop growth season. Pasture growth is influenced by the pattern of yearly rainfall, which varies by agro-ecological location. There are approximately 736 grasses, 358 legumes, and 179 browsing tree species that are excellent for animal nutrition. (CBD 4th Country Report, Ethiopia, 2014). Highly *Eragrostis*, *Trifolium* spp., *Cynodon*, *Digitaria*, *Paspalum*, *Panicum*, *Pennisetum*, *Setaria*, *Cordeauxia edulis*, *Acacia nilotica*, *A. Senegal*, and a few wild edible plant species are among the palatable natural fodder plants (which are threatened with extinction). Overgrazing and inadequate management encourage the growth of weeds, resulting in a shift in pastoral grazing plant composition and a reduction in cattle carrying capacity (Ethiopia's CBD 4th Country Report, 2014).

The most common grassland plants in the highlands and mid-altitudes include *Andropogon*, *Avena*, *Eragrostis*, *Eleusine*, *Cynodon*, *Cyperus*, *Digitaria*, *Paspalum*, *Panicum*, *Hyparrhenia*, *Pennisetum*, *Setaria*, *Trifolium*, and *Medicago*. Pastureland is dwindling due to population pressures, land degradation, and conversion of grazing pastures to arable fields. On mixed crop-livestock systems, this has an especially severe impact. The density and intensity of land cultivation stocking are out of proportion to the land carrying capacity, resulting in rapid and severe soil deterioration. In moderate and high altitude areas, natural pasture yields are around 3 tons of dry matter per ha and 4-6 plenty of dry matter per ha, respectively (Tekalign, 2014).

The size and quality (species composition, vigour, and palatability) of communal grassland has declined significantly in recent years. It is important to note, however, that some farmer groups are taking steps to improve community lands by implementing various management strategies, such as (i) sowing improved species (Rhodes grass), (ii) stopping or controlling grazing, and (iii) hay-mapping. Government ranches, state farms, farmer demonstration plots, commercial dairy producers, and fattening businesses are all growing their pasture and fodder crop plantings. On some smallholder farms, improved fodder is now being used; it is, however, still a work in progress. It makes up less than 0.2 percent of total cattle feed (Yilma et al., 2011). Improved pasture produces 6 to 8 tons of dry matter per hectare, while forage leguminous pasture produces 6 to 8 tons of dry matter per hectare. Oats (*Avena sativa*), vetch (*Vicia* spp.), Napier/elephant grass (*Pennisetum purpureum*), fodder beet (*Beta vulgaris*), siratro (*Macroptilium atropurpureum*), cowpea (*Vigna unguiculata*), Panicum spp., Rhodes grass (*Chloris gayana*), lucerne (*Medicago* (*Cytisus proliferus*)). Forages are preferable. According to (FAO, 2018), they account for 0.15 percent of total livestock feed balance and 0.1 percent of total energy consumed by Ethiopian livestock.

Low adoption of improved forage and utilization systems, insufficient feed and nutrition, lack of awareness of improved forage production and husbandry practices, inadequate market infrastructure, a market-oriented cattle production system, and the prevalence of various diseases are among the major constraints cited as limiting livestock production and productivity in the country. Zekarias Bassa and ESAP (2003) (2015). National, regional, and international research organizations have created a variety of feed production and utilization technologies to alleviate these limits. Despite a lot of initiatives to disseminate new feed technologies and feeding systems, their widespread acceptance is still limited and minor, according to Gebremedhin Berhanu et al. (2003) and Zekarias Bassa (2004). (2016).

According to a CSA analysis from 2015, only 0.3 percent of livestock owners in the country are using improved feed methods for their animals. Limited household resource endowment, particularly labor and land to plant forage; mismatch of farmers' needs and technologies; limited market integration and extension services provision, including weak

information flows and links to other input providers; and multiple bio-physical stress and shocks are all contributing factors (Mulugeta Yitayih et al). (2017). Several studies, including those by Gebremedhin Berhanu et al. (2003), Hassen Beshir (2013), and Mulugeta Yitayih et al. (2017), have been conducted to assess the level of acceptability of livestock feed technology, its impact, and the key reasons for its limited adoption among smallholder farmers .

Conversely, the majority of past research has mostly focused on the rate of technology adoption and the factors that influence it. Furthermore, most of these studies assumed universal adoption of technology, which may not be the case with improved feed technologies. Aside from defining and describing the conditions, previous research have made modest contributions to developing proven and workable solutions that could inform policies and strategies to increase wider adoption of improved feed technologies and impact. The livestock production and feeding system, on the other hand, is quite primitive. However, Dairy farming is primarily subsistence in the North Shoa zone. The common feeding system consists of grazing natural grassland supplemented with low-nutritive-value hay and a local beverage by-product (Lives, 2012). In the area, development of dairy feed processors and suppliers has been minimal, resulting in underdevelopment of the dairy sector.

1.2. Statement of the problem

Subsistence oriented smallholder crop-livestock mixed farming system is the main mode of production in the highlands of Ethiopia. The crop-livestock systems in the Ethiopian highlands are under stress because of shrinking cultivated areas per household due to high rate of population growth, land degradation and reduced pasture land due to gradually turning into crop fields (Funte et al., 2009). This has led to reduction in grazing areas and consequently to shortage of feed to livestock. As a consequence, crop residues have become the dominant ruminant feed resources in the highlands of Ethiopia accounting up to 30-80% of the diet of ruminant livestock (Funte et al, 2009). These feed resources are characterized by their inherent nutritional deficiencies, and are generally low in nitrogen, energy, vitamins and minerals (Solomon et al, 2003).

Many constraints are generally believed to contribute to the low productivity of livestock in the highlands of Ethiopia. In many cases it is the low level of animal nutrition and management, including health care, which limits the productivity. The livestock is mainly dependent on crop residues and native pasture (hay and grazing). The feed supplies fluctuate in both quantity and quality seasonally. According to Getachew et al, (1993) this resulted in fluctuations in animal products such as milk, meat and traction, and at worst animals may die during the periods of feed stress. Crop production also declines due to poor and delayed land preparation using oxen. Moreover the crop and livestock sub-sectors also compete for the scarce farm resources, even though they are complementing each other. An example is the encroachment of cropping on grazing lands. The competition for land, labour and capital becomes more apparent with the expansion and development of livestock production.

The low productivity of the livestock sector is a result of several limiting factors among which feed is the major one Alemayehu Mengistu and Getnet Assefa (2012). In spite of serious problems of feed shortage and large number of livestock in the Ethiopian highlands, adoption and popularization of forage crops is very poor Getnet Assefa (2012).

Various efforts have been made by different organizations, often with the support of externally funded projects to promote improved fodder crops to the farming communities. However, adoption of improved fodders by the farming community has so far been very limited and their potential for sustainable feed supply is largely untapped in the country. For instance, study on the adoption of improved fodder crops in the operational areas of the Improving Productivity and Market Success of Smallholders (IPMS) project showed that only 0.15% of rural livestock keepers reported on-farm production of some fodder crops (Tefera et al, 2010).

Many improved forage crops have been tested and selected for the highlands. Some of them have been demonstrated to farmers, but, their adoption is still very slow (Lulseged, 1987; Zinash et al, 1996). Oats is the only crop, which is widely cultivated both for human food and as forage for livestock in the central highlands of Ethiopia, especially around Selale, Sheno, Debreberhan, and Arsi areas. Oats is becoming very popular in many areas because it performs well on waterlogged and frost problematic areas and on

soils with poor soil fertility which is less suitable for other food crops (Daniel, 1985; Gryseels, 1988). Improved grass forage development is one of the most cost-effective and high value feeds that can be produced and utilized. Improved grass pasture can also provide significant benefits including yields, lower feed costs and improve livestock performance (Beetz and Rinehart (2006) and BMP (2015).

Around Selale and Sheno areas farmers reported that feeding livestock is becoming a difficult duty, particularly for the production of milk and for the animal power as grazing fields are decreasing in size due to expansion of croplands to cope with the high and increasing human population pressure (Chilot et al, 1998). Cultivated forage crops - Conventional cultivation of forage crops is not common among smallholder farmers. Only large private and state farms produce a limited amount of cultivated forages (Zinash et al., 1996). The farmers, especially those who own crossbred animals, supplement their livestock with cultivated oats, oil cakes, and crop by-products and forage crops grown around the homesteads to overcome the feed problem. Other forage crops such as vetches, fodder beet and browse trees are also utilized by some farmers in the highlands (Varvikko, 1993). Introduction and adoption of improved forage crops, which best suit the cropping system, enhances not only livestock productivity but also crop production. However, successful development in introduction and adoption of these forage crops requires an understanding of the overall farming system.

To date, adoption of these technologies has been slow; despite evidence of high returns where the technologies have been extended by extension and development agencies. These include fodder banks in west Africa (El Basha et al. 1999), alley farming in west Africa and Kenya (Jabbar et al. 1996), the napier grass and leguminous tree combination for dairy animal production in coastal and central Kenya (Staal et al. 2001) and oats–vetch (*Avena sativa* and *Viciavillosa* ssp. *dasycarpa*, respectively) intercrop in the highlands of Ethiopia (Darnhofer 1997).

Though there have been various empirical studies conducted to identify determinants of adoption of agricultural technologies in Ethiopia, [for example (Benin et al, 2003; Yitaye, 2008; Zewidie, 2010, Adugna et al, 2012) to the best of the author knowledge, there were no similar studies undertaken in the study area. Moreover, since adoption is dynamic, it is

imperative to update the information based on the current technologies being adopted by farmers.

According to Loiskandl et al. (2008) assessing the impacts of past interventions and investments significantly contribute to the planning of new investments and the design of interventions. Specifically, the findings of such kinds of impact studies are relevant for an improved planning and managing of forage development. Consequently, this paper aims to contribute to filling these gaps.

Hence, generating information on analysis of adoption of improved forage technologies, identifying the available feed resources, the limitations in cultivating forage crops and their contribution to the dairy sub sector and household livelihoods is helpful for future research and development of the crop-livestock farming systems of smallholders in the highlands of Ethiopia. Therefore, with the above backgrounds in mind, the proposed study is conceived with the following general and specific objectives.

1.3. Objectives

1.3.1. General objective

The central objective of this study is to examine the adoption of improved forage technology and its impact on smallholder dairy productivity in Debre Libanose woreda.

1.3.2. Specific objectives

More specifically, the study is planned to:

1. Identify the determinants of adoption of improved forage technology in the study areas
2. Examine the rate and intensity of improved forage technology adoption; and
3. Assess the contribution of adoption of improved forage technology on smallholder dairy productivity and household income

1.4. Research questions

This research was intended to answer the following basic questions which are derivatives of the research objectives:

1. What are determinant factors of forage technologies adoption in the study area?
2. How much is the rate and extent of forage technologies adoption in the study area?

3. What is the implication of improved forage technology adoption on smallholder dairy productivity in the study area?
4. What is the implication of improved forage technology adoption on household income?

1.5. Significance of the study

From the theoretical and empirical literature reviewed, it is understood that, most of the study focused on identifying the determining factors of forage adoption. But this study would try to examine factors that affect the adoption of forage technology, to what extent is the adoption of the household, as well as its implication (impact) on the rural household income and smallholder dairy production. It is intended to contribute the knowledge gap regarding to impact and forage technology adoption. Therefore, the output of this research would improve the knowledge about the role that the sector plays in rural farmers' livelihoods, and would also add information to the limited research done so far on the role of forage technology adoption and impact in the region. Thus, this research was not aimed to replicate or duplicate what has been done by the others, but to fill the gaps that were not observed in other research works. In addition to this, it would help to better design development projects or programs for the farmers to improve their livelihood options. Policy makers would also benefit from the research findings because they require information to formulate appropriate policies with regard to farmers' adoption, and identifying major factors that influence the uptake of improved forage technologies as well as its impact on household income and dairy productivity. The result of this study would be together used as a reference for other similar areas for further study. In general, the study was expected to generate grass root information for different stakeholders in order to develop sustainable strategies that decrease drawbacks and other associated issues in this study.

1.6. Scope and delimitation of the study

The study was confined to a description of the impact of livestock forage system and analysis of factors affecting adoption of forage crops in the single Debre Libanose woreda of Oromia regional state because of limited resources. Hence, the major limitation of the study was mainly related to its limited area coverage within the region.

Besides, it would cover only three KAs out of the total ten rural KAs due to lack of adequate finance, budget, time and other facilities to increase the number of the respondents and widening the study area. This could limit the generalizability of the study to the wider area or region. Even if the study was planned to carry out with the above limitations, the findings would serve as a base for further research in the study area and other areas would have similar physical and socio-economic settings.

1.7. Organization of the thesis

This thesis has five chapters. Chapter one presents the background of the study, a statement of the problem, objective of the study, research questions, scope and limitation, the significance of the study. Chapter two deals with theoretical, empirical and conceptual literature review related to improved forage technology adoption and impact as well as a conceptual framework for the study. The third chapter portrays study area description, research design, sampling method, procedure, and method of data analysis. Chapter Four presents the result of the study and discussion, while chapter five summarizes the finding of the study and provides conclusions and recommendations.

CHAPTER TWO: LITERATURE REVIEW

This chapter deals with the operational definition of technical terms used in the study, theoretical and empirical reviews literature.

2.1. Theoretical foundation and the concept of technology adoption

2.1.1. Technology definition

The term "technology" is defined in a variety of ways by various authors. Rogers (1995) defines technology as the design for instrumental action that reduces the uncertainty within the cause-effect relationship involved in achieving a desired target. A more accurate definition of technology may be a collection of "new ideas." New ideas are associated with a degree of ambiguity and, as a result, a lack of predictability in their conclusion. Blending into the conventional routine of the targeted financial system without disrupting the system's state of affairs is essential for a technology to have an impact on the financial system. This necessitates overcoming the apprehensions surrounding new technologies. As a result, it's no surprise that various research have been conducted to establish what these characteristics are and how they may be avoided (if they are restraints) or increased (if they are enhancers) in order to achieve technological adoption. Enos and Park (1988) define technology as "public knowledge or information that facilitates the accomplishment of certain tasks, the performance of certain services, or the manufacturing of certain items" in their research of imported technology adoption (p.9). (Singh and Abara) (1993) explain that the application of that knowledge is what is referred to as 'technology.' Agricultural technologies are included in this definition, despite the fact that Enos and Park (1988) concentrated on non-agricultural technology.

It is evident from their definition that technology is designed to make the task of the entity to which it is applied easier. As a result, most technologies are labeled as "labor-saving," "time-saving," "capital-saving," "energy-saving," and so on. To economists, this means conserving finite resources. For farmers to achieve greater production or productivity, the application of improved techniques (innovations), whether introduced from within or without, is a major concern. A thought, habit, or item that is seen as new by a personal or other unit of adoption, according to Rogers and Shoemaker (1971). That is to say, a technological invention includes both the thinking and, as a result, the object

components. The software (participation decision-making procedures) and, as a result, the hardware (intensity of use) components are both necessary. The extent to which a technology is used is referred to as adoption intensity. Nkonya et al. (1997) define adoption speed as the degree to which a technology is used.

2.1.2. Technology adoption

Technology adoption is defined by Van den Ban and Hawkins (1996) as the decision to implement an invention and continue to utilize it. The adoption process, according to this definition, refers to the changes that occur in a person's mind in relation to an innovation from the moment s/he becomes aware of it to the final decision to continue using it or not. Adoption is the result of a decision to accept a particular invention. While paraphrasing Roger's earlier work from 1962, Feder et al. (1985) describe adoption as "the process a private goes through from first hearing about an innovation to final utilization." Dasgupta (1989) also defines technology adoption as the utilization of a technology over time (by individuals or group) of the recommended innovation or new practices over a fairly long period.

Choosing which shows cognitive engagement is required when adopting a replacement innovation. Koch is a well-known figure in (1986). This implies that the adoption process occurs within a person's mind, or within the minds of economic units in a highly social organization, or within a close proximity. Adoption is split into two categories by scientists: adoption rate and adoption intensity. Distinguishing between these two notions is important from a policy standpoint since they typically have different policy implications. The factor of 'time' is present in the rate of adoption, which is the relative speed with which farmers adopt an invention. The intensity of adoption, on the other hand, relates to the amount of time that a given technology is used in any fundamental quantity. The introduction of a replacement technology is divided into two phases. The new technology is introduced to farmers in the first phase, for example, by demonstration plots or other means, and the new technology is implemented when it is found to be advantageous.

Campbell's primary phase of adoption model is based on the fact that adopting a new technology isn't always a quick process (1966). Rather, it's a process that unfolds through

time and is influenced by a sequence of events. As a result, the fundamental phase of the adoption process consists of the following five stages: (1) acquaintance: the first time you learn about the innovation (2) curiosity: a desire to learn more about the innovation (3) assessment: assessing the advantages and disadvantages of implementing the innovation (4) trial: a small-scale test of the invention, and (5) adoption: a large-scale application of the technology over traditional methods. However, we must always keep in mind that none of these choices are made in a linear fashion. In fact, according to recent research, these stages may occur simultaneously, and some may or may not occur during the adoption decision-making process Rogers (1995).

The second phase is marked by a gradual decline in the utilization of the new technology until it is abandoned. Yaron and Dinar (1992). The abandonment of a replacement technology could be due to a lack of profitability due to rising input costs, declining yields, or the outcomes of a switch to a more profitable technology. Replacement of an existing better variety with a recently released new one, on the other hand, is considered a continuation of improved technology utilization because the two kinds are interchangeable. Cameron (1999) claims that the dynamic process of adoption entails learning a few different technologies over time. After all, many inventions necessitate a long amount of time, typically several years, from the time they are available to the time they are generally embraced, as Enos and Park point out (1988). The average time between receiving first information and eventual adoption varies greatly depending on the person, location, and practice. The authors show that there are numerous long, varied, and unsure lags between the initial investment in research and the production of pre-technology knowledge up to maximal adoption by producers. Adoption is described as having a logistical nature in this research on the issue. It rises with time (as the amount of information available grows), reaches a peak, and then falls.

Rogers' main premise for explaining the S-shaped pattern of the adoption route was the concept of early and late adopters (1983). To put it another way, the S-shaped curve arises from the fact that only a small percentage of social system members (farmers) accept a replacement technology during the early stages of the diffusion process. Only a few farmers receive complete information about the possible economic benefits of a new

technology during its early phases of introduction, and as a result, acceptance is gradual. Furthermore, whether or not they receive complete knowledge about the technology's potential economic benefits at the outset, most farmers are concerned about the new technology's potential hazards and hence place a lower value on adoption. However, as time passes, potential adopters gain a better understanding of the technology's benefits as well as the degree of riskiness associated with it. Then adoption picks up until it hits an inflection point, at which point it begins to increase at a slower rate and alter surface, eventually hitting an upper ceiling. The S-shaped diffusion curve was attributed to the spread of data by Griliches (1957) and Mansfield (1961) studies. Their research found that the rate of adoption of a technology is a function of the technology's economic profitability, the amount of investment required to adopt the technology, the level of uncertainty associated with it, as well as the technology's availability if the technology is not divisible (e.g., if the technology is not divisible). (For example, irrigation and mechanization). If the technology is divisible (for example, improved seed, fertilizer, or herbicide), the selection method still involves area allocations as level of use or rate of application. Feder and colleagues (1985) Thus, the process of adoption decision includes the simultaneous decision of whether or not to adopt a technology and the extent to which it is used.

2.1.3. Innovation decision model

Model of innovation diffusion According to Feder et al., (1985), adoption is the integration of an invention into a farmer's activity over a period of time; nevertheless, farmers may not be able to continue the adoption process due to many constraints such as institutional, personal, and societal factors. According to Carr (1999), technology adoption is the process of an individual or a group of people choosing a technology. On the other hand, technology adoption theory is essentially a process in which members or groups of a social system communicate an invention through a specific channel. Feder et al., Feder et al., Feder et al (1985). According to Rajesh (2016), one of the most mature areas of research is technology adoption. In most cases, the innovation decision model has five conceptual stages. Knowledge, persuasion, choice, implementation, and confirmation are the processes involved. When a person is exposed to a new innovation and gains some comprehension of it, knowledge is gained. Persuasion occurs when the

decision-making unit develops an honest or unfavorable attitude about the invention. The other is choice, which occurs when a person decides whether or not to adopt or reject an invention. The decision-making unit puts an idea into effect during the implementation stage. Confirmation is the last stage of the innovation decision process, and it occurs when someone seeks confirmation of an innovation decision they have made (Rogers, 1983). (Andesine and Zinnah, 1993).

Furthermore, the aggregate diffusion theory denotes a technology adoption process that an individual perceives as a behavioral change. Individual developments are reflected in the degree to which new technologies are used and their potential. The adoption process, on the other hand, is the diffusion of new technology throughout the region. This means that the overall diffusion rate of new technologies in a given population is monitored in a specific area (PC Lai, 2017)).

2.1.4. Adoption

Adoption is a mental process in which a person progresses from hearing about an idea to acquiring information, learning by doing, and accumulating resources. It refers to an economic unit's decision to employ new technology or practice on a regular basis. Technology adoption can help farmers increase output and consumer expenditure, both of which have an impact on their well-being (Samuel et al, 2016). Immediate and uniform adoption is uncommon in agriculture, with rates ranging across socioeconomic groups and over time (Khanal, 2010). Any agricultural innovation's adoption can be quantified in terms of the number of farmers who use it and the total area on which it is used. In agriculture, however, technology adoption refers to a collection of technological features that boost production and productivity, as well as technical practice, knowledge, and ability that is required for successful and efficient use and can be adopted by individuals or groups (Shahin, 2004).

Adoption is defined differently by different scholars at different eras. Rogers (1983) defined adoption as the use or non-use of a new technology by a farmer over a period of time. It's all about employing technology within a certain amount of time. The adoption decision, according to Feeder et al, cited in Hailu (2008), also includes deciding what share of resources to adopt. (In this case, land) The decision process involves area

allocations as well as level of use or rate of application if the technology is not divisible (e.g., mechanization, irrigation); however, if the technology is divisible (e.g., improved seed, fertilizer, and herbicide), the decision process involves area allocations as well as level of use or rate of application. In this scenario, depending on the technology type, adoption of a technology can be determined by area allocation and level of use. Aggregate adoption, as described by Thirtle and Ruttan (1987), is the diffusion of a new technology across a population. Adoption also considers population coverage in a certain place and at a specific period. Farmers choose technology based on a number of factors during the adoption process. A farmer, according to Hasan (1996), takes a series of interdependent judgments before making adoption decisions. In general, adoption is a decision made by farmers to use or not use a technology within a given time frame based on numerous factors and quantified by area allocation or level of use based on technology type.

2.1.5. Impact evaluation

Impact evaluation is based on econometric and statistical models, according to the theoretical framework. There are three types of impact evaluation designs: experimental, quasi-experimental, and non-experimental, which are related to control, comparison, and non-participants, respectively. The impact of an intervention on beneficiaries is systematically measured through impact evaluation. The key question in all program assessment attempts is whether a particular intervention, as conceived, is effective in achieving its core goals. Because this counterfactual conclusion is never observed, statistical methods must be used to estimate it. The best statistical strategy for solving this problem is Propensity Score Matching (PSM). It takes data from a pool of units that do not take part in the intervention to determine what would have happened if the intervention had not been implemented. It is possible to measure the intervention's impacts by comparing how participants' outcomes change from those of observationally similar non-participants. Approaches that directly match participants with non-participants who have similar characteristics have replaced regression as one of the preferred methods for estimating intervention impacts using comparison group data in recent years, facilitated in part by improvements in computing capacity and associated algorithms (Carolyn et al, 2010).

Score of Propensity Matching creates a statistical comparison group based on observed features and a model of the probability of participation in the therapy. Participants are then matched to non-participants based on this probability, or propensity score. Given specific observed features, the propensity score may be a contingent probability that reflects how likely a participant is to be allocated to or select the treatment condition. This chance is used to condition observed data in a propensity score analysis, for example, by matching on the propensity score (Shahidur et al, 2010).

Conditioning on the propensity score has the goal of achieving balance on the observed covariates and recreating a situation that would be expected in a highly randomized experiment (Felix and Eun, 2009). Matching procedures are used to create a counterfactual or control group that is as similar to the treatment group in terms of observed characteristics as possible.

The idea is to find persons who are observationally similar to participants in terms of 17 qualities not covered by the program from a large population of non-participants. Each participant is matched with a non-participant who is observed almost identically, thus the common difference in outcomes between the two groups is compared to induce the program treatment effect. If differences in participation are thought to be due only to changes in observed qualities, and there are enough non-participants to match with participants, the treatment impact can be calculated (Shahidur et al, 2010).

Ethiopian agriculture is a mixed farming system, with livestock coming after crops as a source of household income and producing the majority of milk and meat (Yenesew et al, 2013.). It accounts for 90% of milk output, 54% of meat production, and is the most common production system for smallholder farmers in many developing nations (Sere et al, 1995). Crop and livestock subsystems in Ethiopia interact in a variety of ways. Within the farming systems, the livestock subsystem has output, input, asset, security, and investment roles. Animal traction and agricultural wastes are the first binders in the crop and livestock sub-sectors (Solomon, 2003). Crop farming receives direct input from draught power and manure generation. Furthermore, animals provide a new market for crop farming by converting crop leftovers and low-quality grains into high-quality human foods such as meat and milk (Tedla et cetera, 1993). Ethiopia's highland crop-related

livestock production system can be found between 1,500 and 3,000 meters above sea level, mainly in Tigray, Wollo, Gondar, Gojjam, Shewa, and parts of Wellega (Mengistu, 2003). Ethiopia's highland mixed crop-livestock agricultural system, in particular, is responsible for two-thirds of the livestock population and nearly all of the produced land (Mengistu, 2003). The highlands are home to about 75 to 80 percent of the country's cattle and sheep, as well as 30 percent of the country's goat flock (Sileshi et al., 2001). Food production, danger minimization, money generation, and internal integration are all reasons why animals are kept in the highlands (Mesfin et al., 2003). Animals convert agricultural waste and other plant material into items that people may utilize, and they either mediate or accelerate up nutrient transfer and turnover to the soil, according to Dowell et al. (1980).

In general, livestock in Ethiopia's highlands contributes significantly to the country's socioeconomic development, providing food, energy, cash income, economic security, and manure for the agricultural community and crop agriculture; hides and skins for export and industrial use; and live animals for export and industrial use (Solomon, 2003).

2.2. Livestock production systems in Ethiopia

Generalizing regarding livestock production methods in Ethiopia is challenging due to the country's distinct geography, climate, and cultural characteristics (Alemayehu, 1985). Pastoral, agro-pastoral, mixed crop-livestock farming, urban and peri-urban farming, and specialized intensive farming systems are the five types of livestock production systems described in Ethiopia (MoA, 1997; Yoseph, 1999; Mohammed et al., 2004; Yitay, 2007). Mixed crop-livestock systems, primarily in the highlands, semi-extensive agro-pastoral systems, which integrate animals with cropping in warm and semi-arid environments, and extensive pastoralists in arid and semi-arid rangelands. Crop livestock integration is a characteristic of the mixed-agricultural livestock system, which includes the use of crop wastes, draught power, and manure. Cereals, oil crops, food legumes, and perennial crops are all farmed here. During the seasons, cattle are raised for draught, milk production, and meat production (Alemayehu, 2004).

The semi-intensive agro-pastoral system is made up of pastoralists who have been involved in a variety of small-scale crop production as well as a less extensive type of

pastoral animal husbandry (Sileshi et al, 2001). Livestock rearing is the mainstay of persons in broad pastoral systems, and livestock and livestock products supply subsistence, either directly as milk, milk products, meat, and blood, or indirectly as cereals (Zinash et al.,2001; Alemayehu, 2004). Livestock are the backbone of life for their owners in the lowland agro-ecological setup with pastoral production system, giving all consumable and saleable outputs and, additionally, constituting a living checking account and style of insurance against adversity (Coppock, 1994). The pastoralists' subsistence is primarily sustained by livestock and animal products in this approach, which is characterized by sparsely inhabited pastoral rangelands. Goats, cattle, sheep, and camels are the most common livestock in this system. Pastoralists tend to have large herds to ensure a sufficient milk supply and earn cash because milk is the most common dietary source (IBC, 2004).

In the middle agro-ecological zones, where crop production has emerged alongside livestock production, the agro-pastoral type of livestock production system predominate (Sileshi et al, 2001). Farmers who grow crops and raise cattle are known as agro-pastoralists. Draught, savings, and milk production are all reasons why livestock is kept. Cattle and small stock play a crucial part within the agro-pastoralist family economy. The assembly method is a sort of milk and/or meat production that is used for survival. Female cattle are often kept by agro-pastoralists to provide milk and protect the herd's reproductive capability. Because oxen are required for draft, the majority of the stock sold consists of oxen and cows that have outlived their usefulness (Sileshi et al, 2001). Due to the low average herd size, many herders are increasingly being forced to sell young males and even females of reproductive age (Sere et al, 1995).

Animals are an element of a mixed agricultural complex in the highland livestock production system (Mengistu, 1987). Other parts of the farm system benefit from livestock's inputs (draught power, transportation, manure) and outputs (milk, manure, meat, hides and skins, wool, hair, and eggs) (Alemayehu, 2004). Around 88 percent of the human population, 70% of cattle and sheep, 30% of goats, and 80% of equines are found in this region (Alemayehu, 2004). The main goal of farmers who practice mixed farming is to acquire a complementary advantage by combining crop and livestock

production in the best possible way and spreading revenue and risk across both crops and livestock production (Bogale, 2004).

2.3. Socioeconomic role of livestock in Ethiopia

Livestock production plays a significant part in farmers' and the country's economics, as well as in meeting a wide range of human requirements, ranging from the supply of natural animal food (very nutritious) to the provision of economic, social, cultural, and environmental benefits (Danthu et al, 2008). Animal husbandry is an essential component of agricultural output. Livestock contribute significantly to household incomes, both directly through milk and meat production and other products, and indirectly through manure traction and other interactions with agriculture, as well as as an investment (Danthu et al, 2008). Furthermore, animals serve a variety of purposes in the Ethiopian economy, including providing food, input for crop development and soil fertility management, a staple for industry, monetary revenue, and promoting savings, fuel, social functions, and employment. According to various estimates, livestock production in Ethiopia accounts for up to 80% of farmer income, 18% of GDP (Alemayehu, 2004), and 45 percent of agricultural GDP. (Including draught power), above 20% of all the national exports (official and cross border trade) and 5% of the overall manufacturing GDP (IGAD, 2010).

In Ethiopia, livestock are an important part of practically all farming systems, providing draught power, milk, meat, dung, hides, and skins. In Ethiopia's mixed crop-animals systems, livestock are subordinate but economically complementary to crop production, providing draft power that could be a crucial contribution to food security. The general need for farm labor (Benin et al, 2002). Cattle are the most important species in the semi-arid lowlands because they produce milk for subsistence pastoral communities (Benin et al, 2002). In more arid areas, goats and camels are the most frequent livestock (Asfaw, 1997). The former provides milk, meat, and cash income, while the latter provides milk, transportation, and, to a lesser extent, meat (Asfaw, 1997).

2.4.Feed resources and feeding systems within the highlands of Ethiopia

2.4.1. Feed resources availability

In Ethiopia's highlands, natural pasture, crop residues, and stubble grazing are important sources of food (Alemayehu, 2004). However, as the extent of the grassland decreased, agricultural by-products became more important as a result of overgrazing, resulting in a rise in arable farming (Alemayehu, 2004). As a result, crop residues play an essential role in the feed resource base (Bogale, 2004). The amount of diverse crop residues produced is determined by the total farmed area, rainfall during the season, crop species, and other inputs such as fertilizers (Daniel, 1988). Grazing is the most common type of ruminant feeding system in most parts of Ethiopia, despite the fact that it is neither quantitatively nor qualitatively equivalent to support successful animal production (Alemu et al, 2013). Ethiopia contains both big and small-scale crop-livestock production zones (Bogale, 2004; Getachew et al., 2002). Furthermore, the protein and fiber content of feed for cattle sourced from natural pasture vary greatly, which are generally inversely associated (Tothill, 1987).

In Ethiopia, hay making is a common feed preservation technique that is expected to alleviate problems with livestock feeding during the dry season, and so such expertise could be a good indicator that certain feed use techniques exist (Alemayehu, 2003). According to the author, the quality of the conserved hay is low due to inappropriate handling and preservation processes. To produce higher-quality hay, some improvements in handling and preservation are required. The term "prime quality hay" refers to forage that has been dried without deterioration and has retained the majority of its nutrients (Greenham et al, 2007). During the season, cereal straw, agricultural by-products of crops and aftermath are accessible after the crop harvest (Alemu et al, 2013). As a result, cereal crop wastes (Straws and Stover) are largely stacked and fed to animals throughout the season when the amount and quality of fodder available from natural pasture decreases dramatically (Tolera and Said, 1994). Furthermore, the protein and fiber content of feed for cattle sourced from natural pasture vary greatly, which are generally inversely associated (Tothill, 1987). The crop residues' plasma membrane (Assefa, 1999). Crop residue conservation and economic use also help to strengthen and improve their use

(Assefa, 1999). The use of urea as an ammonia source to treat fibrous crop remnants could be a way that small farmers could easily manage (Assefa, 1999).

Crop production style and intensity, as well as population pressure, determine the feed resource in Ethiopia's highlands. Crop leftovers account for 10 to 15% of total feed intake on average (Alemayehu, 1998). According to the same paper, in some areas where unique crop/livestock production strategies are used, intake could increase by up to 50%. (Alemayehu, 1998; Alemayehu, 1998; Alemayehu, 1998 Crop residues and stubble grazing provided 74.15 percent of total yearly feed supply, making them the most important feed source. Wet periods when grazing area forage is insufficient or nearly absent (Bogale, 2004).

Similarly, crop wastes and aftermath grazing make up around 60 to 70% of the basic diet in most intensively cultivated areas, with wheat straw being the most prevalent feed in wheat-based systems. (Bediye and colleagues, 2001). Varied research studies suggest a different percentage of agricultural leftovers as livestock feed. This could be due to a wide range of ecological differences between different parts of the country, as well as variations in time, which lead to changes in crop species and cropping intensity. In order to comprehend the feed gap between feed supply and feed requirement within a particular animal production level, a place and time specific feed resource evaluation is necessary (Daniel, 1988). At beef farms, there is a significant preference for supplementing agricultural residues with molasses and/or urea, and some farmer cooperatives conduct pen fattening of cull cows and old oxen on straw-based diets (Daniel, 1988).

In Ethiopia's central highlands, animals graze on seasonal fallow land and permanent pasture areas during the cropping season, as well as croplands after harvest (Sileshi et al, 1995). Seasonality in animal feed supplies and poor quality in the standard of most harvested and stored feedstuffs are major production challenges in most Ethiopian livestock feeding systems. When fed alone, it's often unable to supply even for the upkeep needs of livestock (Anderson, 1987). Crop residues were mostly consumed in two ways by animals. Animals are left to eat from the heaps or fed modest portions in the morning and evening, or for working oxen before and after work, and the wastes are placed near homesteads (Anderson, 1987). Alternatively, the remnants, along with

standing straws left for post-grazing grazing, are left on the threshing site and devoured by animals (Daniel, 1988). In Ethiopia's central highlands, straws laced with molasses and urea are utilized on farms and government-run fattening feed lots (Daniel, 1988). Annual leguminous species combined with grains provide the most straightforward volume and quality of fodder in highland settings, whereas annual legume fodder maximizes forage production in moderate altitude and lowland areas. Fallow reduction tactics with leguminous fodder crops are suitable in these areas. Oats and vetch have tolerated a wide range of AEZs, with oats demonstrating a high level of tolerance for low fertility and poor drainage (Alemayehu, 2002). While alfalfa doesn't perform in Ethiopia's rain-fed settings, Lablab grows at lower altitudes and effectively competes with weeds. Farmers are open to oat/vetch and lablab techniques, especially if fattening or dairy operations are viable (Alemayehu, 2002).

Annual fodder crop strategies will be abandoned in favor of fodder crop methods that can be integrated into cropping systems (Alemayehu, 2002). In government ranches, state farms, farmer demonstration plots, and dairy and fattening areas, improved pasture and forages are grown and utilized. Oats and vetch mixtures, fodder beet, elephant grass combined with siratro and Desmodium species, Rhodes/Lucerne mixture, phalaris/trifolium mixture, and phalaris/trifolium hedgerows are the most common forage crops used for oxen. However, smallholder farming groups have had limited access to better pastures and forages, making adoption of this technology difficult.

Herbaceous and tree legumes can restore soil fertility and forest land degradation while improving crop and livestock productivity on a more sustainable basis. As a result, the introduction of dual-purpose legumes that boost agricultural output while conserving natural resources could help achieve financial and food security as well as reverse land degradation. As a result, incorporating legumes into cereal-based systems can give benefits such as increased quantity and quality fodder production, wear resistance, and soil fertility restoration. Furthermore, when livestock responsiveness to enhanced feed technology and profitability from livestock enterprises is high, demand for forage and chances for forage technology dissemination are also likely to be high. Farmers are aware of the financial benefits that the new technology offers (Stevens and Jabara 1988).

2.4.2. Feed resources and their distribution over seasons

During the dry season, feed shortages are critical. Natural grassland and crop residues provide the majority of the feed in Ethiopia's highlands. Feeds are ample from December to February, after which rationing begins. Draught oxen are provided high-quality feed on occasion, especially during peak farming months when field preparation and planting operations are widespread. Crop residues become the primary feed source in May and June, when there is almost no green feed available but a strong need for draught power. Pulse crop residue is a high-quality feed that is frequently mixed with cereal straw and fed to oxen and milking cows. Crop residues from cereal fields have a low concentration of Metabolizable energy and protein. Crop leftovers will be mixed with various forage legumes to alleviate this problem to some extent. This approach improves rumen fermentation and, as a result, the energy supply from the entire diet. Grass forages that have been improved give a rich supply of energy virtually all year (MoA, 1984).

The amount and distribution pattern of rainfall, as well as the season of the year, influence the availability of feed supplies in Ethiopia (Tedla et al, 1993). Despite the availability of modest supplies during the dry season on unique pieces of land and along riverbanks, natural pasture as a feed source is limited to the rainy season (Sileshi et al, 1995). As a result, animals will be more reliant on crop residues at this time of year. Aside from natural pasture, the contribution of stubble and fallow land grazing is crucial starting at the end of the cropping season, right after harvest. Livestock can graze freely on crop fields during this time period. Standing hay that was closed throughout the wet season is now open for the cropping season's end (Oni, 2001).

Crop residue availability is also linked to the farming system, the type of crops grown, and the intensity of cultivation (Oni, 2001). In integrated crop/livestock systems, crop residues have the greatest potential for use as livestock feed (Daniel, 1988). As more area is converted to agricultural production, livestock feed becomes scarce, and crop leftovers, particularly cereal straws, remain the primary source of nutrition for animals, especially during the dry season (November to May) (Daniel, 1988). As a result, livestock rely on straw from cereal crops, especially during dry years when grazing land resources are few (Bogale, 2004). Seasonal changes in feed quality and quantity are the principal constraint

to animal production and produce productivity fluctuations throughout the year, especially during the dry seasons when feed is sparse and of low nutritional value (Daniel, 1988). The issue of seasonality of feed resources in Ethiopia's highlands is exacerbated by the lack of a controlled breeding strategy that adjusts to seasonal variations in feed supply and demand (Daniel, 1988). As a result, the only method to overcome the dry season economically is to produce sufficient amounts of higher quality dry season forages to augment crop residues and pasture roughages is the only way to economically overcome the dry season constraints affecting livestock production in Ethiopia. Because browse plants have root systems that are better equipped to use soil water reserves than forage species, using deep-rooted perennials like browse legumes reduces the impact of the season (Mengistu and Robertson, 1988). Furthermore, where forage production is seasonal, the farmer can use a variety of methods to ensure adequate year-round feed supplies, such as stock adjustments, seasonal breeding programs, growing a variety of pasture species, grass-legume mixtures, tree legumes, and special fodder areas, and using fodder conservation techniques (Zewdu, 2003).

2.4.3. Feeding systems

In Ethiopia's central highlands, livestock graze on seasonal fallow land and permanent pasturelands during the cropping season, as well as on croplands after harvest (Zinash et al, 1995). Seasonality in animal feed supply and poor quality are major production challenges in most Ethiopian livestock feeding systems. When fed alone, most harvested and preserved feedstuffs are often unable to generate even for the maintenance needs of livestock (Anderson, 1987). Crop residues were mostly consumed in two ways by animals. Animals are left to feed from the heaps or given little portions in the morning and evening, or for working oxen before and after work, and the wastes are piled near homesteads. Alternatively, the residues, along with the standing straws left for post-grazing grazing, are left on the threshing site and devoured by animals (Daniel, 1988). At beef farms in the E.U.'s central highlands, there is a strong trend toward improving crop waste use by supplementing with molasses and/or urea; and at some farmer cooperatives, cull straw-based diets are utilized to feed cows and aged oxen (Daniel, 1988).

2.5. Improved forage production and development in Ethiopia

Despite insignificant output of better pasture and forages, dairy production has increased in several viable areas of the country as a result of development measures supporting intensification and farmers' desire to intensify. Natural grazing and browse, crop leftovers, improved pasture, fodder crops, and agro-industrial by-products are the main sources of animal feed in Ethiopia. As a result of growing human demand and agricultural intensity on coastline resources, grazing pastures are deteriorating. Crop residues are also low-quality feed sources that do not meet the nutritional needs of animals. Furthermore, the costs of industrial by-products are out of reach for small-scale dairy farmers. Producing better forages can assist dairy farmers in overcoming current feed shortages in a number of AEZs. Boosting feed supply is possible if backyard forage production, under-sowing, over-sowing, and generating enhanced pasture and forages are widely adopted in dairy systems where feed shortage is a concern (Alemayehu, 2006).

Several forages have been studied in several AEZs during the last few decades, and significant efforts have been undertaken to assess the adaptability of these crops under varying agro-ecological circumstances. As a result, a large variety of valuable forages for various zones have been developed. Forage crops that have been improved are often produced to feed cows (Alemayehu, 2006). The spontaneous adoption of improved pasture and forages has been limited due to land scarcity and crop-dominated farming systems. However, while creating forage development strategies, there are several methods for improved fodder production that should be explored (Alemayehu, 2002; 2006). To begin with, there is a huge potential for pasture and forage crops to be integrated into the present farming system. Forage crops can only be produced in sufficient amounts if livestock and cropping systems are linked, due to rising pressure on land resources from increasing populations and greater cropping intensity (Alemayehu, 2002).

Agroforestry, intercropping, and alley farming are all examples of ways to integrate livestock and cropping systems. One of the simplest methods for highland farmers to use land successfully is to incorporate pasture and forages into the farming system (Alemayehu, 2006). Second, in addition to increased yield and nutritional value,

cultivated pastures have a longer productive season, which allows dairy and fattening industry to develop and utilize pasture and forage on a larger scale (Alemayehu, 2006). Third, in addition to supplying feed, fodder plants and shrubs help to improve soil fertility, reduce wear, and provide firewood and timber. These legumes are well adapted to this edaphic and grazing environment, will be easily integrated into farming systems, will preserve their feeding value throughout the season, and will show excellent performance in the country's higher potential areas (Alemayehu, 2006).

Fourth, irrigation-based forage production, which takes advantage of the country's vast irrigation potential, could be a good opportunity for dairy farmers in irrigation-rich areas. Small-scale traditional irrigation has been practiced for many years throughout the highlands; small streams are seasonally diverted for limited season cropping. This could be a good time to plant off-season pasture and fodder crops. Medium- and large-scale schemes, which are typically found in cash crop valleys, are much more modern. Within the valley, there is some irrigated pasture growing lucerne/Rhodes combination for commercial fattening and farming. The potential of irrigated forage remains untapped, and there's still a good chance of establishing seasonal and long-term irrigated pastures and forages (Alemayehu, 2006). Farmers who employ a cropping rotation or have enough area will plant short-term fodder crops. These crops are typically reliably introduced across a wide range of sites, although they are best suited to farmers that rely on dairy production for a living. Annual leguminous species combined with cereals generate the most effective quantity and quality of fodder in highland areas, but in moderate altitude areas, annual leguminous species combined with cereals produce the most effective quantity and quality of fodder. Whereas in moderate altitude and lowland areas, annual legume forages maximize forage production. Annual forage crops do not connect livestock and agricultural systems, hence Ethiopian farmers are switching to permanent forage production options. Fallow reduction tactics with leguminous fodder crops are appropriate in these areas. Oats and vetch have performed well over a wide range of agro-ecological zones, with oats demonstrating a high tolerance for low fertility and poor drainage.

In Ethiopia, lablab is quite productive in lowland areas and competes well with weeds, but alfalfa cannot resist rainy conditions (Alemayehu, 2002). Forage and pasture development initiatives, as well as forages, are widely encouraged in the crop–livestock system, traditional grazing regions, and around homesteads, as well as within soil and conservation structures, and under crops and forestry (Alemayehu, 2006). The FLDP's policies in Ethiopia derived from lessons learned in other nations such as Australia, Southeast Asia, New Zealand, and the Caribbean, as well as recognition of the importance of matching forage systems to AEZs (Alemayehu, 2002).

2.6. Oats-vetch production in Ethiopia

It is proposed that the use of enhanced forage legumes integrated into existing agricultural systems as a feasible small-scale dairy farmer's on-farm alternative to purchased protein or energy-rich concentrates is a valuable economic alternative to purchased protein or energy-rich concentrates. One such fodder legume is vetch (*Vicia dasycarpa*). When compared to other crops, vetch has a high concentration of CP (19.9%), in vitro organic matter digestibility (IVOMD) (68.7%), and dry matter (DM) content yield (4–6 t/ha) (Assefa, 1999; Sileshi et al, 1995). Furthermore, it has been adapted and is commonly used in the cold tropical highlands (Assefa, 1999). Vetch in a lactating cow's daily ration, on the other hand, can only be justified if the amount of inclusion is biologically ideal (Assefa, 1999). In Ethiopia's highlands, oats (*Avena sativa*) are a well-adapted fodder crop that may be farmed for a long time (Assefa, 1999). Smallholder farmers who own crossbred dairy cows and certain peri-urban cow producers produce it (Assefa, 1999).

In some sections of the country's central highlands, its grain is also a staple of parents' diets (Hiwot, 1985). Because of its short-term producing qualities, crop rotation convenience, and fodder conservation properties, oats, as an annual forage crop, is highly helpful for integration into the prevailing mixed crop-livestock farming systems of the highlands (Assefa, 1999). Because its husbandry is comparable to that of other grains like barley and wheat, farmers may easily cultivate it (Feyissa, 2009). It can be used for grazing, cut-and-carry, and green production feeding, as well as hay, silage, and as a source of cash through the sale of the green material (Feyissa, 2009). Vetch (*Vicia sativa*)

can be intercropped with oats to create top-of-the-line fodder. Vetch is a nitrogen-fixing leguminous fodder that has the potential to improve both the quality of the fodder and the nitrogen status of the soil where it is grown. Household resource endowment, particularly land and labour, as well as market integration and crop intensification, have been proven to be major drivers in encouraging the adoption of an oats-vetch forage system in previous studies (Feyissa, 2009). However, there is insufficient proof of the economic viability of cultivated fodder production to persuade farmers that it is desirable to participate in fodder production (Feyissa, 2009). Vetches are important feed legumes in the central highlands, where grain is typically sown or grown as a break crop. It's tasty and high in protein, and once vetch plants reach seed setting stage, there's no need to seed again the following season because the seed can stay in the soil for at least two years. Vetches are well adapted to altitudes between 1800 and 2500 meters (masl), with an annual rainfall of about 700 mm (Seyoum and Cajuste, 1980). *Vicia dasycarpa*, *Vicia atropurpurea*, trefoil, and local *Trifolium* species were found to be important for increasing the feed quality of cereal straw at altitudes above 1800 masl (Hiwet and Lulseged, 1985). Butterworth and Mosi (1986) discovered that adding 30 percent *Desmodium* hay to residues of teff, oats, wheat, and maize straw boosted dry matter yields by 10% and sheep feed intake by 20-30% compared to the straw alone.

2.7. Effect of fodder on animal performance

Green feed, as one of the major elements affecting dairy output, with the other factors remaining constant, has a good impact on dairy production performance and body condition (Atsede Teklay, 2017). During the dry and wet seasons, non-adopters' milk yields were estimated to be 1.3 litres/day/cow and 2.4 litres/day/cow, respectively. In the dry season, forage adopters' milk outputs were predicted to be 3 liters/day/cow, and in the rainy season, 6 liters/day/cow (wet season). This shows that fodder adopters produce higher milk yields than non-adopters with the same cow breed, which could be due to a variety of variables, including the usage of improved fodder. The study area's common milk output was comparable to Yayeh et al. (2014), who found an average daily milk yield of 1.500.68 litres and an average lactation length of 8.87 1.55 months for local breed cows in their study. Days open can be at experience when animals consume on quality feeds during the wet season, according to the responses. When there is a dearth of

green feed at this time of year, the days open are longer and the calving interval is longer (Duguma et al, 2012). Feed shortages, silent estrus, and heat sensing challenges, according to the same scientists, may have all had a role in the extended days open. Similarly, poor heat detection, fewer accesses to AI services, and poor feeding practices could all contribute to a longer calving interval (Gebremichael, 2015).

2.8. Improved forage production in the context of Debre Libanos district

In Debre Libanos district, the livestock feeding system have similar trend like that of the region. Most of the small holder farmers in the district feed their animal's natural pasture and crop residues with less nutritional value. Due to this the production and productivity livestock is very low. This initiates stake holders to do much in the adoption and implementation of improved forage varieties. Different governmental and non-governmental organization has been engaged in development and promotion of different improved forage technologies in Ethiopia in general and in Debre Libanos district in particular. So this paper assesses improved forage technologies adoption and impact small holder dairy productivity.

The major livestock reared by households in the district were local and improved cattle, sheep, equine (donkey, horse and mule), improved and local poultry, local and improved beehives and goats. The major improved forage crops adopted in the district were Oat, vetch, Elephant grass, Sesbania, Rhodes grass, Tree Lucerne, Desho grass, Alfalfa and Fodder beet. This study tried to assess the factors responsible for the probability of adoption and intensity of utilization of improved forage technologies and the impact of households' income. Adopters were households who are cultivating and continue using improved forage for feeding their livestock in addition to other common animal feeds. Non-adopters were households that are not engaged in cultivation of improved forage and/or using only natural pasture, crop residue and other feeds for their livestock feed.

2.9. Empirical literature review

2.9.1. Determinants of adoption of forage technologies

Despite many years of effort on forage research and extension activities, the adoption and consumption of improved forages by farmers are very low (Mekonnen Y and Ali S (2013). owing to many reasons of which land shortage, lack of improved forage

seed/planting material and poor extension services were the most restrictive influences in Doyogena District of Kembata-Tembaro Zone, Southern Ethiopia (Bassa et al, 2006). The outcome is in agreement with the result of (Salo et al, 20017). From Anelemo woreda in which farmers do not accept improved forage technology due to land shortage, shortage of forage seed, lack of awareness and poor extension services. Similar to this result, (Mekete B, 2018). also reported that the main reason for not establishing improved forage was shortage of land on which to graze livestock or produce forage, absence of nearby adaptable improved forage seeds/seedling, insufficient extension provision service supplies, shortage of human labor targeted in the production and use of improved forages, lack of access to credit, occurrence of forage pests, weeds invasions, deficiency of fertilizers, scarcity of animal labor and forages plant diseases. According to (Assefa et al,2015) shortage of land, lack of awareness and the increased price of forage seed were the highest limitations that delay the adoption of improved forage in Shashogo Woreda of Hadiya zone.

Likewise, round-trip distance to Development Agent's (DA) office; access to extension services; training attended; number of adult males in family; nitrogen fertilizer used; number of equines owned; and cash income had a negative effect on adoption of improved forages(Abebe et al,2018). The study in wolaita zone, southern nations and nationalities peoples state of Ethiopia conducted by (Bashe et al,2018) showed that family size, farm size, topography and distance from farmers' home (residence) to farmers training centers were the main factors which meaningfully affect the adoption of improved forage technologies. Capacity building and extension system on forage technology packages is very weak (Bassa et al, 2016). Land shortage is the most dangerous problem for adoption of improved forage production (Mekete B, 2018) and (Atsede T (2017). Similar problems were reported in diverse parts of the nation as most limiting factors to encourage forage production. For information and knowledge gap on improved forages (Endalew et al, 2016) and Shimelis M and Temesgen a 2016). Few farmers assign land for forage farming which might be because of lack of awareness (Yadessa et al, 2016) and Shiferaw et al, 2018). Access to training had an extremely important and positive effect on forage adoption. It is not amazing that increasing the knowledge of farmers concerning newly released and adapted forage technologies, and

viewing them in what way to use them, improves the probabilities of forage adoption (Abebe et al, 2018). However, according to the outcomes of (Assefa et al. 2015). Around 37.5 % of the questioned households have access to training on improved forage development, its use and utilization whereas the rest of the respondents did not get the chance of training. So that it is likely to encourage improved forage adoption through awareness formation of farmers with large land size (Bashe et al, 2018). Poor extension services were other causes for adoption of improved forages which desires to be improved (Assefa et al, 2015 and Melese et al, 2018).

Poor extension services were other causes for adoption of improved forages which desires to be improved (Assefa et al, 2015 and Melese et al, 2018). Extension service is vital to increase adoption of forage technology but study result by (Salo et al, 20017). In Anelemo Woreda, Hadiya zone specifies that only 51% of respondents have access to extension service. This can contribute to low delivery of information to farmers. The result is in agreement with the finding of (Abebe et al, 2018). Exposed that better access to extension services is linked definitely with forage adoption. The positive association among extension services and forage adoption shows that increasing access to extension services increases adoption among households, strengthening the result of Beshir H (2014). That agricultural extension services are a main source of information concerning forage technologies for farmers. If the household has access to extension services, the chance of adoption of improved forage varieties enhance by 42% (Abebe et al, 2018). The tendency of improved forage utilization calls for actual extension service to encourage farmers to produce improved forage species (Assefa et al, 2015). Farmers closer to Development Agents office have better access to information on improved practices and other extension services as well as to supply of forage seeds (Abebe et al, 2018). Free grazing is the one bottleneck of the farmers in the adoption and utilization of improved forage crops; especially after crop harvest (Endalew et al, 2016). This can concur with the report of (Ahmed et al,2010).in the central highland parts of Ethiopia. Free grazing has become a challenge for the survival of forage plants (Shimelis M and Temesgen A, 2016). But the timely decreasing rate and increasing knowledge of farmers to free grazing can be promising to the future (Endalew et al, 2016). Legumes can have

poor persistence (particularly under continuous grazing) and low tolerance to poorly drained soils and low soil fertility (Kebede et al, 2016).

Poor coordination among research organizations, governmental and non-government organizations and farmers is one constraint for the poor distribution, production and utilization of the forage technology by the farmers. Owing to lack of good coordination there is loose link among research and extension services. Researchers did not get sufficient response which might have aided them to design their research actions based on the interest of farmers. So, most of the time, plans are proposed based on locally perceived problems (Endalew et al, 2016). (Kebede et al, 2016). Also showed that linking forage technologies with a range of value chain issues in livestock enterprises was found to be indispensable for positive adoption of forage technologies by farmers.

The nonexistence of amount and quality seed and seedling material confines the huge development of improved pasture and forage growth especially around the dairy farming and fattening areas (Mengistu et al, 2017). which is in agreement with statement of diverse authors in Ethiopia (Bassa et al ,2016). Moreover, the shortage of input (seeds/seedlings) is the factor to adoption of improved forages which is in contour with report of (Yadessa et al, 2016) in the Meta-Robi district, west Shewa zone, Oromia regional state of Ethiopia. The study conducted in Northeast Highlands of Ethiopia was discovered that only 1.3% of the total cultivated land is enclosed with improved forage seeds (Beshir H (2013). The higher number of farmers with forage planting material scarcity in some places might be related with the limited forage seed source. Hence, making available quality seed or vegetative planting material appropriate to a given agro-ecology and farmers' need for livestock production is crucial (Bassa et al, 2016). Besides, land shortage and input shortage, lack of money to cover the higher prices of developing improved forage species was raised as reason by the farmers (Endalew et al, 2016) and (Assefa et al, 2015). High price of forage seed production by government agencies are factors of forage production (Mengistu et al, 2017). Cash income of the families showed a positive connection with forage adoption, as families with high cash income showed higher chance of being adopters. A possible clarification for the positive effect of cash income on forage adoption is that families with additional cash can purchase feed from

the market place, allowing extra land to be allocated to forage crop production rather than food crops (Abebe et al, 2018). One of the reasons for inadequate forage growth is the limited financial incentives or the return is not immediate since the production of improved forage crops did not link with productive animals Endalew et al, 2016)

Lack of knowledge or awareness is one of the main constraints identified by (Assefa et al, 2015). As a problem with improved forage adoption. Farmers' awareness for improved forages and forage seed production practices is very low (Bassa et al, 2016). They don't use efficiently their land in the borders, terraces and homestead for the production of forages owing to limited marketing (Emuru D (2015). The existing forage seed market is very much dispersed with weak linkages among suppliers and buyers, and an overall nonexistence of market information (Tekalign E (2014). There is no direct marketing connection amid traders and farmers. There are also no forage seed traders. Low forage seed production, poor quality forage seed, poor seed management (handling and storage), and changeable demand for forage seed, lack of quality control system and lack of working capital are some of the challenges for forage seed marketing (Bassa et al ,2016). This is an unceasing flexible which absolutely and meaningfully affects chance of adoption of improved forage technologies (Bashe et al,2018).The fact that number of adult males in the family had a positive effect on the probability of adoption of improved forages was not amazing as improved practices are labor intensive and households with more family labor are in a better position to adopt forage technologies than households with fewer family labor units (Abebe et al, 2018).Similar findings have been reported by (Beshir H (2014).

2.10. Literature gap

From the above theoretical and empirical literature reviewed, it will be understood that, most of the study focused on either on identifying the determining factors of adoption of improved forage technology. But this study has tried to look at both factors that affect the adoption of improved forage technology, to what extent is that the adoption of the household, likewise as its implication (impact) on the agricultural household livelihoods and dairy productivity. It's intended to contribute the knowledge gap regarding to dairy

productivity, rural household livelihood change and improved forage technology adoption.

2.11. Conceptual framework of the study

The adoption and diffusion of agricultural technology varies a lot from place to place. In general, the variations in adoption patterns proceed from the presence of disparity in agro ecology, institutional and social factors. Moreover, farmers' adoption behavior, especially in low-income countries, is influenced by a special set of socio-economic, demographic, technical, institutional and biophysical factors. Farmer's decision to adopt new technologies can even be influenced by factors associated with their objectives and constraints. These factors include farmers' resource endowments as measured by size of family labors, farm size and livestock ownership, farmers' socio-economic circumstance (age, and formal education) and institutional web available for inputs CIMMIYT (1993). In many developing countries, it's become apparent that generating new technology alone has not provided solution to assist poor farmers increase agricultural productivity and achieve higher standards of living. In spite of the efforts of National and International development organizations, the matter of technology adoption and hence low agricultural productivity remains a serious concern CIMMIYT (1993).

During this study efforts were made to work out adoption, intensity of adoption and impact of improved forage per farmers' personal characteristics, accessibilities to different services like credit, extension, and psychological factors. The framework is constructed using own experiences and reading of varied literatures associated with forage technology adoption during at different time and place. The conceptual framework of this study is discussed and as revealed (see figure-1) below supported the idea that forage technology adoption by small scale farmers are having an excellent role in improving forage production and productivity as well as farm household income. The linkage between adoption of promoted improved forage technologies, its impact on dairy production and farm household income and variables assumed to affect households probability to adopt and participation in forage technologies. It assumed that influenced by personal and demographic, economic, institutional, and social-participation related factors. Conceptual framework model of the study is presented as follows:-

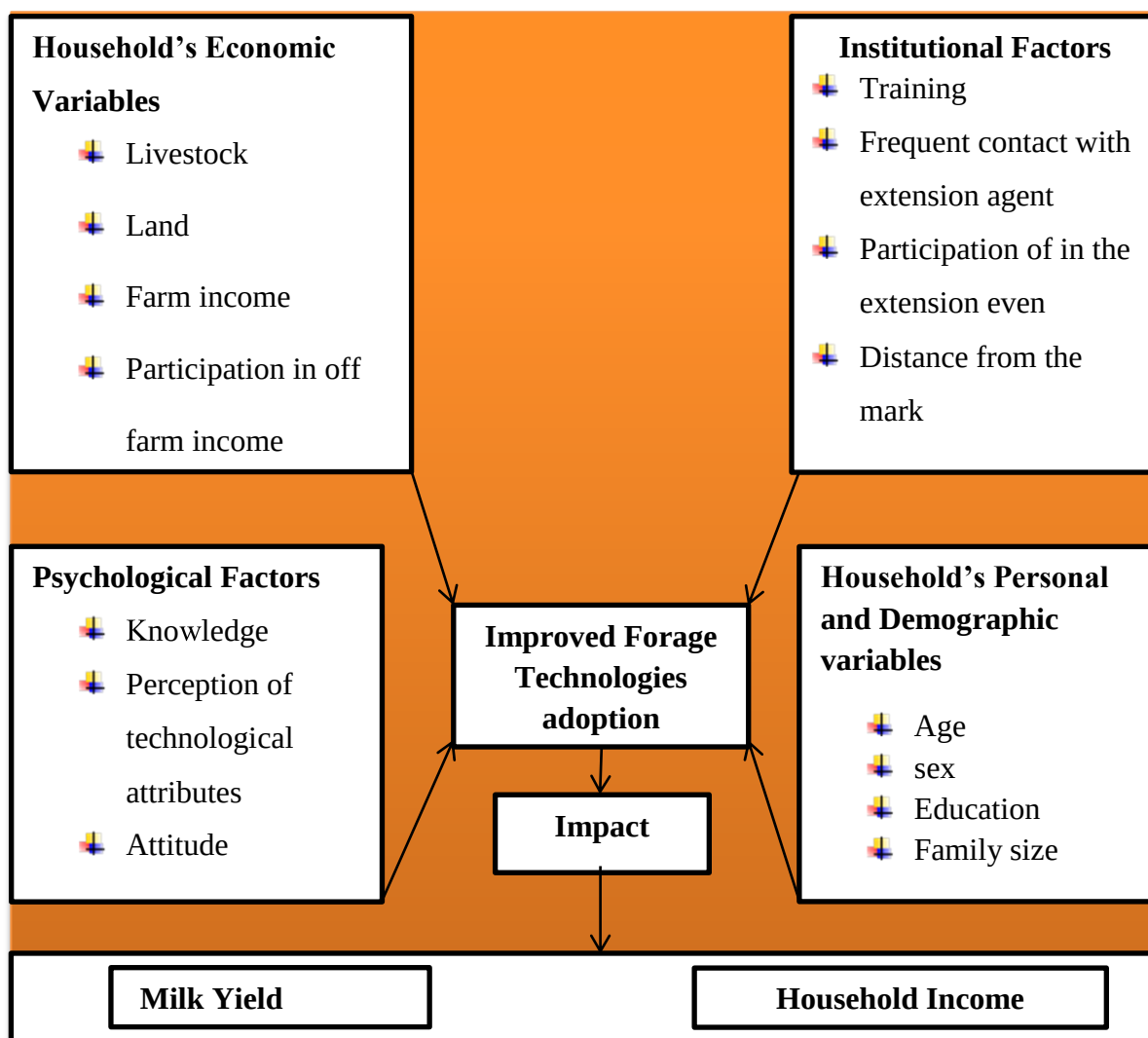


Figure 1: Conceptual framework of improved forage technology adoption& its impact on smallholder dairy productivity and household income

Source: Own developed based on the literature and experiences

CHAPTER THREE: RESEARCH METHODS AND MATERIALS

Before proceeding in to data presentation and data analysis, this chapter describes the study areas, research methods, and model specification of the study.

3.1. Description of the study area

3.1.1. Location and physiographic information

The study was conducted in three selected kebeles of Debre Libanose woreda, North Shewa Zone of Oromia Regional state. Debre Libanose is one in all the thirteen Woredas of North Shewa. Geographically the woreda is found between latitudes of 09°43' 30" N longitudes and 38°51'0"E latitudes. It's located approximately 104 kilometers from capital of Ethiopia and 14 kilometers from Fiche town, the capital of the North Shewa Zone. (Debre Libanose District communication Bureau, 1999).

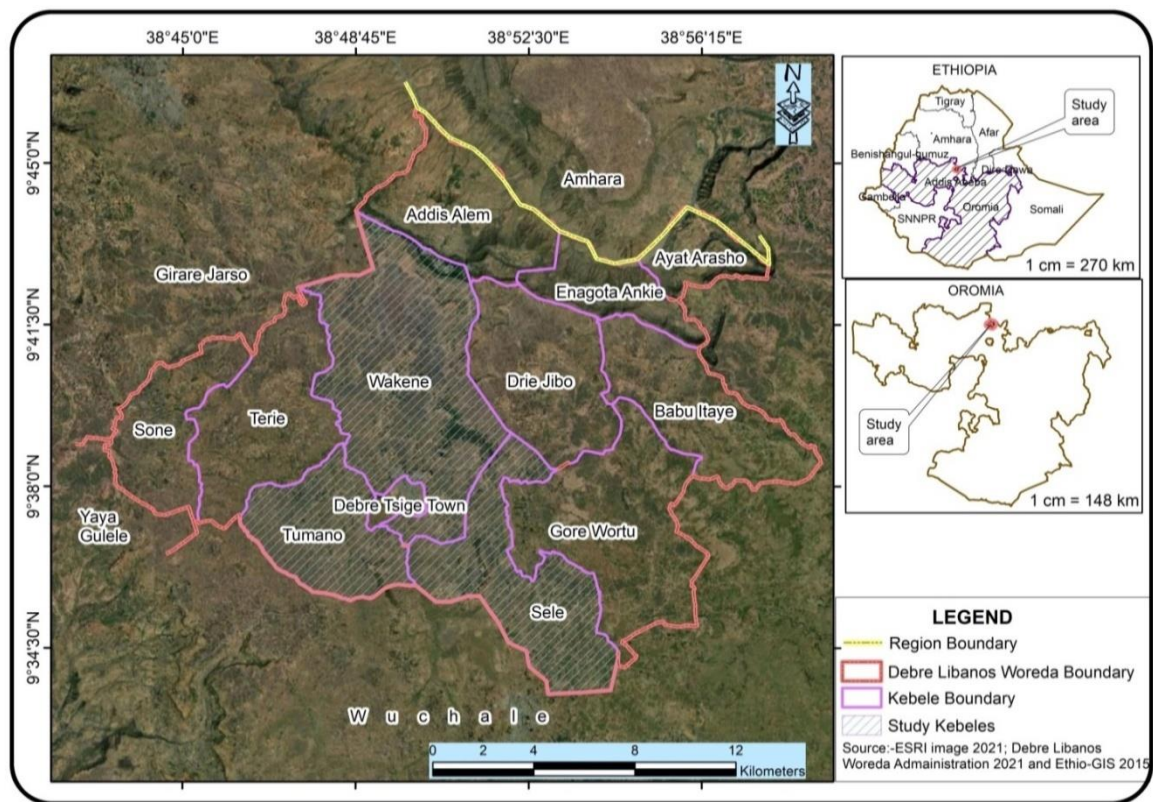


Figure 2: Map of the study area

(Source: ESRI image 2021; Debre Libanos woreda Administration 2021 and Ethio –GIS 2015)

3.1.2. Climate and vegetation

The study area is characterized by heterogeneous landscape, flora, fauna and habitat types. The realm has extremely steep slopes leading up to a strip of plateau. It's bi-modal rainfall pattern starting from 800 mm to 1200 mm with five months of rain (May-September). The season is from December to March. The annual average maximum and minimum temperature of the study area is 23⁰c and 15⁰c, respectively (Tittarelli, 1990). Based on the standard classification, the woreda is split into three agro-ecological zones, locally called Dega, (60 %), Woynadega (30 %) and Kolla (10%) which implies highland, midland and lowland respectively. there's wide variation in altitude, temperature, and rainfall across the agro-ecological zones. it's also characterized by diverse landscape that ranges from steep slope, plateau to mountainous and gorges dissected by rivers. This makes the world to own good opportunity for the inhabitants to involve in various agricultural productions (April, 2017/ North Shewa Zone of Oromia regional state Culture Tourism Office).

3.1.3. Human population

According to the population and housing census by CSA (2007), the entire population of the woreda is 62,830. The rural population is 49,776 (79.2%) and therefore the urban population is 13,054 (20.8%). This shows the bulk of the population lives within the rural areas, rest on crop farming. An oversized number of individuals are settled, and also the population is more evenly distributed on the plateau than within the rugged areas where unevenly distributed settlements are common. (April, 2017/North Shewa Zone Culture Tourism Office).

3.1.4. Livestock population

There are about 81,796 head of cattle, 8480 goats, 24923 sheep, 10200 equines, and 80,305 poultry within the districts of Debre Libanose woreda where the town is Debre Tsige. All of those livestock species are reared mainly by smallholder farmers under intensive, semi intensive, and extensive production system. The district is divided into 11 administrative PAs and 15,000 liters of milk is collected from Debre Tsige town (DWLFO, 2014).

3.1.5. Land use and land cover

The total area of the district is about 27,500 of which 23,960 (87.1%), 2,547 (9.3%), 833 (3.0%) and 166 (0.6%) hectares are agriculture, pastureland, forest land and other use, respectively. (April, 2017/North Shewa Zone Culture Tourism Office).

3.1.6. Economic profile

The main economic activities of those study areas are mixed crop-livestock farming, which been practiced by the smallholder farmers. Agriculture share is 54.3%, pastoral farming 36%, hand work product 5% and other accounts 0.7% respectively. (April, 2017/ North Shewa Zone of Oromia regional state Culture Tourism Office). The world is taken into account as high potential crop-livestock zones where dairy activities play a major role within the livelihood of farmers within the area. Considering the potential of the realm and also the economic significance of dairy production to the area people, there are repeated efforts by governmental and nongovernmental aid organizations to boost the dairy productivity. In addition, compared to other rural areas, this area has better access to livestock development services (both governmental and non-governmental) and milk markets. Thanks to the above mentioned reasons and therefore the economic capacity of the peasant's small-holder dairy production with crossbred milk cow may be a common practice within the area (April, 2017/ North Shewa Zone of Oromia regional state Culture Tourism Office).

3.1.7. Soil type

The soil texture sorts of Debre Libanose district are composed of clay soil, silt soil and sandy soil (10%). The predominant soil texture of the district is silt soil which has 57% coverage followed by clay soil (33%) and sandy (10%) (April, 2017/ North Shewa Zone of Oromia regional state Culture Tourism Office).

3.2. Research design

This study used a cross sectional survey design that comprised both adopter and non-adopter, i.e., the treatment group (technology user households) and the control groups (non-user households) were analyzed. Based on the objectives of the study, quantitative data was collected and analytic result complemented by qualitative data in order to make the result sound.

3.3. Sampling design

The sampling design employed in this study was simple random sampling and probability proportional to sample size in order to have a reasonable sample size. The sampling design for the household survey followed the multistage stratified random sampling technique.

3.4. Sampling technique and sample size determination

Debre Libanose is one in all the thirteen Woredas of North Shewa. According to information received from the administration office of the woreda, the sampling unit in this study was a (household who cultivates improved forage crops at Kebele level, district agricultural experts, researchers and other relevant actors). The sampling size and sample household selection were done on representative approach. In general, a multi-stage sampling procedure was employed in this specific study. In the first stage, the study area was selected from the North Shewa region purposively based on its improved forage production potential and number of dairy technology availability and practiced in the area. At the second stage, three kebeles were randomly selected from the woreda among potential improved forage producer kebeles in collaboration with Kebele leaders and development agents of the respective kebeles. Thirdly, the respondent households were divided into two categories within the selected kebeles: forage technology adopters and non-adopters. Adopters were households who are cultivating and continue using improved forage for feeding their livestock in addition to other common animal feeds. Non-adopters were households that are not engaged in cultivation of improved forage and/or using only natural pasture, crop residue and other feeds for their livestock feed. The households in each of the two categories were selected at random. These sample kebeles were Sele, Tumano and Wakene. At the end, simple random sampling was applied to select the sample household farmers. A total of 319 samples were selected and out of which 128 are adopters and 191 non-adopters farm households participated in the process.

The probability sampling technique was employed to generate the desired sample size of the study sites. The required sample size was determined by using Kothari's (2004) sample size determination formula where the exact number of households in each *Kebele*

or the sampling frame is known. It was used to provide more accurate and estimate samples selected in the study area. A simplified formula provided by Kothari's (2004) to determine the required sample size at 95% confidence level, degree of variability=0.5 and level of precision= 5% (0.05).

The sample of the respondent households was selected representative way of selection with $\pm 5\%$ precision level and 95% confidence interval. The main reason was to get enough number of matches that enabled to give generation on research objectives. To determine respective samples from three kebeles for each stratum, selected by using probability proportional to size of population. Finally, representative sample for each stratum was selected by using probability proportional to size was applied across each category. The selected households were drawn from individual KAs registers which act as a sampling frame.

$$n = \frac{Z^2 pq}{d^2} \quad [1]$$

Where,

n = the desired sample size;

Z= Standard normal variable at the required level of confidence;

p= the proportion in the target population estimated to have characteristic being measured;

d= the level of tactical significance set

q=1-p

Table 1: Distribution of sample respondent probability proportional to size by KA's.

S/N	Kebele's name	Total HH in each KA's	Adopter Households		Non-adopter households		Total sample size
			Total	Sample	Total	Sample	
1	Sele	420	120	30	300	44	71
2	Tumano	480	150	37	330	52	81
3	Wakene	995	285	61	710	95	167
Total		1895	128		191		319

Source: Computed based on data obtained from Debre Libanose *woreda* administration

3.5. Data types, source and collection techniques

In this study, both qualitative and quantitative data type of primary and secondary source were utilized. Secondary data was collected through reviewing published and unpublished documents and internet as well. This information was used to evaluate the existing works and compare the study with the previous studies. Primary data was collected using two-survey procedures, formal and informal surveys.

3.5.1. Informal survey

In informal survey; key informant interview, focus group discussion and transect walk were done using respondent and development agents. These were the first activities, for rapid appraisal of the forage production system, to develop and/or refine workable hypothesis and to develop a structure questionnaire for formal survey.

Key informant interview: According to Elder (2009), KI is individually interviewed on those people who are further enriched the area and can give clear information on major issues of the study. Therefore, in the study, key informants were identified: development agent, Kebele leaders, head of district livestock resource promotion agency and head of district agriculture office. A total of 30 key informant interviews were conducted (15 from local leaders and 15 from experts) interviewed on the overall information on the existing trend of improved forage development. In addition, the socioeconomic status of the communities, livelihood activities of the communities and the current difference observed between the adopters and non-adopters were assessed.

Focus group discussion: The selection of FGD strictly followed purposive sampling techniques, where a group of people having similar concerns and experience regarding a subject is encouraged to participate. FGD was composed of 8-10 individuals. In each KA, two FGDs were organized: one from the adopter and the other from the non-adopter. The discussion was facilitated by the researcher so that the group members enable to talk freely during the discussion. The FGDs were made to clarify the subjective issues and to benefit from the group interactions in getting further insight on the effect of improved forage development on smallholder farmers' livelihood improvement and dairy production.

3.5.2. Formal survey

The household surveys covered personal data, household resources, production, consumption, income, and issues related to improved forage development practice. In the process of household survey, five stages were involved: questionnaires preparation, translation of the questionnaire to the local language, recruitment and training of Enumerators, the questionnaire was pretested on households from each stratum and feedback were obtained before actual data collection and finally the administration of actual fieldwork was carried out. Data was collected using a structured questionnaire by applying face-to-face interview with household heads.

3.6. Ethical considerations

The researcher makes every effort to avoid unnecessary biases and ensures the objective analysis and interpretation of the collected data. Therefore, the researcher gave due respect to the rights, needs, values and desires of the respondents in the course of conducting this study. Moreover, the researcher assures that the information obtained from the respondents used for research purpose only. Finally, anonymity and confidentiality of the respondents respected.

3.7. Method of data analysis

For this particular study, both qualitative and quantitative research, data analysis approaches were employed. Various studies have been conducted on the influence of socioeconomic characteristics on the willingness of farmers to adopt improved forage technology. The rural household decision to adopt or reject new technologies was influenced by the combined effects of factors related to different constraints. In this study the hypotheses will be, “Does adoption of improved forage technologies have an impact on the smallholder dairy production or not?”

The quantitative data analysis involved descriptive statistics (mean, standard deviation percentage, and frequency distribution). Inferential statistics (chi-square test (for categorical variables and t-test (for continuous variables) were used to see the difference between adopter and non-adopter households across dummy and continuous explanatory variables respectively. In addition to this, econometric analyses (“STATA Version 14” software.) were applied. In this regard, Tobit model, binary logistic regression model and

Propensity Score Matching (PSM) econometric model were used for this study. The model helped to explain the link between the end result variable and a group of explanatory variables additionally because the impacts of forage technologies on the smallholder dairy productivity and household livelihoods respectively. The qualitative data that obtained from FGD discussion and key informant interview were simply narrated to substantiate the quantitative findings.

3.8. Statistical analysis tools and empirical models specification

It was applied for summary of statistics such as, percentage, table of frequency distribution, mean and standard deviations. Inferential statistics such as chi-square and t-test accustomed to see the difference between adopter and non-adopter households across dummy and continuous explanatory variables respectively.

Logit econometric model

A logit model was used as one of the analysis tool for this study. The model was chosen since the dependent variable (forage adoption) is a dichotomous (yes/no) variable, and the majority of the independent factors are also categorical. The model helped to estimate the relationship between the dependent and independent variables. Binary logit was preferred to others because it gives standard result for discrete choice estimation. In order to identify the factors influencing adoption of improved technology, and to estimate the probability of adoption between the two groups (Gujarati, 2004).

$$\text{Logit}(p_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_n X_{ni} + e_i \quad [2]$$

Where,

P_i = a dichotomous dependent variable (1 if technology adoption takes place, 0 otherwise)

X = is the i^{th} value of the independent variable

β_i = parameters to be estimated

e_i = is the “error” variability of the dependent variable not explained by independent variable term

n = is the number of independent variables.

Odds ratio is the way to present the probability of an event. The adoption of improved forage technology indicates the probability the household to adopt improved forage technology or not.

$$odds = \frac{p_i}{1 - p_i} \quad [3]$$

In order to know the probability of technology adoption for each farm household, the predictable probability was calculated as suggested by Rosenbaum and Rubin (1985); Baker (2000); Walle (2001). According to them, the treatment groups were compared with control groups using Logistic regression.

Similarly, in this study, the marginal effect of explanatory variables was estimated as follows:

1. The dependent variable y is modeled as follows:

$$y = E(y/x) + \varepsilon \quad [4]$$

Where, $E(y/x)$ is the conditional mean function, x is the vector explanatory variable and ε is the error term.

2. The marginal effect is defined as the instantaneous effects in which a change in one explanatory variable predicts the likelihood of y when the other covariant remains constant.

$$\partial E[x|y] / \partial X = f(\beta' x) \beta, \quad [5]$$

Tobit econometric model

For this study, the Tobit model employed to analyze factors affecting the adoption and its intensity of use of improved forage technologies. The model measures not only the probability that farmers to adopt the new practice but also the intensity of use once they adopted the technologies. Therefore, the application of Tobit model provides the needed information on probability and intensity of adoption of technologies. Thus, it depends on the intensity to use of the technologies (Maddala, 1997).

Estimation of Tobit model

The econometric model was applied in this study to analyze factor affecting adoption and intensity of adoption of improved forage technologies. In addition to this the model also assisted to conduct the adoption decision on whether to adopt and how much to adopt. As a result, a direct application of the Tobit estimator offers sufficient information on the likelihood and intensity of improved forage technology uptake.

Tobit model for the continuous variable adoption index

$$\begin{aligned} AI_i^* &= B_0 + B_i X_i + U_i \\ AI_i &= AI_i^* \text{ if } B_0 + B_i X_i + U_i > 0 \\ &= 0, \text{ if } B_0 + B_i X_i + U_i \leq 0 \end{aligned} \quad [6]$$

Where,

AI_i = adoption intensity of improve forage technologies of i^{th} farmer measured by dividing area under improved forage planting for total area allocated for improved forage production.

AI^* = the latent variable and the solution to utility maximization problem of intensity of adoption subject to a set of constraints per household and conditional on being above a certain limit,

X_i = Vector of factors affecting adoption and intensity of use of improved forage technology,

B_i = Vector of unknown parameters, and

U_i = is the error term normally distributed with mean 0 and variance σ^2 .

To estimate the effect of changing an explanatory variable, compute the derivate of the estimated Tobit model. As a result, Maddala (1997) offered the following strategies for decomposing the effects of explanatory variables into adoption and intensity effects (Johnston and Dinardo, 1997). It has an impact on the conditional mean of AI in the positive half of the distribution, as well as the likelihood that the observable will fall apart of distribution. The marginal effect of explanatory variables was calculated in this study as follows:

1. The marginal effect of explanatory variable on the expected value of dependent variable is

$$\frac{\partial(AI_i)}{\partial X_i} = F(Z)\beta_i \quad [7]$$

2. The change in the probability of adopting a technology as independent variable X_i change is

$$\frac{\partial F(Z)}{\partial X_i} = F(Z)\frac{\beta_i}{\sigma} \quad [8]$$

3. The change in the intensity of adoption with respect to a change in an explanatory variable among adopters is

$$\frac{\partial E(Y_i / Y_i^* > 0)}{\partial X_i} = \beta_i \left[1 - Z \frac{f(Z)}{F(Z)} - \left(\frac{f(Z)}{F(Z)} \right)^2 \right] \quad [9]$$

Where, $F(z)$ is the cumulative normal distribution of Z , $f(z)$ is the value of derivative of the normal curve at a given point and Z is the z-score for the area under normal curve β is a vector of Tobit maximum likelihood estimate and σ is the standard error of the error term.

To check the collinearity of variables, there are two measures that are often suggested to test the existence multicollinearity of the variables. In this study, the Variance Inflation Factor (VIF) was used to examine the association between explanatory variables and the contingency for dummy variables. Variance inflation factor was used to test multicollinearity problem for continuous and dummy variables.

Following (Gujarati 1995; Maddala 1992), VIF is calculated as:

$$VIF(X_j) = \left[\frac{1}{1 - R_j^2} \right] \quad [10]$$

X_j = the j th quantitative explanatory variable regressed on the other quantitative explanatory variables. R_j^2 = the coefficient of determination when the variable X_j regressed on the remaining explanatory variables. As a rule of thumb, if the VIF of a variable exceeds 10 that variable is said to be highly collinear and it can be concluded

that multicollinearity is a problem, if the values around 1, we are in good shape, and can proceed with our regression (Gujarati, 1995).

Propensity Score Matching (PSM)

It employed Propensity Score Matching (PSM) approaches that select, match, and compare forage producing households and without improved forage technologies with similar characteristics. This is used to measure the impact of forage technology adoption on smallholder dairy productivity and household livelihoods. Match treated (adopters) and untreated (non-adopters) observations on the estimated probability of being treated (propensity score). Allows not only for mean matching, but also for balancing the distribution of observed characteristics between treatment and control groups. It is used to match each adopter with an identical non-adopter and then measure the average difference in the outcome variable between the adopter and the non-adopter.

Estimation of propensity score

The first one is concerning the model used for the estimation of variable, and the second is about the variable to be included in the model. In this case application of logit model was used in estimating the logit model. Since this study had binary treatments adopter and non-adopter of improved forage technologies. The dependent variable was dummy variable (improved forage technology adopter in this case). Adopters took a value of one if the households adopt improved dairy technologies and zero otherwise (caliendo and kopeinig, 2008).

$$p_i = \frac{e^{Z_i}}{1 + e^{Z_i}} \quad [11]$$

Where,

Pi is the probability of adoption of improved forage technology

$$Z_i = \beta_0 + \sum \beta_i X_i + U_i \quad [12]$$

Where, β_0 = intercept, β_0 = Regression coefficient to be estimated, X_i = Variable, U_i = Disturbance term.

The probability that a household belongs to the non-adopter's group is:

$$1 - p_i = \frac{1}{1 + e^{Z_i}} \quad [13]$$

The odds ratio can be written as

$$\frac{p_i}{1-p_i} - \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i} \quad [14]$$

Therefore, to estimate average impact of improved forage technology adoption on dairy productivity and household livelihoods

$$E \left[Y_1 - Y_0 \mid D=1 \right] = E[Y_1 \mid D=1] - E[Y_0 \mid D=1] \quad [15]$$

Where, Y is yield per liter (say, in liter or in birr) and D takes the value 1 for adopters (treatment group) and 0 for non-adopters (control group). Thus, the outcome of interest is the average difference in Y_1 and Y_0 . However, since one farmer may only be in one condition at a time, this matching exercise tries to estimate only $E[Y_0 \mid D=1]$, which is the counterfactual or unobservable situation. At a time (either in the treatment group or the control group). In our case, this means, trying to estimate the impact of being an adopter on yield per liter for those farmers who are actually in the control group.

For experimental data in which the farmers are randomly assigned to the treatment and control groups, it would have been possible to estimate the average treatment effect (ATE) as:

$$ATE = E[Y_1 \mid D=1] - E[Y_0 \mid D=0] \quad [16]$$

However, this study is based solely on observational data and does not include any experimental data. And hence, instead of ATE, the issue of interest for this study is average treatment effect on the treated (ATT); based on Rosenbaum and Rubin (1983) to solve the selection bias by estimating the following equation:

$$E[Y_1 - Y_0 \mid Z, D=1] = E[Y_1 \mid Z, D=1] - E[Y_0 \mid Z, D=1] \quad [17]$$

Where, Z is a set of factors that influence a farmer's adoption status. If Z determines the likelihood of becoming an adopter, it is possible to create a control group of non-adaptors with Z values identical to adopters (the treatment group). As a result of equation (3), the Average Treatment Effect on the Treated (ATT) can be calculated as follows:

$$ATT = E[Y_1 - Y_0 | P(Z), D=1] - E[Y_0 | P(Z), D=0] \quad [18]$$

Where $P(Z)$ is the probability of selection conditional on Z or it is the propensity score (Pscore) which is: $P(Z) \equiv \Pr(D = 1 | Z)$.

As a result, the matching is done in two steps with STATA's `psmatch2`. First, the propensity scores (P-scores) are calculated using stata's "pscore" command. The Pscores are the conditional probabilities that a given farmer adopting the improved forage technology. Calculating the propensity score is critical since it is difficult to do the matching on each explanatory variable when there are many covariates. The primary purpose of the propensity score estimation is to balance the observed distribution of covariates between the two groups. Matching test was also performed after matching to check whether or not the differences in covariates in the two groups in the matched sample have been eliminated. Finally good matching quality was achieved. In the second stage, the average treatment effect on the treated (ATT) was estimated using `psmatch2`. Robustness of the ATT found by using `psmatch2` was also checked by running matching algorithms such as the nearest neighbor (NN), kernel and Radius matching techniques. `Psmatch2` is selected due to the fact that it estimates both propensity score and ATT by itself.

1. Model specification for matching algorithm

Kernel Matching

The model is applied to pool data from both treated and untreated subjects an estimated probability of participation for each subject.

$$E[y_i^1 - y_i^0 | p(x_i), T_i=1] = \frac{1}{n^1} \sum_{i=(T_i=1)}^{n^1} [y_i^1(x_i) - w_j(p(x_i))y_j^0] \quad [19]$$

Associate to the outcome y_i of treated unit i . the matched outcome given by kernel-weighted average of the outcome of all non-treated units. Where the weight given to non-treated unit j is in proportional to the closeness between i and j .

Nearest Neighbor model specification

C is the set of control (non-adopters) unit, denoted by C (i) the set of control units matched to treated unit i with an estimated value of the propensity score p_i . Nearest Neighbor matching set

$$C(i) = \min_j \|p_i - p_j\| \quad [20]$$

Radius matching

If the control units with estimated propensity scores falling within a radius r from p_i are matched to the treated unit i.

$$C(i) = \{p_j \mid \|p_i - p_j\| < r\} \quad [21]$$

Each treated unit is matched only with the control unit whose propensity score falls into a predefined neighborhood of the propensity score of the treated unit.

3.9. Definition of variables and working hypothesis

The data covered information necessary to make farm level indices of economic, institutional, social and demographic factors that influencing improved forage technologies adoption in the study area. Both continuous and discrete variables will be used on economic theories and findings to answer the research questions of this study, the following variables are constructed.

Outcome Variables

The outcome variable for this study was a continuous variable that represents the probability of the household whether they can be benefited from improved forage technologies or not. These benefits or impact indicators that will be examined include impacts on household income and increment on dairy yield.

Dependent variable: In the case of logit the dependent variable is adoption decision of improved technology. The variable takes value of 1 for the household that cultivated improved forage crops otherwise 0 for household that did not cultivate improved forage crops. In the case of Tobit model the intensity use of improved forage technology is a continuous variable that measured by area coverage of improved forage cultivated in 2020/21 production season /year.

3.10. Definition of independent variables and their hypothesized relations with adoption

Explanatory variable: Independent variables are variables that stand alone and are not changed by the other variables but cause change in dependent variable(s). The independent variables for this study are identified based on review of different literatures and carefully identified only those affects households decision to participate in improved forage technologies and outcome considered by the study. Based on this, those include household's personal and demographic variables; economic variables; institutional variables; and social variables are identified as independent variables for this study. The independent variables (as outlined in the conceptual framework) that are most likely to influence the adoption of recommended improved forage technologies in the study area and their impact on dairy productivity and farm income would be discussed. Those include household's personal and demographic variables; economic variables; institutional variables; and social variables.

Age of household: It is continuous variable and measured in number of years. Age of farmers can generate or erode confidence. Farmers' risk aversion to new technologies can change as they get older. The direction of influence, however, has shown mixed outcomes. It is assumed that households with an older age have control over more resources and more experienced, a better reputation, and more responsible. In other words, as the age of the household head increases, the probability of adoption decreases. Because, with age, a farmer can become more risk averse and then tend to be reluctant to new technologies Admassie and Ayele (2010). Therefore, in this study it is hypothesized that age of household head are more likely to affect improved forage technologies negatively/positively.

Sex of the household: it's the maleness and femaleness of household head. It's nominal variable used as dummy, which take a value of 1 if male, zero if female. Gender difference is found to be one among the factors influencing adoption of new technologies. Because of many socio-cultural values and norms, male have freedom of mobility and participation in numerous extension programs and consequently have greater access to

information. Therefore, it's hypothesized that male farmers are more likely to adopt package (Mesfin, 2005, and Taha, 2007).

Education level: It is defined as the number of schooling in years maintained by the respondents. It is continuous variable. It enables farmers to have access to new information and idea. Formal education of household in the family would increase the farmer's ability to use information relevant to the adoption of improved technologies (Haji, 2003). Based on his study, household head's educational level is thus expected to influence the probability of adoption of forage technologies positively. So it plays an important role in adoption of innovations/new forage technologies. Further, education is believed to improve the readiness of the household to accept new ideas and innovations and get updated demand and supply. Therefore, the more educated the household head, the higher the likelihood to decide for forage technology adoption. It is hypothesized that education of household head has a positive impact on adoption of improved forage technologies.

Farm land size: In the present investigation farm size is defined as the total farm size owned and rented by the household in hectares. It is a continuous variable and farmers with less land were expected not to be willing to adopt improved technologies since they were thinking that the technologies need extra land to establish various fodders and can be used for grazing. Farm size is an indicator of wealth and social status that influence within community. Farmers with large land size can adopt new agricultural technologies than smallholders (Kaba, 2009). It is hypothesized because there is a direct relationship between the farm size of land held by farm households and forage technologies adoption. Therefore, it is hypothesized that land size would initiate to adopt improved forage technologies.

Annual income: It is assumed that annual income is positively associated with the use of improved variety. Farmers with a high annual income are hypothesized to be more likely to adopt improved agricultural technologies than farmers experiencing low level of income (Zhera, 2014).

Improved cattle owned in TLU: It is continuous variable and measured in Tropical Livestock Unit (TLU). Households that have more large number of improved livestock are likely to adopt more innovations than others who have less number of livestock because the farmers with more number of livestock have better opportunity to get credit. In this study it is assumed that livestock ownership and adoption will be related positively. Therefore, it is expected that number of livestock owned would have positive influence on the adoption and intensity of improved forage technologies. Adoption and intensity of adoption were projected to rise as livestock ownership increased, and these two factors were found to be positively correlated (Birhanu, 2002). It was therefore, improved livestock ownership is hypothesized to be positively related to the adoption of forage technology.

Access to extension service: This variable is measured as a continuous variable taking a value based on the frequency of contact households with the extension agent. Efficiency of extension service depend on the frequency that extension agent visits of a given household in a specific crop year. According to Kidane and Degnet (2001) high frequency of extension contact accelerates effective dissemination of information that enhances adoption of new agricultural technologies. The more access to extension service positively influences the decision to use improved varieties. The positive relationship between extension services and forage adoption suggests that increasing household access to extension services enhances adoption, confirming Beshir's (2014) result that agricultural extension services increase household adoption that agricultural extension services are a major source of information regarding forage technologies for farmers. Thus, it is hypothesises that extension access or services positively affect adoption of improved forage.

Attend field day: Farmers who have attended field days, visited demonstration plots, and participated in formal agricultural training are expected to have a good attitude about agriculture.to the adoption of improved wheat varieties and fertilizer (Tesfaye,2001).Thus ,attendance in field day hypothesized to positively influence the farm household's adoption decision to improved forage varieties.

Attend Training: Training builds farmers' capacity and improves the knowhow of the technology. Household adoption of forage was also positively associated to access to training sessions. It's unsurprising that improving farmers' understanding about newly released and adapted forage technology, as well as demonstrating them how to utilize them, increases the likelihood of adoption. (Alemayehu Abebe et al., 2018). Thus, it is expected to have a positive attitude to the adoption of improved forage technology.

Distance to markets: Distance is a continuous variable measured in kilometers and refers to place of the farmer's house from the market. Proximity of the market from their residence determines for their input to purchase and sell their produce. According to Birhanu Gebremedhin et al. (2003), Ibrahim Ahmed (2012), Mulugeta Yitayih et al. (2017) and Kinuthia and Mabaya (2017). Farmers located closer to the input and output markets have better access to inputs, technology and output market and also easily get information about improved technology than those who are in distant areas and can make early decision of adoption. Different studies result indicated that distance from the market has significant and negative effect on the farmers' decision to adopt agricultural technology (Admassie and Ayele, 2010; Hagos & Zemedu, 2015). It was therefore, market distance is hypothesized to negatively affect participation in improved forage technology adoption.

Table 2: a summary of explanatory variables, their description, measurement and its expected sign

Explanatory variables	type of variable	Measurement unit	Expected sign
Dependent variable			
Adoption of improved forage technology	Dummy	1 if a household used improved variety ,0 otherwise	
Area coverage of improved forage cultivated	Continuous	Hectare	
Outcome variables			
Income from sales of milk	Continuous	Birr	
Milk yield	Continuous	Liter	
Independent Variable			
Age of the household (AGE)	Continuous	Age of household head in year	-/+ve
Sex of a household	Dummy	0 for Female ,1 for Male	-ve
Educational level (EDULEVEL)	Continuous	Year	+ve
Total land size	Continuous	Land holding (ha)	+ve
Annual income (farm and non-farm)	Continuous	Household annual income in Ethiopia birr	+ve
Improved cattle owned	Continuous	Livestock ownership in TLU	+ve
Extension contact	Categorical	More than twice, twice1` a month ,once a month .ones in the season	+ve
Attend filed day	Dummy	1 if household participate in field day , 0 otherwise	+ve
Attend in Training	Dummy	1 if household attend in training , 0 otherwise	+ve
Market distance	Continuous	Distances of market in kilometer	-ve

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

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This chapter of the thesis presents the results of the statistical analyses and the discussions based on the collected data generated through formal and informal survey.

4.1. Descriptive results

Descriptive statistics analysis of the selected demographic and socioeconomic characteristics of sample household is vital, as it would help to frame the econometric analysis. Chi-square and T- statistic test were employed to compare improved forage technology adopter and non- adopter groups with respect to some explanatory variables. Accordingly, the t-test is used to test the significance of the mean values of continuous variables while chi-square is used to test the significance of the values of the potential dummy variables, with comparison of the adopter and non-adopter households.

4.1.1. Demographic and socioeconomic characteristics of respondents

This sub-section described the household characteristics that explain the information on demographic and socio-economic characteristics. In this study, a total of ten explanatory variables were identified and out of these variables eight of them revealed significant association with the adoption and intensity of use of improved forage technology. Variables such age, education, TLU and farm size and Field day are continuous, whereas age of household, training, filed day and extension contact are dummy variables that show statistically significant at 1% , 5% and 10 % significant level with the adoption decision. Differently, market distance and off farm income, had not statistically significant relation with the adoption decision. Summary of the overall descriptive results of this study is presented in table 3 and 4 below.

As indicated in the Table 3, the mean age of the adopters is 42.61 while, it is 45.5 years for non- adopters. The mean age of the adopters is less than the mean age of the non-adopters in technology adoption. Thus, the mean variation was found to have statistically significant with ($P=0.039$) value, this implies that there was significant difference on the mean age of the household head in the two groups at 5% level of significant. This suggests that young people tend to be more adopters of new technologies than the old aged people.

Table 3: Test statistics of demographic and socioeconomic characteristics for continuous variables (t-test)

Types of Variables	Adopter (N=192)		Non-Adopter (N=128)		Combined		T-value	p-value
	Mean	Std	Mean	Std	Mean	Std		
Age (Number)	42.61	11.3	45.5	12.8	44.3	12.3	2.064	0.039**
Education (Year)	1.16	0.88	0.59	0.75	0.81	0.85	-6.1707	0.000***
TLU (Number)	8.65	3.89	6.54	3.42	7.39	3.76	-5.1040	0.000***
Farm size (Hectare)	2.61	1.24	1.90	1.12	2.19	1.22	-5.3363	0.000***
Market distance (walking distance in minutes)	34.24	24.9	32.5	23.7	33.2	24.2	-0.6038	0.5464

Note: ***, **, *, show significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively

Source: Computed from own survey (2021)

Education is one of the other most important factors that determine the decision to accept new agricultural technology. This is due to the fact that literate household heads are more likely to see the benefits of technology and contribute to improved innovation and invention. The results further depicted that the year of education of the adopters is 1.16 while the figure is 0.59 for the non-adopter households, respectively. Furthermore, the mean difference was found to be statistically significant. The calculated probability implies that there was significant mean difference in education status of the adopter and non-adopter households ($P=0.000$). This finding is conformity with work of Haji Biru (2003) indicated that literate farmers' are better in adopting improved technologies compared to illiterates.

Farm animals (TLU) have an important role in rural livelihood. They are source of draught power, to supplement protein needs, as prestige, cash, animal dung for organic fertilizer and fuel, means of transport and as a hedge against hard times in general. The types of livestock found in the study area were cattle, sheep, and goat, equine and chicken. Mixed farming system (i.e. integrated crop and livestock production) is the main agricultural activity in the study area. Accordingly, the draught power is taken as major source of production in the study area. Beside this, the effect of livestock ownership was

found have a significant effect on adoption of improved forage technology. The average livestock ownership for adopters and non- adopters was found to be 8.65 and 6.54, respectively. The p-value implies that there is a significant mean difference between two groups ($P=0.000$). Accordingly, the adopter household has more livestock owners than non-adopters. This finding is in line with study by Birhanu Bedassa (2002) reported that as livestock ownership increases adoption and intensity of adoption was expected to increase and correlate positively.

On the other hand, farm size is a more decisive socioeconomic variable that is vital for agricultural practice and livelihood improvement. In comparison with improved forage adoption, the average cultivated land size of the adopter households was 2.61 ha and the corresponding figure for the non- adopters was 1.90 hectare (Table 3). The mean difference of the two groups was found to have statically significant ($P=0.000$). The result is consistent with Kaba Merga (2009) Finding that there is a direct relationship between the farm size of land held by farm households and forage technologies adoption. Therefore, Farmers with large land size can adopt new agricultural technologies than smallholders and land size would initiate to adopt improved forage technologies.

Table 4: Test statistic of demographic and socioeconomic characteristics for dummy variables (chi²-test)

Variable s	Catego ries	Adopter N=192		Non- Adopter N=128		Total value		chi ² - value proba bility	p-value
		Co unt	%	Cou nt	%	Coun t	%		
Sex	Male	115	42	158	58	274	85.89	2.75	0.097*
	Female	13	29	32	71	45	14.11		
Training	Yes	58	79.45	15	20.55	73	22.88	60.93	0.000****
	No	70	28.46	176	71.54	246	77.12		
Field day	Yes	64	90.14	7	9.86	71	22.26	95.09	0.000***
	No	64	25.81	184	74.19	248	77.74		
Extensio n contact	Yes	123	67.96	58	32.04	181	56.74	134.88	0.000***
	No	5	3.26	133	96.38	138	43.26		
Income from off farm	Yes	34	46.58	39	53.42	73	22.88	1.64	0.200
	No	94	38.21	152	61.79	246	77.12		

Note: ***, **, *, show significance at $p<0.01$, $p<0.05$, and $p<0.1$, respectively.

Source: Computed from own survey (2021)

Among the dummy variables, the sex distribution of sample households, from the total sample household, 85.89% of them were male and 14.11% of them were female headed. With regard to the sample respondents improved forage technology adoption status 89.84 % of improved forage technology practitioners were male household head while the rest 10.16 % were female. From the non-adopter's household side, around 83.25 % and 16.75 % of the total respondents were male and female respectively. On average, the chi-square test of sex distribution between the adopters and non-adopters was found to be statistically significant ($P=0.097$) and this shows that, there is strong significant relationship between sex of adopters and non-adopters in improved forage technology adoption. This finding is conformity with the work of (Mesfin, 2005, and Taha, 2007) as stated that due to many socio-cultural values and norms, male has freedom of mobility and participation in different extension programs and consequently has greater access to information. Therefore, it is hypothesized that male farmers are more likely to adopt package.

On the other hand, participation in training, In terms of technology specific training the result of descriptive analysis indicated those 22.88% sampled household have attended training while the rest 77.12 % of have not attended training. Training can improve the knowhow of farmers on technology. The more farmers involve in training the more they make a decision to use a technology. It means that, around 54.69% of adopters group and 92.15% of non-adopters responded that there were not attended training. In the revers, 45.3% of adopters and 7.85% non-adopter group that they were attended training. The Chi-square test confirmed that the association between attained training and improved forage adoption was significant ($P=0.000$). The finding is in line with the findings of Alemayehu Abebe etal (2018) who reported those farmers with access to trainings have better chance to adopt improved forage.

Farmer's participation in field day and demonstration activity indicated that 22.26 % of sample household have participated while the rest 77.74 % of household have not participated in field day and demonstration activities. It means that, around 50% of adopters group and 96.34% of non-adopters households responded that there were not participated in field day and demonstration activity. Whereas 50% of adopters and 3.66%

non-adopter group have participated. This implies that farmers were interested to learn from field day activities. The chi-square test indicated that there was a significant association between attending field day and improved forage technology adoption ($p=0.000$).

Extension contact believed to enhance awareness among smallholder farmers about new agricultural technologies and farming activities. Mainly Keble extension agents and district supervisors capacitate smallholder farmers in various ways. For example, participation in demonstration day, providing technical assistance, provides improved varieties of seeds and practical training to innovative farmers. The survey result revealed that out of the total sample household farmer`s (56.74 %) of sample household have contact with extension agents while the remaining 43.26 % of household have no contact. It means that, around 3.91% of adopters group and 69.63% of non-adopters households responded that there were not contacted with extension agents. Whereas, 96.1% of adopters and 30.4% non-adopter group have contacted with extension agent. The chi-square test confirmed that the association between extension contact and improved forage technology adoption was significant ($p=0.000$) and suggesting that extension contact is important in highly influencing farmers' decision to adopt improved forage technology. This finding is conformity with the work of Beshir H (2014).

Regarding, adopter's participation on off-farm income activities from the total sample households it was found to be 22.88% for adopter household that was engaged in off farm income activity and the rest 77.12% of the households not engaged in off-farm activities. While from non-adopters 20.42% are engaged in the off-farm activities and 79.58% are not part of it. Conversely, from adopters 26.56% are engaged in the off-farm activities and 73.44% are not part of it. However, the chi-square result indicated ($P=0.200$) that there was no variation between adopters and no-adopters in participation on off-farm income activities in improved forage technology.

4.2 Adoption status of improved forage technologies

4.2.1 Major feed resources in the study area

Farmers depend on various sources of animal feed, most of which are obtained in their locality and from their own farms. As shown in (Figure 3) below 87.15 % of the farmers majorly depend on both from crop residues and natural pasture as source of animal feed. The types of residues fed to animals often depend on the types of crops grown in different parts of the country. For instance, straws of teff, wheat and barley are common in the agro-ecology ranging from mid altitudes to highlands while stalks of maize and sorghum are common feed types in the lowlands. Wherever it is, residues of crops are often stored for use in the later season especially when feed scarcity is encountered. Hay (33.54%), crop aftermath (31.33%) and improved forage (14.11%) mainly oats and vetch are also major sources of feeds for animals in the study area. Green feed supply commonly oats and elephant grass is usually practiced as cut and carries systems especially during rainy season. Concentrate was also reported to be a common source of animal feed by 22.57% of the households. These concentrates mostly include noug seed and linseed cake, and by-products of grains and local beverages. Others also contributed to the overall feed resource types in the study area as stated in (figure 3).

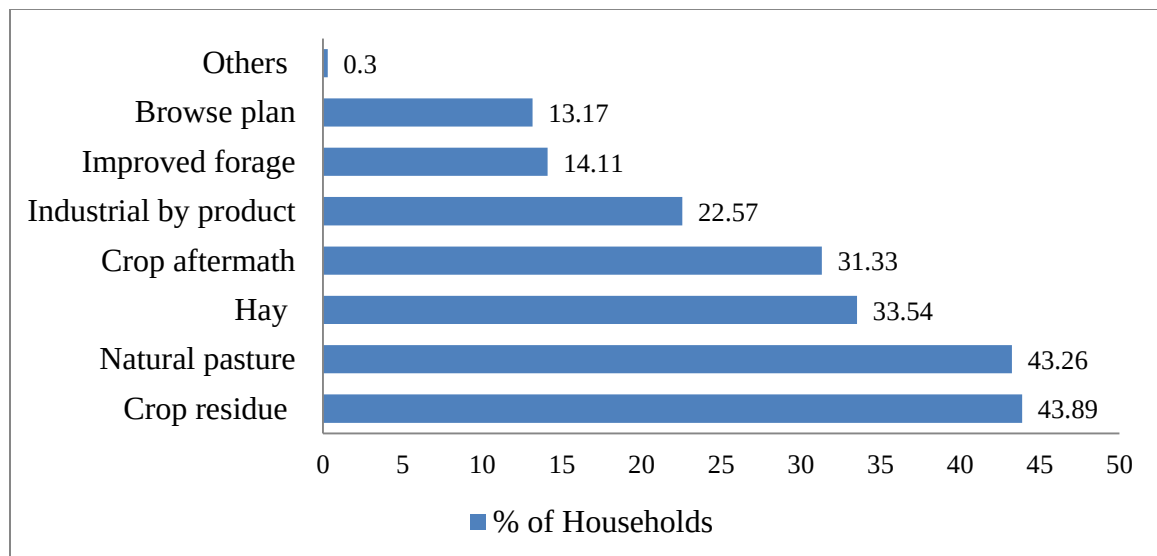


Figure 3 : Major feed resources used for feeding animal

Source: Computed from own survey (2021)

4.2.2 Adoption rates and intensity of forage technologies

Improved forages of various types have been released for utilization since decades ago. The findings, therefore, present how these technologies have been adopted and utilized by dairy farmers in the study areas. In this study, adopters of forage technologies are defined to be farmers who have allocated a plot of land to grow forage crops with last five years. Accordingly, Out of the total 319 respondents, 128(40 %) of them has been found to be adopters and the remaining larger proportion 191 (60%) of them were found to be non-adopters of improved forage in Debre Libanose woreda (Figure 4, below).

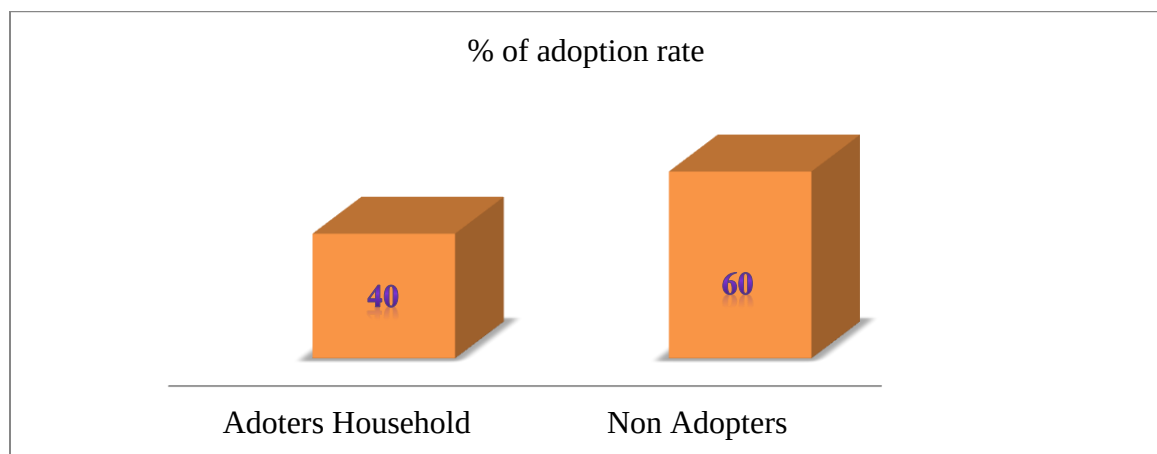


Figure 4: Adoption rates of improved forage technologies

Source: Computed from own survey (2021)

The focus group discussion /FGD/ participants from the three kebeles of the woreda indicated that, adoption status/rate/ of improved forage are increasing year to year at lower rate. They indicated that, the low level of land allocation to improved forage is due to the lack of training. The farmers indicated that, if not for the skill and knowledge from the model farmers, majority would not have conducted it due to big lack of training on livestock production in general and improved forage in particular. Hence, during the focused group discussion /FGD/ the farmers capitalized on more organized quality training so as to help them make more use of the improved forage advantage, and to attract more other non-adopters in to the improved forage production system.

Under this particular study the Extent of adoption of improved forage technology depicts that only 6.4% of the farmland (0.17 ha on average) was allocated for production of

forage crops (Table 5). The actual area allocated for feed could be more than this if we take into consideration of the area allocated for grazing and hay making. There is also statistically significant difference ($P<0.01$) among the adopters households. Households ranging from none (0.0 ha - 1.0 ha) maximum in this specific study area. Conventionally, farmers tend to allocate more area of farmlands for the production of food crops than forage crops. This is partly because of limited land holding or farm size and attitudinal perception of the farmers that animals can get feed freely from elsewhere and that it is a waste of land to allocate for forage crops. Limited awareness on the importance of forage crops is also another factor that hindered wider use of forage technologies.

Table 5: Adoption intensity of improved forage crops in Debre Libanose woreda

Woreda	Total area (ha) of land Cultivated (sample mean)		Total area (ha) of land cultivated (forage growers mean)		
	n	Total sample average (ha)	n	Area allocated for forage (ha)	% of area allocated for forage production
Debre Libanose	319	2.63	128	0.17	6.4
Statistical test $P<0.01$					

Source: Computed from own survey (2021)

4.2.3. Varietal level adoption rates of improved forage crops

Various stakeholders were engaged in the promotion of these forage crops, such as Office of Agriculture, Agricultural Research Institutions, Higher Learning Institutes, special purpose projects (such as 4th Livestock Project, ILRI (the then ILCA) projects, Smallholder Dairy Development Projects and others). According to the findings this study, the different varieties of forage crops have varying levels of adoption rates. As presented in Table 6, the two major forage crops that have relatively been expanded and grown in the study areas included oat-vetch (58.9%), elephant grass (7.2%), and sesbania (4.7%), Rhodes grass (4.1%) and tree lucerne (2.2%). On the other hand, Desho grass (0.94%), alfalfa (0.30) and fodder beet (0.30%) were the least adopted forage crops under this particular study area. The major reasons behind the less adoption rates of forage

crops is associated with ,limited access to improved forage seeds ,shortage of farmlands and the consequent interest of the farmers to give priority for food than forage crops.

Table 6: Varietal level adoption rates of improved forage crops in the study area, 2021

Improved feed packages	Freq.	Adoption rates (%) (N = 128)
Oat-vetch	188	58.9
Elephant grass	23	7.2
Sesbania	15	4.7
Rhodes grass	13	4.1
Tree Lucerne	7	2.2
Desho grass	3	0.94
Alfalfa	1	0.30
Fodder beet	1	0.30

Source: Computed from own survey

4.3. Awareness and sources of improved forage seed technologies

Adoption of a new technology and practice is often preceded by knowledge of its existence. Accordingly, 60.5 % of the overall households were aware of improved forage technology and the remaining 39.5% responded households in the study area were not aware of this particular technology and as far as source of improved forage seed in the study area concerned about 56.5% of the households, accessed improved forage seed was mainly sourced from government Office of Agriculture through its channels of extension service provision (figure 5). The second essential source of improved forage seed technology was NGO for about 31% of the households,8.9% of the household was also accessed through private source (revolving seed that) and 3.6% of the seed source was from national agricultural research and higher institution. In this regard, agricultural research centers have also contributed to creating knowledge of improved forage technologies of the households through direct engagements so far in demonstration of best promising materials to the area. However, the contribution of the national agricultural research systems and international research organizations was fundamental through awareness creation, outreach programs, capacity building and empowerment means through indirect means as well.

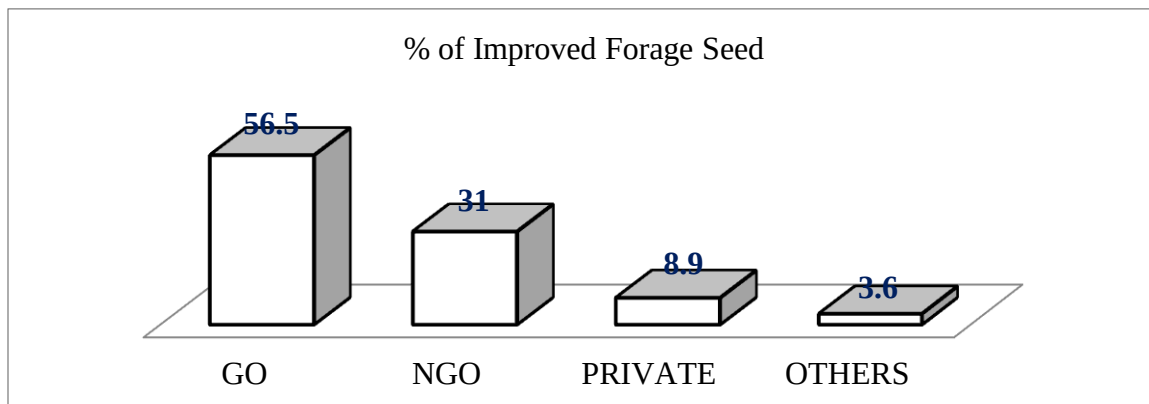


Figure 5: Source Improved Forage Seed Technology, 2021

Source: Computed from own survey (2021)

As presented in (figure 6 below), 4% of the households in the study area were aware of improved forage technologies since more than 10 years. Whereas, there was also difference among the household in the study areas that 25% of household were aware of it with in the last 2 years, 32% of within range of 3 to 5 years and 38 % was range from 6 to 10 years where the majority fall in the time Zone that households became aware of improved forage technologies. In general, majority of the household 74% of the overall households got the awareness of improved forage technology within the last 10 years' time. This might be because of the decentralized administrative set up and empowerment of districts with well-organized extension programs designed based on the needs of beneficiaries and prevailing development needs.

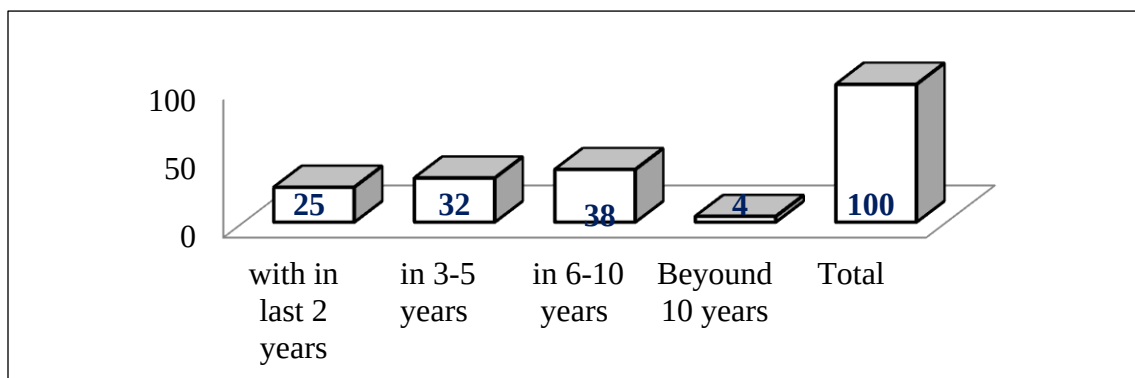


Figure 6 : Time since when households became aware of improved forage technology

Source: Computed from own survey (2021)

4.3.1. Experiences of improved forage cultivation in the study area

The experiences of improved forage cultivation in this study area has shown different year of experience among the adopter categories (Table 7 below). The adopter household categories has started utilizing different improved forage materials in different years, 9.4% of the respondents of adopters household experienced in utilizing improved forage technologies since less than one year, the other majority (23.2%) of the adopter households experienced within the range of 1 to 5 years, (6.9 %) of them experienced for the last 5 to 10 years and remaining (0.31%) has been stayed with the technology since more than 10 years .experience of improved forage is directly associated with households with improved cattle's owned. hence, one without other is unproductive and this finding is conformity with focus group discussion .

Table 7: Improved forage growing experiences by adopters, 2021

Experiences in growing improved forage	Freq.	%
0	192	60.19
< 1 Years	30	9.4
[1-5 Years)	74	23.2
[5-10 Years)	22	6.9
[> 10 Years)	1	0.31
Total	319	100

Source: Computed from own survey (2021)

4.3.2. Gender perspectives in the adoption of improved forage technologies

The study has also attempted to assess whether there is gender disparity in the adoption of improved forage technology. It was noticed that there was a difference in the adoption rates for male and female-headed male-headed households, as indicated in (Table 8). The result revealed that out of the total adopters respondents 115 (89.8%) were male -headed households and 13(10.2%) were female -headed households. This indicates that male-headed households had higher probability of adoption improved forage technology in the study area than female- headed households. Within both household types, hug variability was observed to be statistically significant. This might be due to the labour intensive nature of the technology. Thus, of the males strongly engaged in forage production and as

a result of getting access to information and training of males-headed household are better off than female-headed household.

Table 8: Gender perspectives of improved forage technology adoption rates

Study Woreda	With Adopters category				Overall %
	Female-Headed household	%	Male-Headed household	%	
Debre Libanose	13	10.2	115	89.8	100
Statistical test P<0.01					

Source: Computed from own survey (2021)

4.3.3. Reasons for farmers not adopt of improved forage technologies

The study revealed that Even though limited proportions of households have already started using, large proportions of them have not yet started adopting improved forage technology. There are key factors behind this dis-adoption. As indicated in Figure 9, the six major reasons described by farmers included land shortage as reported by 50.8% of the households, unavailability of sources technology (seed shortage (40.7%), unawareness about improved forage technology (28.1%), labour shortage (24.1%), problem of other inputs (15.3%) and problem of health bloating (6.3) had been reported . The first two reasons were found to be critical for the dis adoption of for this particular technology in the study area. The basic reason of this occurrence is acute supply shortage due to unavailability of reliable and capacitated formal improved forage multiplication and distribution centers in the country. The government has given a due focus for the establishment of seed multipliers of improved forage crop variety both at Federal and Regional levels, so far it has been done through small pack seed delivery via national agricultural research system and this kind of working platform couldn't able to reach the large mass of the population. The other major reason was related with awareness and knowledge of improved forage technology. Therefore, intensive training should be given to bridge the gap.

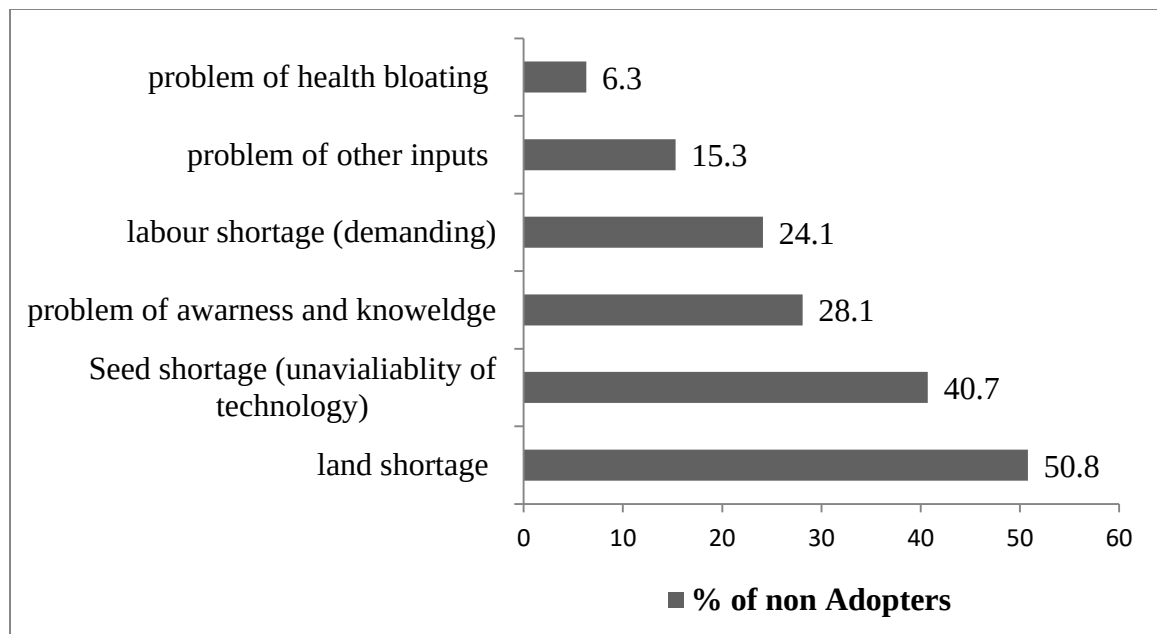


Figure 7: Reason for not adopting improved forage technology, 2021

Source: Computed from own survey (2021)

4.4. Econometric statistical analysis

Model diagnostic test results

This study conducted the entire necessary model diagnosis test which comprise model specification test for the overall model fit (goodness of fit), multicollinearity problem and test for model specification error test. In this regard, model test carried out before running the logistic regression while model specification error tests (linktest) were carried out after running the regression.

The explanatory variables were checked for existence of multi-collinearity or association between the dependent variables to identify the determinant factors that affecting adoption of improved forage technologies. Whether there is or not multi-collinearity among continuous independent variables it was tested using variance inflation factor (VIF). Accordingly, the result revealed that there is no problem of multi-collinearity observed because the tolerance greater than 10% among explanatory variable and for categorical independent variables used in this study were checked for the existence of multi-collinearity and the degree of association using the contingency coefficients test (CCT). The values of contingency coefficient ranges between 0 and 1, with zero

indicating no association between the variables and values close to 1 indicating a high degree of association accordingly, the results of the computation reveal that there was no problem of association among the explanatory variables since the result shows as it is below 0.75 as the result is indicated in Table 9 below. The result of the test also indicated in page 93 (appendix2). (Gujarati, 1995).

Table 9: Test estimation

Tests	Test name	Factors of Adoption
estat gof	Pearson>chi2	0.858
linktest	_hat	0.000
	_hatsq	0.193
VIF	Multicollinearity	1.29
CCC	Multicollinearity	< 0.75

The model fitness test of the logistic equations justified the actual fact that the models are enough to elucidate the dependent variables. This evidenced by the actual fact that the Pseudo R^2 statistics of the model is 0.858 which is lies between 0 and 1. The result confirmed that the explanatory variables (independent variables) of the model could explain the variable quantity and well fitted (see appendix 1).

The link test identified the model specification error occur when the relevant variables are omitted from the model or one or more irrelevant variables are included within the model. The null hypothesis shows there's no model specification error. During this specific study the p-value of hatsq result was found to be insignificant then we fail to reject the null hypothesis and conclude the model is correctly specified. In this regard, for the linkage between technology adoption and factor affecting the choice of households to adopt improved forage technology the p-value is 0.193 (see appendix 2).The p-value implies it's not significant so we fail to reject the null hypothesis and conclude that there's no model specification error (Gujarati, 1995).

4.5. Determinants of probability of adoption of improved forage technology

4.5.1. Logit model result

To identify factors affecting adoption of improved forage technologies, logit model was used to predict the probabilities of adoption of improved forage crops using the hypothesized independent variables. Accordingly, estimates of the parameters of the variables expected to work out the adoption of improved forage development are displayed in (Table 10). A complete of ten explanatory variables were included into the econometric model out of which seven variables were found to be significantly influence probabilities of adoption of improved forage crops. These were age, education, market distance, extension contact, participation in training, field day and improved cattle ownership. Conversely, the remaining explanatory variables were found to have no significant influence on adoption status of the households. These were sex of the house hold head, farm size, and farm income. The constant term is significant in this case, implying that important variables influenced the likelihood of improved forage technologies adoption. However, due to significant multicollinearity existence among the independent variables, they are omitted. The result of the test indicated in (appendix 4).

Table 10: Logistic regression estimates for improved forage technology adoption

Variables	Odds Ratio.	Marginal effect dy/dx	St.Err.	Z	p-value
SEXHHEAD	0.751164	-.065249	.4446473	-0.48	0.629
AGEHH	1.030092	.0065782	.0167485	1.82	0.068**
EDUHH	1.610852	.1057817	.3580113	2.15	0.032**
FARMSIZE	-0.973829	-.0058839	.1896029	-0.14	0.892
DISTAWORMKT	1.016346	.0035974	.0065929	2.50	0.012**
ACCESTOEXTES	16.9979	.5080644	9.304402	5.18	0.000***
TRAINING	2.73146	.2229459	1.194584	2.30	0.022**
FILEDAYDEMO	16.3326	.6027121	9.266719	4.92	0.000***
IMPROVEDCAT	1.54224	.0961242	.1279083	5.22	0.000***
FARMINCOME	1.00003	7.48e-07	2.99e-06	1.13	0.259
_cons	0.000172		.000294	-5.08	0.000

(*) dy/dx is for discrete change of dummy variable from 0 to 1
 $y = Pr(ADOPTION) (predict) = .33229432$ Sample (N) =319 Likelihood ratio = -103.9228

Note: ***, **, *, show significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

Source: Computed from own survey (2021)

The result provide in (Table 10) above show that keeping other factors constant, **Age of household (AGEHH)** significantly affect the likelihood of adoption of improved forage technology in the positive direction at 5% ($P=0.068$) probability level. A plausible explanation for this is that older households might have better awareness about the benefit of new agricultural technologies from their life experiences. In addition, older households may have also larger farm size and better endowed with different assets which help them to adopt more agricultural technology. This result is consistent with the findings reported by Admassie and Ayele (2010).

Education of the household head (EDUHH): Education is one of a decisive factor in influencing the decision to adopt new technology and improving households' livelihood. This is attributed to the fact that educated household heads would be expected to better visualize the benefits of technology and help for better innovation and invention. Accordingly, the model test also shows that there was significant difference between adopters and non-adopters in relation to education level at 5% ($P=0.032$) probability level. Results from FGD and the KI interviews complemented that recently basic adult education was given to farmers by development agents, which helped in improving farmer's ability to read and write. Thus, Better education attainment of farmers can increase adoption of new agricultural technology. This finding also in line with findings of Zekarias Bassa (2016) indicated that literate farmers' are better in adopting improved technologies compared to illiterates.

Market distances (DISTAWORKT): was also one of the independent variables included in logit-analysis. In this study, distance from the market was found to have a significant and positive effect on the farmers' decision to adopt improved forage technology at 5% ($P=0.012$) probability level as shown in (Table 10) above. Contrast to hypothesized, as a negative determinant variable, the result of regression analysis showed positive correlation. Different studies result indicated that distance from the market has significant and negative effect on the farmers' decision to adopt agricultural technology (Admassie and Ayele, 2010; Hagos & Zemedu, 2015). A plausible explanation for this contradicting result would be those households far from the market (town in this cases) might have better extension service provision and able to adopt different technologies.

Access to extension services: This variable happened to have positive and significant effect on the probability of household's decision to adopt improved forage technology at 1 % ($P=0.000$) probability level. It indicates that those households having more number of contacts with development agents are more likely to adopt improved forage compared to households with no or little extension contact. The positive relationship between extension services and forage adoption indicates that increasing access to extension services increases adoption among households, reinforcing the finding of Beshir (2014) that agricultural extension services are a main source of information regarding forage technologies for farmers. Sikhulumile et al. (2014) found that farmers with extension service will have better access to updated information which will in turn increase enhance their probability of adopting new forage technology. Moreover, this finding is in line with Yikaaly Teklay and Zebrhe Teklay (2015), Musba Kedir(2017), Kinuthiaand Mabaya (2017) and Alemayehu Abebe et al.(2018) who found positive and significant effect of number of extension contacts on the decision to adopt improved forage.

Training (TRAINING): is one amongst the extension events where by farmers got practical skill and technical information for new technology from different government and non-government sources. Accordingly, as the model result indicates, participation in training was positively and significantly affected the adoption of improved forage technology at 5% ($P=0.022$) probability level. This could be explained by the actual fact that farmers who get training gain better knowledge on improved forage development practices than non-trained ones which can help them to extend their production and productivity. The effect of training for this study is consistent with the findings Musba Kedir (2017) and Alemayehu Abebe et al. (2018) which indicate that training was positively related to adoption of improved forage technology.

Field Day (FIELDDAY): Farmers can acquire new knowledge through participation in demonstration activities which may enable them to improve production and productivity of agriculture. The logit result indicates that the probability of improved forage adoption was positively and significantly affected by field participation at 1% ($P=0.00$) probability level. This implies that demonstration approach is one of the important approaches to transfer practical knowledge on agricultural production and technologies to farmers.

When farmers conducting a new practice they can weigh the advantage and disadvantages of the new technology and this can facilitate adoption and help them to implement the new technology properly. This result shows that farmers who participate in demonstration activities are more likely to adopt new improved technology than others. This suggests that wider demonstration would speed up the adoption of agricultural packages and hence calls for development of the existing limited demonstration practices. Similar results were reported by (Tesfaye, 2001), Belay Kassa (2003), Tariku Bezabih (2012), Ibrahim Ahmed (2017) and Musba Kedir (2017). These studies indicated that demonstration and dissemination of information through field day and demonstration activities might facilitate adoption of improved varieties.

Improved cattle owned in TLU (IMPROCATTLE): was found that it is positively associated with the probability of adoption of improved forage technology at 1% ($P=0.000$) probability level. The result of the logit estimation revealed that Adopter households with improved cattle's have showed high probability of adoption of improved forage than the counterpart household with local cattle only in the study area. The reason for this positive effect was that improved forage and improved cattle are much intertwined and hence its availability could increase area under cultivation and the probability of adoption. Therefore, it is expected that number of improved cattle owned would have positive correlation on the adoption improved forage technologies and this finding is conformity with (Birhanu, 2002).

4.6. Factors determining the extent of improved forage adoption.

4.6.1. Tobit model result

This part presents on factors determining the extent of farmers' improved forage adoption .the Tobit regression econometric model estimates of the magnitude of the adoption of improved forage technology used in this case. The factors considered are related with personal, socio-economic, institutional and socio- psychological variables relevant to the magnitude of adoption of improved forage technology. Looking at the estimated parameters, results of the analyses also indicate that from the total of ten explanatory variables hypothesized to influence extent of improved forage adoption, it is possible to highlight that the coefficients of five variables are statistically significant at different

significance levels in influencing magnitude of adoption of improved forage technology (Table 11). Multicollinearity was tested using variance inflation factor (VIF) and it revealed that no problem of multicollinearity observed among each explanatory variables (the independent variables).the result of the test indicate in the (Appendix 4).

Table 11: Tobit estimate of factors affecting the intensity use of improved forage technology

Variables (Intensity)	Coef. Std.	Std. Err.	t	P-value
SEXHHEAD	-.1095343	.07335	-1.49	0.136
AGEHH	.0025707	.0026297	0.98	0.329
EDUHH	.1047785	.0354715	2.95	0.003***
FARMSIZE	.03225	.032306	1.00	0.319
DISTAWORMKT	.0023993	.0011319	2.12	0.035**
ACCESTOEXTESI	.5013175	.08315	6.03	0.000***
TRAINING	.0533578	.0602003	0.89	0.376
FILEDAYDEMO	.1927861	.0648478	2.97	0.003***
IMPROVEDCATTLE	.0519982	.0110967	4.69	0.000***
FARMINCOME	-1.07e-07	5.02e-07	-0.21	0.831
_cons	-1.054023	.1990597	-5.30	0.000
/sigma	.3825875	.0271747		
Sample (N) =319		Log likelihood = -129.28649		
LR chi2 (10) = 168.80		obs, summary:195 left-censored observations at		
INTENSITY<=0				
Pseudo R2 =0.3950		124 uncensored observations		
Prob > chi2= 0.0000		0 right-censored observations		

Note: ***, **, *, show significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

Source: Computed from own survey (2021)

Household head education level (EDUHH): As expected, education level had a positive and significant relationship with the magnitude of adoption of improved forage technology at 1% ($P=0.003$) probability level as shown above (Table 11). The Tobit analysis shows that, the magnitude of improved forage adoption by farmers who were literate is more likely to be greater than farmers who were illiterate. This means that being literate would improve access to information, capable to interpret the information, easily realize and analyze the situation better than illiterate farmers. So, farmer who are literate were likely to cultivate and use improved forage technology properly with higher extent than those illiterate farmers. This result has supported by other previous studies by Haji Biru (2003).

Market distances (DISTAWORKT): The result of Tobit regression analysis pointed out that distance from the market was found to have a significant and positive effect on the farmers' intensity use of improved forage technology at 5% ($P=0.035$) probability level as shown above (Table 11). Contrast to hypothesized, as a negative determinant variable, the result of regression analysis showed positive correlation. Different studies result indicated that distance from the market has significant and negative effect on the farmers' decision to adopt agricultural technology (Admassie and Ayele, 2010; Hagos & Zemedu, 2015). A plausible explanation for this contradicting result would be those households far from the market (town in this cases) might have better extension service provision and able to adopt different technologies. Hence, increase area under cultivation of improved forage technology.

Access to extension service (ACCESEXTENSION): it was found that number of extension service or contact positively and significantly affect the intensity use of improved forage at 1% ($P=0.000$) probability level. Number of extension contact gives smallholder farmers greater technical support. In study area, the frequency of times that the respondents were visited by development agents happened to have positive and significant impact on the level of intensity of use of improved forage technology. It indicates that those households having more number of contacts with development agents are more likely to use improved forage in greater level compared to households with no or little extension contact. In the literature, Sikhulumile et al. (2014) found that farmers experience on extension service and access to updated information leads the probability of adopting new technology, since they could use the resources wisely with proper execute of input for better production and productivity of high value crops. Moreover, this finding is in line with Musba Kedir (2017) and Alemayehu Abebe et al. (2018) who found positive and significant effect of number of extension contact on the decision to utilize intensively improved forage.

Field day (FIELDDAY): the model result indicates that participation in field day event was found to have positive and significant correlation related to intensity use of improved forage production at 1 % ($P=0.003$) probability level. A marginal change in number of participation in field day visits increases probability of adoption and intensity of adoption

of improved forage technology by 19.27 percent. Field day is an important method of extension to pull farmers in accepting technologies. This idea was supported by FGD and key informant discussants.

Improved cattle owned in TLU (IMPROCATTLE); the result of the Tobit regression model analysis shows that improved cattle had positively and significantly influenced the household adoption and intensity of use of improved forage production at 5% ($P=0.00$) probability level of significance. As improved cattle holding increase by one unit the probability intensity use of adopting improved forage technology is increased by 51.2%. The potential reason for this result could be households who owned large improved cattle have positive tendency to adopt improved forage technologies since improved forage and improved dairy production are inseparable, as improved cattle increase and improved forage also increase as well. Thus, it implies that improved cattle's is very important factor that influence the level of adoption of improved forage technology.

4.7. Impacts of improved forage technology adoption on milk yield and farm income

This section describes econometric analysis which was followed to spot the impact of improved forage production technologies adoption on milk yield and farm income. The section was analyzed that the estimation of propensity scores, choosing matching algorithm and calculate Average Treatment Effect (ATT) on treated.

Propensity Score Matching (PSM) is employed to match adopter and non-adopter so as to form reasonable counterfactual (Rosenbaum and Rubin, 1983). Propensity score construct a statistical comparison between treated individual with control individual based on similarities in all observable characteristics except the treatments so as to compute the difference within the outcome variable. This implies that the average treatment effect of the technology adoption is calculated as the mean difference in outcomes across the two groups. (Rosenbaum and Rubin, 1983). According to khandker et al., (2010) the PSM effect validity depends on conditional independence and sizable common support across the adopter and non-adopter sample household.

In the first step, logit model is used to estimate the propensity scores for matching purpose Baker (2000). Accordingly, in this study ten explanatory variables were

identified and used to fulfill the criteria of the balancing propensity among those variables, seven of them were found to be significant variable that determine the decision of adopting improved forage technologies and use of improved forage technologies positively and significantly While the rest of three variables were not significant in explaining the variation in the dependent variable. (See logit regression model result on table 10).

The next step after balancing the predicted probability values, from the binary estimation, matching was done by using matching algorithm. A matching algorithm is selected based on the data at hand in order to select the control group who are matched with the treated group based on the covariant which needs to be controlled.

Propensity score histogram

The propensity score matching (PSM) is to match each participant based on an identical common characteristic with non-participants. Thus, the distribution helps to identify the impact of forage technology adoption on milk yield and farm income. In line with this the density distribution of propensity scores for adopters and non- adopters is shown in (Figure 8), the bottom half of each graph shows the propensity score distribution of non-treated (non-adopters) while the upper-half refers to treated individuals. The y-axis indicated the frequency of the propensity score distribution.

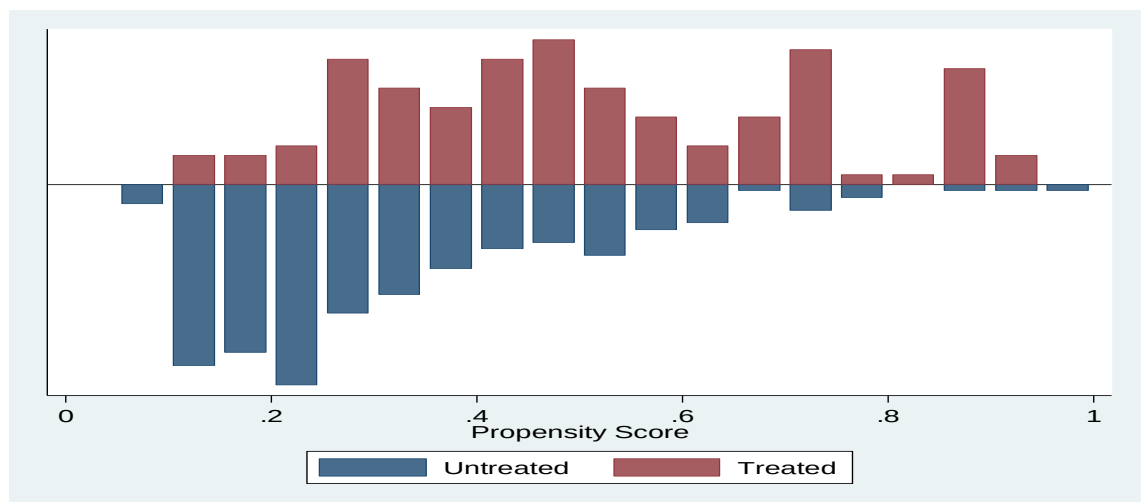


Figure 8: Propensity score distribution and common support region between treated and untreated

As shown within the above figure treated on support indicated the farmers within the adoption group who find an acceptable match, whereas untreated indicate non-adopters. (Table 12) below presents, the result of covariate balancing test to check the hypothesis that both groups have similar distribution in covariates after matching. The result revealed that the covariates means, the percentage bias and also the p-value difference in mean before and after matching. Choosing the best performing matching algorithm was to check the balancing of covariate by comparing before and after matching algorithm significance difference using the selected matching algorithm.

Table 12: Testing of covariance balance using propensity score (evaluation of quality of match)

Covariates	Samples	Mean		% of bias	% reduction bias	p-value
		Treated	Control			
SEXHHHEAD	Unmatched	0.84375	0.80105	11.2		0.073*
	Matched	0.83621	0.56034	2.1	56.0	0.169
AGEHH	Unmatched	42.609	45.503	-3.9		0.040**
	Matched	42.069	39.595	10.4	14.5	0.193
EDUHH	Unmatched	1.1563	0.58639	69.4		0.000***
	Matched	1.1121	1.3448	-18.3	59.2	0.143
FARMSIZE	Unmatched	2.2252	1.7718	50.6		0.000***
	Matched	2.1701	2.3677	-2.0	56.4	0.127
DISTAWORMKT	Unmatched	34.242	32.571	6.9		0.546
	Matched	33.845	25.474	4.4	40.8	0.672
ACCESTOEXTESI	Unmatched	0.9375	0.4293	130.1		0.000***
	Matched	0.9310	0.9482	-4.4	96.6	0.583
TRAINING	Unmatched	1.3672	1.5445	-6.1		0.002***
	Matched	1.3793	1.3017	15.8	56.2	0.214
FILEDAYDEMO	Unmatched	0.5	0.03665	122.2		0.000***
	Matched	0.4652	0.3607	17.3	77.7	0.111
IMPROVEDCATTLE	Unmatched	6.2344	3.0262	116.3		0.000***
	Matched	5.6724	6.6379	-5.0	69.9	0.454
FARMINCOME	Unmatched	1.0e+05	54517	71.6		0.000***
	Matched	93714	1.1e+05	-17.8	75.2	0.189

(Figures in bold shows significant covariates)

Note: ***, **, *, show significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

Source: Computed from own survey (2021)

The above table and figure results revealed that the mean standardized bias difference in before matching is in a range of 6.9% - 130.1 % in absolute value and P-value in the same table shows 80 % of chosen variables exhibited a statistically significant difference at before matching. Whereas, after matching the standardize bias/standard error difference of explanatory variables lied between 2.1 %-17.3%. If the value of this statistics exceeds 20 the covariate is assumed to be unbalanced (Rosenbaum & Rubin, 1985). Accordingly, in all cases, it had been evident that sample differences within the unmatched data significantly exceeded those in the samples of matched cases. Hence, the method of matching created a high degree of covariate balance between the treatment and control samples that were ready to be used in the estimation procedure. The result of the test indicated in (appendix 5). The below figure indicated that the standardized % bias across covariates (unmatched with matched covariates).

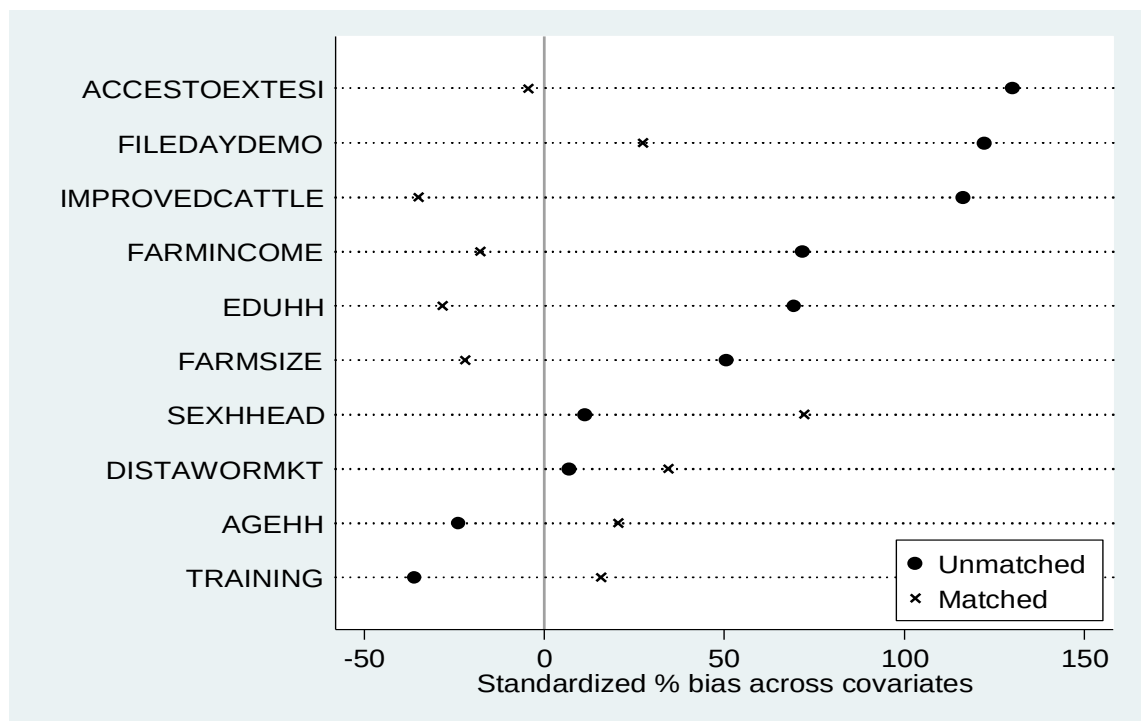


Figure 8: Unmatched and Matched standardized % bias across covariates

Source: Computed from own survey (2021).

Similarly, the joint significant test in (table 13) below revealed that the value of Pseudo R^2 was very low it had been minimized to 0.001 and the t-test was not significant. The low value of Pseudo R^2 indicated that the improved forage technology adopter and non-

adopter households had same distribution in the covariates after matching. The mean bias is additionally minimized from 63.8 to 4.3 .Beta is also minimized to 24.0 which is less than 25 so; these also gives as guarantee that the matching process created good balance between participants and non-participants based on the included covariates. Therefore, estimation of the Average Treatment Effect on the Treated (ATT) was preceded.

Table 13: Post estimation of PSM

sample	Ps R2	LR chi2	p>chi2	Mean bias	Med bias	B	R
Unmatched	0.511	219.47	0.000	63.8	60.0	212.8	29
Matched	0.001	52.70	0.874	4.3	3.7	24.0	0

Source: Computed from own survey (2021)

4.8. Estimating Treatment Effects (ATT)

To check the robustness of the result, different matching methods such as kernel-based matching (KBM), nearest neighbor matching (NNM) and radius matching (RM) were computed for both outcome variables; namely, milk yield and farm income (milk income) as indicated in (Table 14) below and The impact of the adoption is shown by the difference in ATT.

In general, all the three matching methods revealed that, adopters of improved forage technologies have generated significantly higher output (milk yield litter/annum and milk income birr/annum) compared to the non-adopters households ,with a statistically significant difference at (p=0.01) level. This implies that, better milk production and much better farm income were gained by adopting improved forage technology; which in turn encourages adoption of the improved forage technologies. Based on the study result, all of the below result (Table 15) suggested that the matching algorithm chosen relatively for this study. Therefore, it is possible to proceed to estimate the average treatment effect on the treated (ATT) for the sample households.

Table 14: Performance criteria of matching algorithms

Outcome variable	Match algorithms (kind of matching)	Matched samples		ATT (Impact)	Bootstrapped Std. Err.	t-test
		Adopters	Non-adopters			
Milk yield	Kernel-based matching (KBM)	128	191	5701.92	1287.26	4.41***
	Nearest neighbor matching (NNM)	128	191	5701.92	1072.99	3.99***
	Radius matching (RM)	128	191	5701.92	1429.81	4.10***
Milk income	Kernel-based matching (KBM)	128	191	26050.79	5803.38	4.88***
	Nearest neighbor matching (NNM)	128	191	26050.79	6718.919	4.86***
	Radius matching (RM)	128	191	26050.79	4808.817	4.26***

Source: Computed from own survey (2021) Note: *** statistically significant at $p < 0.01$

In general, all the three matching methods revealed that, adopters of improved forage technologies have generated significantly higher output (milk yield litter/annum and milk income birr/annum) compared to the non-adopters households, with a statistically significant difference at ($p=0.01$) level. This implies that, better milk production and much better farm income were gained by adopting improved forage technology; which in turn encourages adoption of the improved forage technologies. Based on the study result, all of the below result (Table 15) suggested that the matching algorithm chosen relatively for this study. Therefore, it is possible to proceed to estimate the average treatment effect on the treated (ATT) for the sample households.

4.9. The impact of adoption of improved forage technologies on milk yield

The estimated average treatment effect (ATT) results of sample households found by using `psmatch2` revealed that adoption of improved forage technologies generated positive and statistically significant milk yield differences between treated and controlled group, measured in milk production (lit/annum). (Table 15) below shows that, the average treatment effect on the treated (ATT) of milk yield of adopters and non-adopters

for the production year of 2012/13 E.C had been 4241.23 milk yield (liters/annum) difference over the untreated is statistically significant at 5 % ($t = 2.49$; $P = 0.05$) probability level. In terms of the average yield (milk) of the treated and the non-treated, the psmatch2 result showed that, treated groups harvested average milk yield of 7760.02 (liters/annum), while the non-treated/ control/ groups harvested average milk yield of 3518.79 (liters/annum) which is also statistically significance at 5% ($t = 2.49$; $P = 0.05$) probability level. This suggests that improved forage technology adoption has increased the household milk yield by 29.32%. Therefore, intensification of improved forage technology should be given due emphasis in order to increase yields and improve dairy farmers' livelihoods. This confirm that, improved forage technologies worth adopting. Adopter participants in the focus group discussion/FGD/ indicated that, the cultivation/production of improved forage crops is very useful in a way that it is improving fertility of their soil, increasing dairy production and productivity, while also increasing their income and improving their livelihood. The result of the test indicated in (appendix 6).

Table 15: Estimation of ATT for milk Yield (lit/annum)

Outcome variable	Sample	Treated	Control	Difference	S.E.	T-stat
Yield (milk)	Unmatched	8264.75	2562.827	5701.92277	1033.4196	5.00
	ATT	7760.02	3518.793	4241.23276	1139.5171	2.49

Source: Computed from own survey (2021)

To supplement the impact study in addition to PSM method, regression adjustment has been employed and the estimated average treatment effect (ATET) results of sample households found by using regression adjustment revealed that adoption of improved forage technologies generated positive and statistically significant milk yield differences between treated and controlled group, measured in milk production (lit/annum) as depicted in (Table 16) below.

Table 16: Estimation of regression adjustment for milk Yield (lit/annum)

	Milk yield	Coef.	Robust Std. Err.	z	P> z
ATET					
	Adoption (Adopter vs Non adopter)	4308.87	1539.803	2.80	0.005
POmean					
	Adoption Non adopter	3955.88	814.2236	4.86	0.000

Source: Computed from own survey (2021).

4.10. The impact of adoption of improved forage technologies on farm income

The estimated average treatment effect on treated (ATT) of sample small holder households showed that, adoption of improved forage technology has strong positive significant effect on farm income too, measured in birr per annum. The ATT result found by using psmatch2 showed that adoption of improved forage technologies has created on average positive farm income differences between adopters and non- adopters . The (table 17 below) shows that, the average treatment effect on the treated (ATT) of farm income obtained from milk sale has 18,495.879 ETB difference over the controls. Similarly, just like the yield advantage seen above, the treated (adopters) are beneficiaries of economic advantage due to the adoption of improved forage technologies and their difference is statistically significant at 5% ($t = 2.02$; $P = 0.05$) probability level. In line with average annual income of the treated and the non-treated, the psmatch2 result showed that, treated groups earned average annual income of 41,970.146 ETB, from sale of milk commodity as adopters while, the control groups earned average annual income of 23,474.267 ETB, from sale of milk which is statistically significance at 5% ($t = 2.02$; $P = 0.05$) probability level. And this implies that improved forage technology adoption has increased the household farm income (income from milk sale) by 19.56 %. It can be seen that, both the yield and income result favored the treated groups who are adopters of the improved forage technologies.

Table 17: Estimation of ATT for Farm income (Birr/annum)

Outcome variable	Sample	Treated	Control	Difference	S.E.	T-stat
Farm income (milk sale birr/annum)	Unmatched	41042.9922	14992.19	26050.798	4966.261	5.25
	ATT	41970.1466	23474.26	18495.879	9175.714	2.02

Source: Computed from own survey (2021)

Hence, the study shows that, the non-adopters lose on two grounds: i) Adopters have better yield and income advantage over the non-adopters by adopting the improved forage technologies (as indicated in yield ATT section). Therefore, huge effort is needed from research and extension service in availing and diffusing new and improved forage crop varieties and technologies in order to generate additional income for smallholder dairy producers. The result of the ATT test indicated in (appendix 7).

Similarly, for farm income generated from sale of milk regression adjustment has been also employed to substantiate the PSM impact study method and The estimated average treatment effect on treated (ATET) results of sample households found by using regression adjustment revealed that adoption of improved forage technologies generated positive and statistically significant farm income differences between treated and controlled group, measured in (Birr/annum) as depicted in (Table 18) below.

Table 18: Estimation of regression adjustment for Farm income (Birr/annum)

Farm income(milk sale)	Coef.	Robust Std. Err.	z	P> z
ATET adoption				
(Adopter vs Non adopter)	15191.56	7515.397	2.02	0.043
POmean				
Adoption Non adopter	25851.43	5136.166	5.03	0.000

Source: Computed from own survey (2021)

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

The study was conducted with the main objective of evaluating the adoption of improved forage technologies and their impact on dairy productivity as well as farm household's welfare in Debre Libanose Woreda, North Shewa Zone of Oromia National Regional State. Adoption of improved forage technologies and their impacts on dairy productivity in the study area were not methodologically studied so far. This study is therefore initiated to fill this gap in the literature. Both primary and secondary data were used. A cross-sectional survey design and multi stage sampling procedures were employed. The sample selection method carried out for the study was the probability sampling proportional to size of the respondents. The primary data was mainly collected from 319 farm households living in three randomly selected kebeles. The samples were 128 improved forage technology adopters and 191 non-adopter households. Secondary data were collected from different sources. A structured questionnaire, focus group discussion and key informant interview were key data collection tools.

Descriptive and econometrics data analysis model were employed to analyzing the collected data. Binary logistic regression model estimation was executed to identify the factors influencing the improved forage technology adoption. Factor affecting and intensity was analyzed using Tobit regression model to analyze the current use of improved forage technologies. Whereas impact of technology on dairy productivity and household income was analyzed by using Propensity Score Matching Model since there was no baseline data. In addition to this, the characteristics of the households' were analyzed by using t-test and chi-square test for continuous and dummy variables respectively. Model specification tests include goodness of fit collinearity problem and matching quality test such as matching algorithms have been conducted.

The descriptive result showed that, from the total explanatory variables used, sex of the household head, age of the household head, education, access to inputs, livestock holding, training, extension contact, farm size and field day were the variables that showed significant relation with probabilities of adoption of improved forage crops and found to have significant difference between improved forage adopters and non-adopters.

The binary logistic regression result revealed that a total of ten explanatory variables were included into the econometric logit model out of which seven variables were found to be significantly influence probabilities of adoption of improved forage crops. These are age of household head , education of household head, market distance, extension contact, participation in training, field day and improved cattle ownership have positively and statistically significant effect to determine the household improved forage technology adoption status. Whereas, the remaining three explanatory variables had insignificant relationship with the household improved forage technology adoption.

Similarly, the result of Tobit model revealed that five out of ten explanatory variables were found to have significant effect on the extent of improved forage technology adoption. These variables were education of household head, market distance, extension contact; field day and improved cattle ownership are found to be affecting the extent of improved forage technology positively and significantly at 1%, 5% and 10% of probability level. In the same result, the rest of other variables were not found to have statistically significant effect on the extents of improved forage technology adoption.

Besides, the study evaluated the impact of adoption of improved forage technology on milk yield and on farm income. A propensity score matching (PSM) approach was employed to compare adopter households with non-adopters in terms of yield which is measured in (Liter/annum) and farm income which is measured in (Birr/annum). Finally the propensity score matching method generalized that the estimated ATT result found that adoption of improved forage technology had positive impact on treated farmers in terms of yield as well as income in the study area. Robustness of psmatch2 result was also checked by using different matching methods; such as: nearest neighbor matching,

kernel-based matching method and radius matching methods. In all the matching methods, average treatment effect (ATT) both on yield and farm income was found positive and strongly significant. Generally, main conclusions can be drawn from the results of this study that adoption of improved forage technology has a positive and significant impact on dairy productivity and household farm income to the group of farm households that did adopt than the group of farm households that did not adopt. Hence, encouraging farmers towards adoption of improved forage technology is necessary by properly addressing identified determinant factors.

5.2. Recommendations

Based on the empirical findings of this study, recommendations are suggested for future research, policy and development intervention activities to promote adoption of improved forage technology in order to improve dairy productivity and smallholder farmers' livelihood. Therefore, the following recommendations were generalized and forwarded based on results of this study:

- The results of this study revealed that Adopters have better yield and income advantage over the non-adopters by adopting the improved forage technologies. This implies that introducing and disseminating of appropriate improved forage technologies to smallholder farmers could improve dairy productivity and income of smallholder. Thus, huge effort is needed from key stakeholders like national and regional agricultural research institutes and extension service in availing and disseminating new improved forage crop varieties and technologies.
- According to the finding of this study, improved forage technologies adoption was positively and significantly affected by age of household head, education, extension contact, input access, training, participation in field day demonstration, distance to market and improved cattle ownership. Hence, future development intervention and the collective efforts of stakeholders should give emphasis to these variables in order to enhance the probability of adoption and strengthening intensity of use of improved forage technologies to enhance the livelihoods of farming households.

- Age of the household head affected participation in improved forage technologies positively and significantly. This result indicates that aged households are more likely to participate in improved forage technologies compared to younger household heads. Thus, the concerned stakeholders including development agents need to improve the awareness of the younger household heads using trainings and experience sharing to make them participate in improved forage technology and so as to benefit from it and improve their dairy productivity and livelihoods.
- The study result revealed that participation of households in different field day demonstration and access to extension service were influenced intensity of use of improved forage crops improved forage technology positively and significantly. Therefore, institutional support should be provided to this sub-sector in order to boost output and productivity, as the service provided is not at the expected level.
- The study finding indicated that improved cattle ownership positively and significantly influenced participation in improved forage technologies adoption in the study area. This means households who owned improved cattle's are more likely to participate in improved forage technology adoption compared to those households who owned local cattle's. Thus, governmental and non-governmental institutions and other stakeholders should promote improved cattle breed management to enhance improved forage technology adoption level in the study area.
- Finally, to mitigate adoption problems of improved forage technologies strongly requires lifting the entry barriers for participation of the private seed industry and encouraging the growth of the informal sector by providing adequate access to basic or foundation seed and extension advice on seed production and storage. The private sector lacks the incentive to participate in the enhanced delivery of seeds of such forages as the size of the market is small and farmers are able to use maintained and recycled seed for 3–5 years and strengthening the farmer based seed production program and revolving seed scheme by improving farmers' skills in seed multiplication can assist in increasing the supply of seed for improved forage varieties both within communities and to the formal seed system.

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Appendixes

Appendixes 1: Logistic model test (goodness of fit, linktest and VIF)

```
. estat gof
```

Logistic model for ADOPTION, goodness-of-fit test

```

number of observations =      319
number of covariate patterns =    247
Pearson chi2(236) =      389.53
Prob > chi2 =      0.858

```

Appendixes 2: Multicollinearity test (VIF)

```
. linktest
```

Source	SS	df	MS	Number of obs =	319
Model	41.452428	2	20.726214	F(2, 316) =	186.13
Residual	35.1870704	316	.111351489	Prob > F =	0.0000
				R-squared =	0.5409
				Adj R-squared =	0.5380
Total	76.6394984	318	.241004712	Root MSE =	.33369

ADOPTION	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
_hat	1.176405	.1449142	8.12	0.000	.8912863 1.461523
_hatsq	-.1781378	.1366122	-1.30	0.193	-.4469222 .0906465
_cons	-.0190598	.0315784	-0.60	0.547	-.0811903 .0430708

```
. estat vif
```

Variable	VIF	1/VIF
IMPROVEDCA~E	1.54	0.650242
FARMINCOME	1.52	0.656794
ACCESTOEXT~I	1.47	0.680220
FILEDAYDEMO	1.34	0.748792
AGEHH	1.28	0.780314
FARMSIZE	1.27	0.785888
EDUHH	1.26	0.792839
TRAINING	1.19	0.838974
SEXHHEAD	1.05	0.949852
DISTAWORMKT	1.02	0.976890
Mean VIF	1.29	

Multicollinearity Test (Contingency coefficient test)

```
. Pwcorr ADOPTION SEXHHEAD AGEHH EDUHH FARMSIZE DISTAWORMKT ACCESTOEXTESI TRAINING FILEDAYDEMO
IMPROVEDCATTLE FARMINCOME
```

	ADOPTION	SEXHHEAD	AGEHH	EDUHH	FARMSIZE	DISTAW-T	ACCEST-I
ADOPTION	1.0000						
SEXHHEAD	0.0191	1.0000					
AGEHH	0.0563	0.0302	1.0000				
EDUHH	0.1159	0.1255	0.3148	1.0000			
FARMSIZE	0.1154	0.0096	0.2724	0.1011	1.0000		
DISTAWORMKT	0.0593	0.1779	0.2620	0.1719	0.0215	1.0000	
ACCESTOEXT~I	0.1062	0.0667	0.0691	0.0826	0.1377	0.0859	1.0000
TRAINING	0.0928	0.0600	0.0024	0.1043	0.1163	0.0272	0.0042
FILEDAYDEMO	0.0633	0.0430	0.2745	0.1778	0.0501	0.0954	0.1936
IMPROVEDCA~E	0.0229	0.2483	0.2222	0.0689	0.2546	0.0341	0.0201
FARMINCOME	0.0886	0.0865	0.1260	0.2906	0.2335	0.0232	0.0936

	TRAINING	FILEDA-O	IMPRO~LE	FARMIN-E
TRAINING	1.0000			
FILEDAYDEMO	0.3404	1.0000		
IMPROVEDCA~E	0.1025	-0.0676	1.0000	
FARMINCOME	-0.0470	-0.0565	0.5320	1.0000

Appendixes 3: Regression estimation result for improved forage technology Adoption (marginaleffect)

```
. logistic ADOPTION SEXHHEAD AGEHH EDUHH FARMSIZE DISTAWORMKT ACCESTOEXTESI TRAINING FILEDAYDEMO IMPROVEDCATTLE FARMINCOME ,
> r
```

```
Logistic regression              Number of obs   =          319
                                Wald chi2(10)    =          78.36
                                Prob > chi2      =          0.0000
Log pseudolikelihood = -103.92288              Pseudo R2   =          0.5163
```

ADOPTION	Odds Ratio	Robust Std. Err.	z	P> z	[95% Conf. Interval]	
SEXHHEAD	.7511674	.4446473	-0.48	0.629	.2354372	2.396616
AGEHH	1.030092	.0167485	1.82	0.068	.997783	1.063447
EDUHH	1.610852	.3580113	2.15	0.032	1.042021	2.490204
FARMSIZE	.9738295	.1896029	-0.14	0.892	.6648987	1.426298
DISTAWORMKT	1.016346	.0065929	2.50	0.012	1.003506	1.02935
ACCESTOEXTESI	16.99779	9.304402	5.18	0.000	5.813723	49.69707
TRAINING	2.731436	1.194584	2.30	0.022	1.1591	6.436666
FILEDAYDEMO	16.3326	9.266719	4.92	0.000	5.371611	49.65995
IMPROVEDCATTLE	1.54224	.1279083	5.22	0.000	1.31086	1.814462
FARMINCOME	1.000003	2.99e-06	1.13	0.259	.9999975	1.000009
__cons	.0001724	.000294	-5.08	0.000	6.09e-06	.0048792

```
. mfx
```

```
Marginal effects after logistic
y = Pr(ADOPTION) (predict)
= .33229432
```

variable	dy/dx	Std. Err.	z	P> z	[95% C.I.]	x
SEXHHEAD*	-.065249	.13891	-0.47	0.639	-.33751 .207012	.818182
AGEHH	.0065782	.00368	1.79	0.074	-.000637 .013794	44.3417
EDUHH	.1057817	.05172	2.05	0.041	.004407 .207157	.815047
FARMSIZE	-.0058839	.04322	-0.14	0.892	-.090586 .078818	1.95374
DISTAW-T	.0035974	.00139	2.59	0.009	.00088 .006315	33.2414
ACCEST-I*	.5080644	.06412	7.92	0.000	.382392 .633736	.633229
TRAINING	.2229459	.09234	2.41	0.016	.041958 .403934	1.47335
FILEDA-O*	.6027121	.08763	6.88	0.000	.430962 .774463	.222571
IMPRO~LE	.0961242	.01813	5.30	0.000	.060587 .131662	4.31348
FARMIN-E	7.48e-07	.00000	1.13	0.259	-5.5e-07 2.0e-06	73159.6

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Appendixes 4: Regression Estimation result for Factors affecting the intensity use of improved forage technology (Tobit)

```
. tobit INTENSITY SEXHHEAD AGEHH EDUHH FARMSIZE DISTAWORMKT ACCESTOEXTESI TRAINING FILEDAYDEMO IMPROVEDCATTLE FARMINCOME, ll
```

```
Tobit regression                                Number of obs   =       319
                                                LR chi2(10)    =      168.80
                                                Prob > chi2    =      0.0000
Log likelihood = -129.28649                    Pseudo R2      =      0.3950
```

INTENSITY	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
SEXHHEAD	-.1095343	.07335	-1.49	0.136	-.2538628	.0347943
AGEHH	.0025707	.0026297	0.98	0.329	-.0026037	.007745
EDUHH	.1047785	.0354715	2.95	0.003	.0349823	.1745746
FARMSIZE	.03225	.032306	1.00	0.319	-.0313177	.0958176
DISTAWORMKT	.0023993	.0011319	2.12	0.035	.0001721	.0046265
ACCESTOEXTESI	.5013175	.08315	6.03	0.000	.3377056	.6649293
TRAINING	.0533578	.0602003	0.89	0.376	-.0650966	.1718122
FILEDAYDEMO	.1927861	.0648478	2.97	0.003	.065187	.3203853
IMPROVEDCATTLE	.0519982	.0110967	4.69	0.000	.0301637	.0738328
FARMINCOME	-1.07e-07	5.02e-07	-0.21	0.831	-1.09e-06	8.80e-07
_cons	-1.054023	.1990597	-5.30	0.000	-1.445707	-.6623391
/sigma	.3825875	.0271747			.3291167	.4360584

```
Obs. summary:      195 left-censored observations at INTENSITY<=0
                   124 uncensored observations
                   0 right-censored observations
```

Appendixes 5: Propensity score matching (PSM) for outcome variable (milk yield)

```
. psmatch2 ADOPTION SEXHHEAD AGEHH EDUHH FARMSIZE DISTAWORMKT ACCESTOEXTESI TRAINING FILEDAYDEMO IMPROVEDCATTLE FARMINCOME ,
> outcome ( milkyield ) common
```

```
Probit regression                                Number of obs   =       319
                                                LR chi2(10)    =      219.47
                                                Prob > chi2    =      0.0000
Log likelihood = -105.11518                    Pseudo R2      =      0.5108
```

ADOPTION	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
SEXHHEAD	-.122981	.2520964	-0.49	0.626	-.6170808	.3711188
AGEHH	.0168632	.0098397	1.71	0.087	-.0024222	.0361487
EDUHH	.2824132	.1231641	2.29	0.022	.041016	.5238104
FARMSIZE	-.0392576	.1190296	-0.33	0.742	-.2725514	.1940361
DISTAWORMKT	.0088351	.0040876	2.16	0.031	.0008235	.0168466
ACCESTOEXTESI	1.501237	.2644498	5.68	0.000	.9829246	2.019549
TRAINING	.4554027	.2159989	2.11	0.035	.0320526	.8787528
FILEDAYDEMO	1.531016	.2663857	5.75	0.000	1.00891	2.053122
IMPROVEDCATTLE	.2369878	.0427528	5.54	0.000	.1531939	.3207817
FARMINCOME	1.75e-06	1.85e-06	0.94	0.346	-1.89e-06	5.38e-06
_cons	-4.59559	.757911	-6.06	0.000	-6.081069	-3.110112

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
milkyield	Unmatched	8264.75	2562.82723	5701.92277	1139.51712	5.00
	ATT	7760.02586	3518.7931	4241.23276	1702.62191	2.49

Note: S.E. does not take into account that the propensity score is estimated.

Appendixes 6: Testing covariates

. pstest,graph both

Variable	Unmatched Matched	Mean		%bias	%reduct bias	t-test		V(T) / V(C)
		Treated	Control			t	p> t	
SEXHHEAD	U	.84375	.80105	11.2		0.97	0.073	.
	M	.83621	.56034	2.1	56.0	4.78	0.169	.
AGEHH	U	42.609	45.503	-23.9		-2.06	0.040	0.77
	M	42.069	39.595	10.4	14.5	1.68	0.193	0.98
EDUHH	U	1.1563	.58639	69.4		6.17	0.000	1.37
	M	1.1121	1.3448	-18.3	59.2	-2.04	0.143	1.11
FARMSIZE	U	2.2252	1.7718	50.6		4.46	0.000	1.13
	M	2.1701	2.3677	-2.0	56.4	-1.53	0.127	0.75
DISTAWORMKT	U	34.242	32.571	6.9		0.60	0.546	1.10
	M	33.845	25.474	4.4	40.8	2.77	0.672	1.37
ACCESTOEXTESI	U	.9375	.42932	130.1		10.75	0.000	.
	M	.93103	.94828	-4.4	96.6	-0.55	0.583	.
TRAINING	U	1.3672	1.5445	-36.1		-3.15	0.002	0.94
	M	1.3793	1.3017	15.8	56.2	1.25	0.214	1.12
FILEDAYDEMO	U	.5	.03665	122.2		11.60	0.000	.
	M	.46552	.36207	17.3	77.7	1.60	0.111	.
IMPROVEDCATTLE	U	6.2344	3.0262	116.3		10.39	0.000	1.49*
	M	5.6724	6.6379	-5.0	69.9	-2.88	0.454	0.77
FARMINCOME	U	1.0e+05	54517	71.6		6.44	0.000	1.74*
	M	93714	1.1e+05	-17.8	73.2	-1.32	0.189	1.05

* if variance ratio outside [0.71; 1.42] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.511	219.47	0.000	63.8	60.0	212.8*	1.46	29
Matched	0.001	52.70	0.874	4.3	3.7	24.0*	0.89	0

* if B>25%, R outside [0.5; 2]

Appendixes 7: Propensity score matching (PSM) for outcome variable (milk income)

```
. psmatch2 ADOPTION SEXHHEAD AGEHH EDUHH FARMSIZE DISTAWORMKT ACCESTOEXTESI TRAINING FILEDAYDEMO IMPROVEDCATTLE FARMINCOME ,
> outcome ( milkincome ) common
```

```
Probit regression               Number of obs   =       319
                               LR chi2(10)      =      219.47
                               Prob > chi2       =       0.0000
Log likelihood = -105.11518     Pseudo R2      =       0.5108
```

ADOPTION	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
SEXHHEAD	-.122981	.2520964	-0.49	0.626	-.6170808	.3711188
AGEHH	.0168632	.0098397	1.71	0.087	-.0024222	.0361487
EDUHH	.2824132	.1231641	2.29	0.022	.041016	.5238104
FARMSIZE	-.0392576	.1190296	-0.33	0.742	-.2725514	.1940361
DISTAWORMKT	.0088351	.0040876	2.16	0.031	.0008235	.0168466
ACCESTOEXTESI	1.501237	.2644498	5.68	0.000	.9829246	2.019549
TRAINING	.4554027	.2159989	2.11	0.035	.0320526	.8787528
FILEDAYDEMO	1.531016	.2663857	5.75	0.000	1.00891	2.053122
IMPROVEDCATTLE	.2369878	.0427528	5.54	0.000	.1531939	.3207817
FARMINCOME	1.75e-06	1.85e-06	0.94	0.346	-1.89e-06	5.38e-06
_cons	-4.59559	.757911	-6.06	0.000	-6.081069	-3.110112

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
milkincome	Unmatched	41042.9922	14992.1937	26050.7985	4966.26145	5.25
	ATT	41970.1466	23474.2672	18495.8793	9175.7145	2.02

Note: S.E. does not take into account that the propensity score is estimated.

Appendix 8: Matching algorithm for outcome variable (Milk yield)

Kernel matching (KM)

```
. attk milkyield ADOPTION ,comsup boot reps(50) dots logit
```

The program is searching for matches of each treated unit.
This operation may take a while.

ATT estimation with the Kernel Matching method

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	5701.923	.	.

Note: Analytical standard errors cannot be computed. Use
the bootstrap option to get bootstrapped standard errors.

Bootstrapping of standard errors

```
command:      attk milkyield ADOPTION      , pscore() comsup logit  bwidth(.06)
statistic:    r(attk)
(obs=319)
.....
```

Bootstrap statistics

Variable	Reps	Observed	Bias	Std. Err.	[95% Conf. Interval]		
bs1	50	5701.923	295.7825	1290.239	3109.091	8294.755	(N)
					3590.749	8562.136	(P)
					3519.975	8562.136	(BC)

N = normal, P = percentile, BC = bias-corrected

ATT estimation with the Kernel Matching method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	5701.923	1290.239	4.419

.

Nearest neighborhood matching (NNM)

```
. attnd milkyield ADOPTION ,comsup boot reps(50) dots logit
```

The program is searching the nearest neighbor of each treated unit.
This operation may take a while.

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	5701.923	1344.665	4.240

Note: the numbers of treated and controls refer to actual
nearest neighbour matches

Bootstrapping of standard errors

```
command: attnd milkyield ADOPTION , pscore() logit comsup
statistic: r(attnd)
(obs=319)
.....
```

Bootstrap statistics

Variable	Reps	Observed	Bias	Std. Err.	[95% Conf. Interval]		
bs1	50	5701.923	17.50874	1427.799	2832.654	8571.192	(N)
					3411.322	8828.914	(P)
					2852.853	8828.914	(BC)

N = normal, P = percentile, BC = bias-corrected

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	5701.923	1427.799	3.994

Note: the numbers of treated and controls refer to actual
nearest neighbour matches

.

Radius matching (RM)

```
. attr milkyield ADOPTION ,comsup boot reps(50) dots logit
```

The program is searching for matches of treated units within radius.
This operation may take a while.

ATT estimation with the Radius Matching method
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	5701.923	1344.665	4.240

Note: the numbers of treated and controls refer to actual
matches within radius

Bootstrapping of standard errors

```
command:      attr milkyield ADOPTION      , pscore() logit  comsup radius(.1)
statistic:    r(attr)
(obs=319)
.....
```

Bootstrap statistics

Variable	Reps	Observed	Bias	Std. Err.	[95% Conf. Interval]		
bs1	50	5701.923	95.29779	1387.803	2913.029	8490.817	(N)
					2807.923	8858.632	(P)
					2807.923	8858.632	(BC)

N = normal, P = percentile, BC = bias-corrected

ATT estimation with the Radius Matching method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	5701.923	1387.803	4.109

Note: the numbers of treated and controls refer to actual
matches within radius

Appendix 9: Matching algorithm for outcome variable (Milk income)

Kernel matching (KM)

```
. attk milkincome ADOPTION ,comsup boot reps(50) dots logit
```

The program is searching for matches of each treated unit.
This operation may take a while.

ATT estimation with the Kernel Matching method

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	26050.799	.	.

Note: Analytical standard errors cannot be computed. Use
the bootstrap option to get bootstrapped standard errors.

Bootstrapping of standard errors

```
command:      attk milkincome ADOPTION      , pscore() comsup logit      bwidth(.06)
statistic:    r(attk)
(obs=319)
.....
```

Bootstrap statistics

Variable	Reps	Observed	Bias	Std. Err.	[95% Conf. Interval]	
bs1	50	26050.8	-1011.96	5317.879	15364.12	36737.48 (N)
					17193.45	35200.14 (P)
					17193.45	36776.9 (BC)

N = normal, P = percentile, BC = bias-corrected

ATT estimation with the Kernel Matching method

Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	26050.799	5317.879	4.899

Nearest neighborhood matching (NNM)

```
. attnd milkincome ADOPTION ,comsup boot reps(50) dots logit
```

The program is searching the nearest neighbor of each treated unit.
This operation may take a while.

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	26050.798	5795.516	4.495

Note: the numbers of treated and controls refer to actual
nearest neighbour matches

Bootstrapping of standard errors

```
command:      attnd milkincome ADOPTION      , pscore() logit  comsup
statistic:    r(attnd)
(obs=319)
.....
```

Bootstrap statistics

Variable	Reps	Observed	Bias	Std. Err.	[95% Conf. Interval]		
bs1	50	26050.8	-1168.444	5355.998	15287.52	36814.08	(N)
					17282.24	36655.36	(P)
					19286.25	40242.11	(BC)

N = normal, P = percentile, BC = bias-corrected

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	26050.799	5355.998	4.864

Note: the numbers of treated and controls refer to actual
nearest neighbour matches

.

Radius matching (RM)

```
. attr milkincome ADOPTION ,comsup boot reps(50) dots logit
```

The program is searching for matches of treated units within radius.
This operation may take a while.

ATT estimation with the Radius Matching method
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	26050.798	5795.516	4.495

Note: the numbers of treated and controls refer to actual
matches within radius

Bootstrapping of standard errors

```
command:      attr milkincome ADOPTION      , pscore() logit  comsup radius(.1)
statistic:    r(attr)
(obs=319)
.....
```

Bootstrap statistics

Variable	Reps	Observed	Bias	Std. Err.	[95% Conf. Interval]		
bs1	50	26050.8	-383.3755	6102.042	13788.29	38313.31	(N)
					16497.87	40615.28	(P)
					18596.41	46898.02	(BC)

N = normal, P = percentile, BC = bias-corrected

ATT estimation with the Radius Matching method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
128	191	26050.799	6102.042	4.269

Note: the numbers of treated and controls refer to actual
matches within radius

.

Appendix 10: Conversion factors used to estimate Tropical Livestock Unit (TLU)

Livestock	Conversion factor
Cow	1
Ox	1
Bull	0.60
Heifer	0.75
Calves	0.20
Donkey/Mule	0.70
Horses	1.10
Shoats	0.13
Poultry	0.013

Source: Stock, et al., 1991

Appendix 11: Household questionnaire

Household Survey

Household ID-----

Questionnaires For: Improved Forage Technology Adoption and Its Impact on Smallholder Dairy Productivity: The Case of Debre Libanos Woreda, Oromia Region, Ethiopia

Instruction

- ⌚ Introduce yourself and get introduced with the respondent.
- ⌚ Tell to the respondent about the purpose of the study kindly and confirmed them that the Information that you give is strictly for academic purposes and will be treated with maximum Confidentiality. Thank you in advance for your cooperation.
- ⌚ Check that all questions are asked and responses are filled accordingly.

Date of the interview ----- (DD/MM/YYYY)	
Interviewer name	
Supervisor name	
Checked on (DD/MM/YYYY)	
Region :Oromia District :Debre Libanose Kebele :-----Village/Got-- ---	

Part one: Information on socio demographic characteristics of the household

1.	Respondent Name (can be head or HH members)	-----
2.	Respondent Category	1)Adopter /user 0) Non Adopter /Non user
3.	Sex of the household head	1= Male headed 0= Female headed
4.	Age of the household head	-----
5.	Education level of the household head	0=Not read and Write 1=Informal education 2=Formal education
	If yes, Q3 is formal, enter grade completed	-----
6.	Education level of the partner /spouse of the household head	0= not read and Write 1= informal education 2=Formal education
	If yes, Q4 is formal, enter grade completed	-----
	Maximum education level in the household	-----
7.	Marital status of the household head	1=Married 2=Divorced 3=Widow/widower 4=Never married 5. Other, specify.....

	Age category HH members	Number of persons	Number of household members engaged in forage production activity
1.	<7		----- per household
2.	7-14		
3.	15-64		
4.	>64		

Part two: Information on socioeconomic characteristics of the household

Q1- Information on experience of farming

1.	Experience of household in farming	-----in years	Remark
2.	Experience of household in improved dairy farming technologies	----- in years	
	1=Cross breed cow	----- in years	
	2=Artificial insemination (AI)	----- in years	
	3=Improved forage varieties	----- in years	
	4=Management (feeding)	----- in years	
	5=Health service	----- in years	

Q2- Information on land ownership and land size holding

	In Timad (ጥግድ)	In ha
1. Total land holding of household in last cropping season (2012/13)	-----	-----ha
1.1 Total crop land	-----	-----ha
1.2 Total wood land	-----	-----ha
1.3 Total grazing land	-----	-----ha
1.4 Total improved forage land	-----	-----ha
1.5 Total rented in land	-----	-----ha
Purpose of rented in land? 1. For crop production 2. For forage production	-----	-----ha
1.6 Total rented out land	-----	-----ha

Q3- Off-farm and Non-farm activity of the household members (Income obtained in 2012/13 E.C)

1.	Are you engaged in off-farm activity? 1=Yes 0=No	In Birr
	1.1 If yes, how much did you get from off-farm activity (income amount in annum)	-----
	Livelihood activities;	-----
	1.Petty trade (small shops)	-----
	2.Hiring out labor	-----
	3.Charcoal and firewood collection	-----
	4.Renting out animal drawn cart	-----
	5.Grain trading	-----

6. House rent income	-----
7. Remittance income	-----
8. Sale of handicraft	-----
9. Production and sale of beverages (local beer, tea, coffee)	-----
10. Livestock trading	-----
Others	-----
Total	-----

* If payments were made in kind, convert them to Birr at the prevailing price.

*(Non-farm income which framers received as wage or salary from nonfarm employment).
whereas, Off-farm income encompasses all agriculture-related activities that occur beyond the farm).*

HOUSEHOLD EXPENDITURES

Food Expenditure: Indicate the type and amount of expenditures of your family for the year 2012/2013E.C. We would like to ask you about all the food that was bought for consumption, own production and obtained from other relatives as gift/remittance for the last one month. Please do not include food bought for resale, even after processing.

I. Information On Household food expenditures of the year 2012/2013

Food type bought or Consumed during The year.	1. Bought/Consumed 1. Yes 2. No	2 How frequent does the Household buy/Receive/consume this item? 1. Daily 2. Weekly 3. Monthly 4. Yearly	3. Amount Purchased/Consumed during the year		4. Consumed from gift/remittance during the year	
			Amount (qt) or kg	Cost/Value (Birr)	Amount (qt) or kg	Cost/Value (Birr)
Maize						
Finger millet						
Wheat						
Teff						
Barely						
Pulses/oilcrops						
Chick pea						
Faba bean						
Filed pea						
Nug						
Ground nut						
Lentils						
Vetch						
Fruits						
Mango						
Lemon						
Papaya						
Avocado						
Banana						
Vegetables						

Tomato						
Onion						
Cabbage						
Garlic						
Pepper						
Coffee						
Tea						
Beef/meat						
Cow milk						
Butter						
Cheese						
Egg						
Potato						
Carrot						
Sugar						
Salt						
Breads/prepared						
food Oil						
Honey						
Biscuits						
Macaroni						
Soft Drinks						
Traditional alcohol						
Ranii						

II. Information Non-food expenditure of the year 2012/2013

Item	1.Bought/ consumed 1.Yes 2.No	2 How frequent does the HH buy or consume this item? 1. Daily 2. Weekly 3. Monthly 4. Yearly	Total Expendi ture (birr)
Privat goods			
Clothes and shoes			
Cosmetics/chief			
Entertainment			
Public goods			
Kitchen equipment			
Furniture			
Building material for house			
Ceremonial expense(wedding, funereal, birth etc)			

Donation to community, church			
Taxes			
Expense for traditional medicine			
Farm inputs purchased from own cash			
Farm implements			
Purchase of furushka			
Purchase of grain for livestock			
Salt for livestock			
Fuel (kerosene)			
Charcoal			
Fire wood			
Lighter/kibrite			
For Transportation of produce & human			
Permuz/small cooler can			
Soap			
Others specify			
Miscellaneous			

Q4- Information on current Livestock ownership of the household

		Do you own 1=Yes 0=No	Improved (Number per Household)	Local (Number per Household)	Total
1.	Milking cows				
2.	Non-Milking cow (mature)				
3.	Heifers				
4.	Calves				
5.	Bull				
6.	Oxen				
7.	Chicken				
8.	Fatten oxen				
9.	sheep				
10.	Goat				
11.	Mule				
12.	Horse				
13.	Donkey				

Q5- Information on Livestock production challenges (Rank in order of importance)

Type of challenges	(Rank 1-5)
Feed shortage	
Disease	
Poor breed performance	
Water shortage	
Market problem	

Others (specific)-----	
Do you often encounter feed shortage for your livestock? 1. Yes 2. No If yes, when?	----- ---
How do you cope up with feed shortage in your locality? (MP is possible) 1. Change feed resources based on availability and cost 2. Reduce herd size 3. Use crop/ food waste 4. Other specify	----- ----

Q6-Information on major crops grown and estimated yields in last year (2012/13 cropping season)

Type of crop	Area covered (timad/ha)	Estimated grain yield (in quintal)	Remark
wheat			
barley			
Teff			
Faba bean			
Filed pea			
maize			
Chick pea			
Others (specify)			

Q7 –Information on major feed resource of livestock and area coverage

1 .	What is the major source of feed in the area and area coverage	Rank	Area(plot, fence, number)
	Natural pastures		
	Crop residues		
	Crop aftermath		
	Hay		
	Browse plants		
	Industrial by products		
	Improved forages		
	Others		

Q8- Information on adoption

1.	Are you aware about improved forage crops? 1=Yes 0=No If yes, since when did you know about improved forage crops?	-----
	If no go to part three question	
2.	Are you using improved forage crops? 1=Yes 0=No If yes, since when did you start using improved forage crops?	----- -----

If you are not using why? (multiple answer possible) 1=Not aware 2=Land shortage 3=Unavailability of technologies 4=Cost of technologies 5=Not interested 6=Other specify.....	-----
---	---------------

Q9- Information on adoption and level of intensity on improved forage crops

1.	Adoption of improved forage											
	Have you ever planted improved forage crops?	1 =Yes	0= No									
2.	2.1 If yes, what are they? (multiple answer possible) 1.Feed oats 2.Vetch 3.Rhodes grass 4.Elephant grass ----- 5. Tree lucerne 6.Sesbainia sebabe 7.Alfalfa 8. Other ----- specify ----- 2.2 Level of use of improved forage technologies <table border="0" style="width: 100%;"> <tr> <td>0 =Very low</td> <td>1= Low</td> <td></td> </tr> <tr> <td>3= High</td> <td></td> <td>2=Med</td> </tr> <tr> <td></td> <td></td> <td>ium 4 = Very high</td> </tr> </table>			0 =Very low	1= Low		3= High		2=Med			ium 4 = Very high
0 =Very low	1= Low											
3= High		2=Med										
		ium 4 = Very high										
	2.3 Experience in growing forage? 1) < 1 years 2) 1- 5 years 3) 5-10 years 4) > ----- 10 years											
3.	3.1 List the common cultivated forages available and area coverage? (plot can be filed/ fences, number (for tree types) Hectare per-filed, and meter per-fence 1.Feed oats (የመኖ ሲናር) 2.Vetch (የመኖ ጓያ) 3.Elephant grass (የዝሆኔ ሣር) 4.Alfalafa 5.Rhodes Grass 6.sesbania sebabe Tree 7.Tree Lucerne 8.others	Type	Area coverage									
	-----	-----	-----									
	-----	-----	-----									
	-----	-----	-----									
	3.2 Where did you get these forage seed? 1) Gov't 2) NGO 3) Private 4) Others(Multiple answer is possible)											
	3.3 Which cropping system you adopted? Name intercropping in% of each Strategies , Backyard=1, irrigated=2 , alley=3, intercropping=4, under cropping=5, enclosures=6, swc structures=,7=hedge etc. (Multiple answer is Possible)											
	3.4 What propagation methods did you used? (MP is possible) (a)=seeds (b) =seedling c)=cutting (d)others specifies											
	3.5 Why did you decide to try it? because (1)It is drought resistance (2) It is high productivity (3) its palatability (4)Others specify (MP is possible)											
	3.6 If no, used why not you use improved forage crops? (1) Seed not available (2)Not heard introduction of it in to this area (3) Not good for feed for animals (4)Depletes the soil (5) Not good for											

	traditional feeding for animal (6) Current market price is not attractive (7)Others (MP is possible)	
	3.7 If you know improved forage crops how do you compare with substitute local feeds?(1)Better (2)Inferior (3)No change	-----
	3.8 For what purpose do you plant improved forage crop (1) Sell (2) feed for animal, (3)others specifies (MP is possible)	-----
	3.9 If you compare feeding to your animals its yields better for what Products? (1) Dairy (2) Fattening (3)others specifies (MP is possible)	-----
4.	Adoption of feeding improved forage crops (MP is Possible)	
	4.1 Did you feeding your livestock recommended feed? (Concentrates, improved forage and standardize crop and hay supplements).	1 =Yes 0= No
	4.2 What kind of fodder you have been feeding your livestock's	1=Forage legume 2=Standardize crop 3=Hay supplement
	4.3 Current level of use recommended feeding practice (forage legume, standard crop, hay supplement)	0 =Very low 1= Low 2=Medium 3= High 4 = Very high
	4.4 If you feed for dairy estimate milk produces litters per- day?	-----
	4.5 Would you meet animals feed requirement from your own production? (1)Yes (2) No	-----
	4.6 If you sell yours improved forage planted what you get from it in years 2012 to 2013 EC, Value of sold in birr and which forage type you sold	-----
	4.7 Have you increased market-oriented livestock product since, growing improved forage crops? (1) Yes, (2) No	-----
	4.8 If yes, what are the types of livestock product that you have sold? (1) Live animals (cattle Goat sheep etc.) (2)Milk liters (3) Butter _kg (4) others specifies (MP is possible)	-----

Q10 –perception of farmers on improved forage crops

Did you perceive any Advantage? Yes No	If yes, in what term? Tic on the provided space	
	Increased milk yield	
	Increased growth/fattening	
	Improved disease resistance	
	Improved breeding	
	Improved work/draft	
	Improved reproductive	
	Soil fertility improvement	
	Pest control	
	Others	

Q11, Constraints for forage production management and utilization

Do you face problem in forage production, management and utilization? 1) Yes 2) NO	Rank	Remark
If yes, rank them according to their importance. (from listed below)		
Land shortage		
Shortage of knowledge & Awareness		
Seed shortage		
Labor demanding		
Lack of capital		
Lack of input		
Low production		
Lack of credit		
Health bloating		

Part three: Information on factor determining the adoption of improved forage technology / institutional determinants of adoption/

Q1- Access to infrastructure and distance

1.	Do you sale milk, Butter, yogurt, feed and cheese? 1=Yes 0=No	
		In minutes of Walking distance (minutes)
2.	If yes, how far is the village market from your residence?	-----
3.	How far is the Woreda market place from your residence?	-----
4.	How far is the nearest farmer milk collection center from your residence?	-----
5.	How far is the nearest agricultural extension office from your residence?	-----

Q2- Social capital and Networking (multiple answers possible)

1.	Are you participate in any social institution in your village? 1=Yes 0=No	
	If yes, in which institution currently participated? 1= Agricultural cooperative 2= youth association 3=women association 4=multipurpose cooperatives 5=Water association 6= Equb 7= Edir 8=Other specify..... (MP is possible)	----- ----- ----- ----- ----- ----- -----

Q3- Cooperative or milk collection center (multiple answer possible)

1.	Is there any milk cooperative in your area? 1=Yes 0=No	
2.	If yes, are you a member of milk cooperative 1=Yes 0=No	
	2.1 If yes, what is the benefit from engaging in cooperative 1=Market access for dairy product 2=Less cost for dairy technologies 3=Access to dairy technologies (breed, feed) 4=Credit 5=Other specify.....	

Q4- Access to credit (multiple answer possible)

1.	Have you ever taken credit in the last 2years? 1=Yes 0=No	
	If yes, amount of credit that you taken	-----Birr
2.	For what purpose you take the credit? 1=To purchase cross breed cow 2=To purchase improved forage/pasture/ 3=For household consumption 4=Other specify....	-----

Q5- Access to input multiple answer possible)

1	Do you have access to forage technology input supply? 1=Yes 0=No	
	If yes, for which forage technologies 1=Improved forage seeds 2=inorganic fertilizer 3=forage planting materials 4=others	

Q6- Extension contacts multiple answer possible)

	Does an extension agent visit you for cases related to improved forage management? (MP is possible) 1=Yes 0=No	
1.	If yes, during which operation? 1= land preparation 2= planting/transplanting 3 = weeding 4= applying agro chemicals 5= watering 6= harvesting 7= Soil conservation advice 8= Animal production and forage development advice 9= to collect tax and other debts	
2.	If yes, how often the extension worker visits you in one month	-----times
3	Did your family members take training on forage crops? (1)Yes (2) No	-----
4.	How much training did you get in one month	-----times
5.	Have you ever attended any field demonstration day of improved forage crops? (1) Yes (2) No	-----times

Access to mass media : Indicate your access to and frequency of use of the following media on agricultural programs related to improved forage technology.

Mass Media	Do you have?		How often you use them for attending agricultural programs/obtaining messages				
	1=Yes	2=No	Never(1)	Rarely(2)	Occasionally(3)	ften(4)	Very often(5)
Radio							
Television							
others							

Q7 –Labour availability

	Do you have enough labor for accomplishing farming activities of forage on time? 1) yes and 2) no	
1	If the answer is no, which activities are most affected by labor shortage? 1) land preparation (Plowing) 2) Planting (sowing) 3) Weeding 4)Harvesting 5) in all times 6) others (specify)	----- ----
2	How do you overcome labor shortage? _____ 1. Family labor 2. Debo /Jigi/ 3. Hired labor 4. Family labor and hired labor 5= family labor and Debo /Jigi/ 6. Other,	----- -----
3	If you hire labor, how many laborers do you hire per year? _____	

Part four: Impact of forage on animal performance

Q1- 1.How do you describe the impact of feeding improved forage crops on your animals (1=very good, 2=good, 3=moderate, 4=low)?

Species	Impact on animals' production		
	Production level		
	Milk amount	Increasing Body	Health condition of
1.Feed oats (የመኖ ሲኖር)			
2.Vetch (የመኖ ጓያ)			
3.Elephant grass (የዝሆኔ ማር)			
4.Alfalafa			
5.Rhodes Grass			
6.sesbania sebabe Tree			
7.Tree Lucerne			
8.others			

Q2- Information on household source of income in year (multiple answer possible)

Source of income	Amount the household got/produced	Estimated price brought (Birr)
1. Crop production		
2. Livestock and their product sell		
3. Working on others farm (labor)		
4. Lease and land		
5. Sale of wood and charcoal		
6. Remittance		
7. Other specify.....		
Total income		

Checklists for Key Informants Interview (KII)

Please note that your insightful answers are crucial to our efforts in understanding overall assessment of adoption and impacts of improved forage technology to small holder dairy production and productivity.

1. Do many people participate in the agricultural extension services?
2. Do farmers participate in establishing improved forage crop technology?
 - 2.1. If yes, in what kinds of technologies? / improved feed,
3. What are the constraints for the adoption of improved forage crop technologies?
4. What the community members involved in improved forage extension (the rich/poor, female /male HHs, the literate/ illiterate, or other?)
5. Do improved forage technologies improve dairy sector production & productivity better than conventional feed sources? If yes how?
6. Do you farmers get sufficient extension service and training from GO & NGO?
 - 6.1. Is the improved forage technology profitable to farmers after participating in the technology?
7. What are the changes/ improvements/ you observed the impacts on household's status (dairy production and productivity patter)?
8. What intervention must be used for better implementation of improved forage technologies in the future to increase the level of adoption in the area?
9. Please mention all problems associated with improved forage production in the area?
10. Describe any social, economic and environmental problems in the district associated with improved forage technology adoption?
11. What potentials are there for improved forage technology extension in your area?

Check list for Focusing Group Discussion (FGD)

For extension agent

1. Did you know about improved forage concept?
2. What are the main constraints or challenges faced in the area during forage technologies transfer?
3. How is the improved forage adoption status of the household in the study area?
4. Which method you prefer to transfer improved forage technologies in the area?
5. Did you get on improved forage technologies and production related training?

For sample households

1. What is your perception on the improved forage technologies?
2. How do you express the nature of improved forage technologies?
3. Which improved forage technologies are difficult to adopt (production, forage, feeding)?
4. What kind of problem faced time of adopting improved forage technologies?

Thank you very much for your Genuine Information!