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Drivers to Adoption of Irrigated Fodder Technologies and Its Impact on þÿSmallholder Farmers Income: Evidence from Innovation Lab for Small-Scale Irrigation Project Sites, Ethiopia.

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M.Sc. Thesis

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THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. Sisay Getaneh entitled "drivers to adoption of irrigated fodder technologies and its impact on smallholder farmers' income: evidence from innovation lab for small-scale irrigation project sites, Ethiopia". We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Agricultural Economics.

Board of Examiners

Name of External Examiner ______________________ Signature __________Date____________

Name of Internal Examiner _______________________ Signature__________ Date___________

Name of chairman _______________________________Signature __________Date____________

DECLARATION

This is to certify that this thesis entitled "drivers to adoption of irrigated fodder technologies and its impact on smallholder farmers' income: evidence from innovation lab small-scale irrigation project sites, Ethiopia". Submitted in partial fulfillment of the requirements for the award of Master of Science in Agricultural Economics to the Graduate Program College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. Sisay Getaneh who is an authentic work carried out by himself under our guidance. The matter embodied in this thesis work has not been submitted earlier for the award of any degree or diploma to the best of our knowledge and belief.

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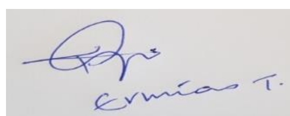
Name of the Advisor:



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Advisor	Signature	Date

DEDICATION

This thesis is dedicated to my parents Getaneh Teklie and Muluye Anteneh for their love, prayers, kindness, and endless support.

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ABSTRACT

The low livestock productivity and persistent food insecurity in Ethiopia are important development gaps that need context-specific technological interventions. One of the major causes of low livestock productivity is shortage of feed for year-round livestock feeding. Adoption of improved fodder technologies by smallholder farmers, especially the production of perennial forages with supplemental irrigation, is expected to improve feed resource availability and household income. However, the main drivers to the adoption of fodder technologies and the subsequent impact on income and livelihood of farmers are not well investigated in the smallholder system. Therefore, this study explored the driving factors that influence the adoption of irrigated fodder and estimated the resulting impact on household income. For the analysis, household-level data was obtained from 351 farm households, in the project intervention areas through purposive sampling with stratification. Both primary and secondary data were collected through interviews and scoping review. A probit model was employed to analyze the driving factors and the endogenous switching regression (ESR) model was used to estimate impact. Among the total sample, 51.57% were found to be adopters. The findings suggested that fodder adoption probability increases with irrigated land size, participation in dairy cooperatives, forage seed access, dairy farm experience, education, extension service, number of milking cows, training, and dairy cow breed type, while adoption was affected negatively by age, water use association, and distance to FTC. The ESR model result showed that the adopters' dairy income and total farm income had increased by 3,975.08 ETB[1]*, and 10,427.20 ETB respectively. Whereas non-adopters dairy income and household farm income are decreased by 3,044.41 ETB, and 35,994.58 ETB because of not adopting respectively. This study highlights the importance of strengthening dairy-cooperative and local forage seed production capabilities, as well as market linkage. A comprehensive and integrated approach is needed for better and widespread adoption. Besides, continuous capacity building and follow-up extension support are needed for the adopters to continue adopting and bring non-adopters to adopt the new practices.*

Keywords: *Livestock, irrigated fodder, adoption, impact, farmers, probit, ESR, Ethiopia.*

[1] ETB is Ethiopian birr currency (purchasing power parity) which is equivalent with 1USD = 40.25 ETB (March month, 2021).

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ABBREVIATIONS AND ACRONYMS

ADLI	Agricultural Development Lead Industry
ANRS	Amhara National Regional State
ARARI	Amhara Regional Agricultural Research Institute
ATA	Agricultural Transformation Agency
ATT	Average Treatment effect on the Treated
ATU	Average Treatment effect on Untreated
CSA	Central Statics Agency
DA	Development Agents
EIAR	Ethiopia Institute of Agricultural Research
ETB	Ethiopian Birr
ESR	Endogenous Switching Regression
FAO	Food Agriculture Organization
FGD	Focus Group Discussion
FRG	Farmer Research Group
FTC	Farmers Training Center
GDP	Gross Domestic Product
IALC	International associations of Livestock Conference
IFPR	International Food Production Research Institute
ILRI	International Livestock Research Institute
ILSSI	Feed the Future Innovation Lab for Small-Scale Irrigation
JICA	Japan International Cooperation Agency
MoA	Ministry of Agriculture
MoFED	Ministry of Finance and Economic Development
NGO	Non-Governmental Organizations
OECD	Organization for Economic Co-operation and Development
SRARI	South Region Agricultural Research Institute
TLU	Tropical Livestock Unit
USAID	United States Aid for International Development
VIF	Variance Inflation Factor
WEF	World Economic Forum
ZEF	The Center for Development Research

Chapter 1. INTRODUCTION

1.1. Background of the study

Ethiopia's economy is dependent on rain-fed agriculture. The sector contributes about 46.3% of the total gross domestic product (GDP), 60% of exports, and 80% of total employment (Yokamo Solomon, 2020). Smallholders drive their benefits either in cash from the sale of a product or through their consumption of agricultural products. The production system constitutes crop and livestock rearing accounting for 70%, and the pastoral production system accounts for 30% (IFPRI, 2018).

Ethiopia has the largest livestock population in Africa, and the livestock sector plays multiple roles in the Ethiopian economy as the majority of farmers own some livestock (Birara Endalew & Zemen Ayalew, 2016; Kebebe Ergano, 2015a). Nationally, livestock assets are valued at 720 USD per farm on average (IFPRI, 2018). Despite the large headcount livestock population in Ethiopia economic benefits derived from the sector is low (Yenesew Abebe *et al*., 2015; Zemedu Lemma *et al*, 2015). The low productivity and benefit of the sector are mainly due to the lack of improved breeds, inadequate improved feed supply, and poor livestock market chain (Bereket Dindamo *et al*., 2016; Melkamu Bezabih *et al*., 2016; Zemedu Lemma *et al*, 2015). Livestock production, in general, is an essential activity for achieving food security and enhancing household income-generating potential (Hintsa Hailesilassie *et al*, 2016).

Inadequate improved feed supply has remained to be the most limiting factor for livestock production (Asaminew Tassew, 2009). The major feed resources in most areas of Ethiopia are grazing land and crop residue which are poor in nutritional value (MoA and ILRI, 2013; Yisehak & Janssens, 2014). Particularly, quality feed shortage is the major constraint for the development of market-oriented livestock (ARARI, 2018; Firew Tegegne & Getnet Assefa, 2015). Livestock technologies, such as improved breeds and improved fodders, have the potential to improve the livelihoods of smallholders through higher yields, better household income, and improve nutrition (Neamn Gebreselassie, 2020; Kebebe Ergano, 2015a). Improving the quality and availability of fodder can play a great role in increasing livestock productivity, and the overall profitability of the mixed crop-livestock system (Gebregziabher Gebrehaweria *et al.*, 2014; Balana *et al.*, 2018).

In Ethiopia, during the last few decades, the national feed research program has developed, adapted, and recommended different forage cultivars with their agronomic practices to different agro-ecologies of the country (Aranguiz and Creemers, 2019; Esubdink Tekalign, 2014; Yokamo Solomon, 2020). However, the challenge for livestock producers in Ethiopia is still low adoption of forage grass such as desho (*Pennisetum glaucifolium*), vetch (*Vicia sativa*), *napier (Pennisetum purpureum)*, alfalfa, Rhodes, and desmodium (Kebebe Ergano, 2019). To ensure adoption and the economic impact of these fodder technologies, understanding the farming system and selecting a suitable promotion strategy have paramount importance (Gebregziabher Gebrehaweria *et al.*, 2014). The development of perennial improved fodder using supplemental irrigation and using it to feed productive dairy animals is proved to be an effective pathway (ILSSI, 2015; Wondatir Zewde & Damtew Elias, 2015).

In this respect, ILRI has been implementing irrigated fodder research and development under the Innovation Laboratory for Small Scale Irrigation (ILSSI) project in collaboration with ARARI, SARI, and Bahir Dar University since 2015. To pinpoint where to scale these practices were mapped areas suitable for desho (*Pennisetum glaucifolium*), vetch (*Vicia sativa*), *napier (Pennisetum purpureum)*, alfalfa, and desmodium fodders, taking into account factors such as climate, soil, infrastructure, and market access (ILSSI, 2018). Additionally, local interest also other criteria for project sites selection. Continuous engagement with farmers through on-farm trials and demonstrations piqued farmers' interest in irrigated fodder production. For instance, in the Robit Bata kebele of Bahir Dar Zuria district, 15 farmers participated in evaluating the quality of fodder during the first year of the project, in 2015. They allocated plots of land ranging between 50 and 140 m^2 per household for Napier grass production. The continued farmer participation and strong collaboration with local partners meant that more farmers adopted the practice, reaching 400 farmers by 2018, and with many households allocating as much as 1,000 m^2 for irrigated fodder (ILSSI, 2018). Similarly, more than 580 by 2018 farmers were reaching using irrigated fodder in Haysie, Jawe, and Kerekicho kebeles of project intervention area, South region.

Following on-farm trail, demonstrations, training, and practical exposures, farmers have started to adopt irrigated fodder in the project sites, by dedicating land which has been used to produce other cash crops, such as Khat. Farmers witnessed an increase in milk production as a result of the new practices (Michael and Abbera Adie, (2019). Taking into account the prevailing climatic uncertainties, with unpredictable patterns of temperature and rainfall, small-scale irrigated technologies are an essential strategy to sustain the income of farmers (Gebregziabher Gebrehaweria *et al*., 2014; Ademe Mihretu, and Lijalem Abebaw, 2019) (Melisse Birhanu, 2018; Keba Alemayehu, 2019). Thus, wider adoption of improved irrigated fodder is a continuous activity, perceived as a significant pathway because this enables to increase productivity and achieve food self-sufficiency (Guye & Sori, 2020).

However, the drivers and economic viability of the adoption of such technologies are not well known. Constraints to the adoption of technologies are mostly context-specific and it may that local farmers have no control over (Adane Hirpa *et al*., 2016). Even if there is no such specific study on the adoption of livestock feeds, ILRI's ILSSI intervention showed a promising prospect in the future to continue using new forage options with supplemental irrigation. On the other hand, since irrigated fodder production competes for resources with other farming practices, the adoption decision and continues using irrigated fodder depends on the economic impact and overall sustainability of the practice.

1.2. Statement of the problem

Agricultural technology generation is not an end goal by itself. Therefore, in the last two and more decades, the agriculture and development policy of Ethiopia has been geared to facilitate the efficient use of fodder grass such as desho (*Pennisetum glaucifolium*), vetch (*Vicia sativa*), *napier (Pennisetum purpureum)*, alfalfa, Rhodes and desmodium (MoFED, 2003; Diriba Welteji, 2018). So that they are widely practiced among smallholder farmers (Tewodros Assefa *et a1.*, 2016; Kebede Yohanss *et al.*, 1990). Following this, according to ATA and MoA, (2014), the research-based extension system has been promoting better adoption of improved technologies.

However, achieving wider adoption is not an easy task due to heterogeneous factors (Hall, 2002; Khanal *et al.*, 2010; Takahashi *et al.*, 2020). Glover *et al.*, (2016) and ATA & MoA, (2014) showed that farming systems, extension services, and attribution of the technologies are the main problems for low adoption. Similarly human capital, institutional, and policy variables are also influencing the adoption and decisions of household farmers (Rovere *et al.*, 2010; Rahman & Daniel Chima, 2015). This is because the technology adoption process starts from the view of the farmer, looking beyond the initial decision to adopt or not also incorporating the farmer's effective and profitable use of the technology (Getnet Kindie *et al.*, 2017; ZEF, 2012).

The use of irrigated forages such as Napier grass, Rhodes grass, Alfalfa, desmodium, and Susbania are not common and the concentration of feeding is generally low in Ethiopia. Major feed resources in the ILSSI intervention sites are traditional mostly crop residues, natural pasture, hay, and grazing its nutritional value is low (ILRI, 2014; Mengistu Alemayehu *et al.*, 2016). Even though, feed shortages happen both in the dry and wet season the practice of growing irrigated fodder technologies for livestock feed did not apply (Wondatir Zewdie *et al.*, 2015a; Wondatir Zewdie & Damtew Elias, 2015b). To overcome the seasonal shortage of feed, the farmers used their adapting strategies by conserving feed in the form of hay and storing crops (Asaminew Tassew, 2009). Despite the nutritional value of crop residues has very low; hence, the product value generated from the sector has been too small (Mulubrhan Balehegn, 2019; Melkamu Bezabih *et al*, 2020).

To solve such problems, the use of irrigated fodder production has been demonstrated and promoted to the farming community by ILRI ILSSIs project. Because irrigated fodder help to mitigate critical feed shortage challenge during dry season by providing fresh grass to dairy cows which is highly palatable and digestible and it improves milk yield. Furthermore, the quality of fodder is higher under irrigated production than rain fed/i.e. it is less watery/. The relative advantage of irrigated fodder is rain is not available all year round so the land and family labor stay without profit during the dry season. Rain inconsistency/dry spells, shortage of rainy season/period, and unpredictability are also challenging. Based on this fact, although from the total household farmers in each intervention kebele Haysie (18%), Jawe (22.9%), Kerekicho (37.97%), and Robit Bata (28.31%) of household farmers have used the new practice, the rests have not adopting the technology. This indicated that information is lacking why some farmers are easily adopting and using the technology and why others are not despite being engaged and exposed to the technology. It is known that area-specific factors like socioeconomics, institutional, and technologies attribution are influencing adoption (Mozzato *et al*., 2018; OECD, 2001). Hence, this study aims to explore the driver to the adoption of irrigated fodder production and its impact on smallholder farmers' income in the ILSSI project sites.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study was to evaluate drivers and impacts of irrigated fodder technologies' adoption on smallholder farmers' income in Ethiopia.

1.3.2. Specific objectives

The specific objectives of the study are the following:

1. Analyze the factors affecting irrigated fodder technology adoption.
2. Analyze the impact of irrigated fodder technologies on households' income.

1.4. Research questions

1. What factors are driving the adoption of irrigated fodder technologies?
2. Does adopting irrigated fodder have an impact on household income?

1.5. Significance of the Study

The Ethiopian government has been engaged in the different agricultural development policies issued by the country. Irrigation development is one of the strategies in the development plan. However, the irrigated fodder technology research and extension are not currently well aligned with crop and livestock integration. Because of the current need for attaining food self-sufficiency in Ethiopia, irrigation potential areas are one of the entry points to fulfill this requirement.

Hence, the findings of this study will be consulted for the planning of small-scale irrigation integrated with forage and dairy farm development activities of districts, zones, and regions with similar agro-ecological and socioeconomic settings as of the project sites. The study findings can also be used as reference material for similar studies.

1.6. Scope and Limitation of the Study

In terms of geographical coverage, the study was conducted across two regions of the country level the ILSSI project is implemented by ILRI and its partners. As the intervention has targeted smallholder farmers, the study also focused on smallholder farmers' adoption driving factors, and the impact on dairy and household income. Although the study was conducted across two regions, it was limited to project intervention sites.

1.7. Organization of the study

The study is organized into five chapters. The first chapter consists of the introduction part which deals with the background, statement of the problem, objective, research questions, scope and limitation, and significance of the study. The second chapter presents the theoretical and empirical literature reviews and conceptual framework used in the study. The third chapter describes the methodology of the study as a whole. The fourth chapter deals with the result and discussion of the study. Finally, the conclusion and recommendations are presented in the fifth section.

Chapter 2. LITERATURE REVIEW

2.1. Basic concepts and theoretical definitions

Technology: It is compatible with resources, such as labor, skills, materials, and capital, available to target farmers and products that are suited to the targeted community as well as the market (JICA, 2015; IALC, 2005). It is also referred to as the applying of knowledge and skill to the practical objectives of a human being's life or changing and manipulating the surrounding environment (Wadsworth, 2005).

Agricultural technology development: It may include demonstration and implementation of new fodder production, small-scale irrigation enhancement, genetically breed, greenhouse technology, inorganic fertilizers, pathological technologies, and the application of other scientific expertise and skills (Melisse Birhanu, 2018). Agricultural technology advancement is a necessary strategy for enhancing agricultural productivity, attaining food security, and reducing the poverty among small-scale farmers in Ethiopia (Feyisa Bekele, 2020b).

Small-scale irrigation: Defined as irrigation, usually on small plots, in which small farmers have the controlling influence, using a level of technology which they can operate and maintain effectively. Irrigation is one way to increased agricultural production to meet the world's rising food demands (Beyan *et al*., 2014). In Ethiopia's highland, small-scale irrigation has the potential to promote the intensification of the crop-livestock system (ILSSI, 2014; Gebregziabher Geberhawaria *et al*., 2009). It makes a significant contribution to agriculture sector growth including livestock and plays much to the national economic development (Sileshi Bekele, 2010). It also ensures the cultivation of suitable multiple forage and crop practices in a season.

Fodder production: Fodders crops are cultivated plant species that are utilized as livestock feed. It also refers mostly the crops which are harvested and used for animal feed. Fodder production and its consumption are influenced by cropping patterns, climate, socio-economic conditions, and type of livestock (Yenesew Abebe *et al.*, 2015). Crop residues planted fodder, and fodder from common property resources like forests, permanent pastures, and grazing lands are the three major sources of fodder supply (Mishra *et al.*, 2015; Mulubrhan Balehegn *et al.*, 2019).

Agricultural technologies dissemination: This is a process that involves passing innovative technologies from the area to the end-user (JICA, 2015; IALC, 2005). It requires the farmers to have certain scientific and technological knowledge and skills (Gatzweiler & Von Braun, 2016).

Irrigated fodder technologies: Considering the lack of green fodder during dry periods irrigation alongside food crops is not widely practiced to produced improved forage (Gebregziabher Geberhawaria *et al.*, 2009). This is probably because of a shortage of awareness or the impression that the production of fodder using irrigation is not economically attractive (Melkamu Bezabih *et al.*, 2016). According to Hintsa Hailesilassie *et al*, (2016), the feed resources available to livestock in most areas of Ethiopia is crop-residue, natural pasture, weeds, and improved fodder crops dominantly oat-vetch through the cut and carry system.

Adoption: It is described as the making combination of new innovative technologies into farmers' normal farming activities over an extended time (Melisse Birhanu, 2018). Even though, Adoption is not a permanent behavior, which may be changed after a certain year (Rogers *et al*., 2003). According to Melisse Birhanu, (2018), and Dontsop Nguezet *et al.*, (2010) adoption at the individual farmers' level is defined as the degree of use of new technology in long-run equilibrium when the farmer has full information about the new technology and its potential. According to Rogers *et al.*, (2003), the main farmers in the diffusion of innovations theory are innovator, early adopter, early majority, late majority, and laggards. The rate of adoption is the relative speed with which an innovation is adopted by members of a social system (Rogers *et al.*, 2003). Diffusion of adoption is the process by which the innovation spreads to the member of the social system (IALC, 2005).

Impact of technology intervention: An impact intervention is the changes in the well-being of individuals that can be attributed to a particular project, program, or policy (FAO, 2009). Interventions in agriculture's new technologies lead to a shift in food production, production variability, dietary variety, labor productivity, and profitability (Paul J. *et al*, 2016).

Effectiveness evidence from interventions is that takes place in normal circumstances, using regular implementation channels and aim to produce findings that can be generalized to a large population.

Farm income: It refers to benefits and losses that are obtained through the conduction of agriculture (Mango *et al*., 2018). Farm income generation simply means gaining or increasing income or money that households receive from new intervention agricultural technologies or in exchange for providing a good or service after investing capital (Onyebu, 2016).

2.2. Overview of livestock production in Ethiopia

Despite Ethiopia has the leading livestock populations by number in Africa, it lacks modern and improved livestock feeding practices. As a result, current livestock productivity is poor, while the cattle population continues to rapidly increase in both the highlands and lowlands of the country (Sircely & Eba, 2020). Based on Getnet Assefa *et al.*, (2017), studies livestock production is essential for improving households' nutrition and used as wealth accumulation and prestige. However, there are serious issues with livestock development, for instance, artificial insemination, lack of improved cattle breeds, drug resistance problem, shortage of feed, zero-grazing use adverse effect on small ruminant and equine production, and lack of market facilities (ARARI, 2018).

According to FAO, (2019) projection, the future livestock sector will undergo significant changes to respond to the rising demands. FAO predicts the population of livestock is increased by 80% and the demand for livestock products will be raised. By 2050 the majority of livestock products will be sold and consumed in cities. The consumption of livestock will be changed by 200% like beef, milk, and poultry meat, and also milk consumption by 100% (FAO, 2019). However, changed rainfall patterns and more frequent severe weather events will make livestock production increasingly challenging.

Additionally based on CSA and FAO information from 1970 to 2015 is shown that the livestock population in Ethiopia continues to grow. From 1970 to 2015 the cattle population grew from 26.2 million to over 57.8 million. The livestock population of the country will continue to grow. In 2024/25 the cattle, sheep, and goat population in Ethiopia are estimated to reach 75, 42.8, and 39.6 million heads, respectively. The mid-year cattle, sheep, goat, poultry camel, and equines population of the country from 1970 to 2015 is presented in Graph 1.

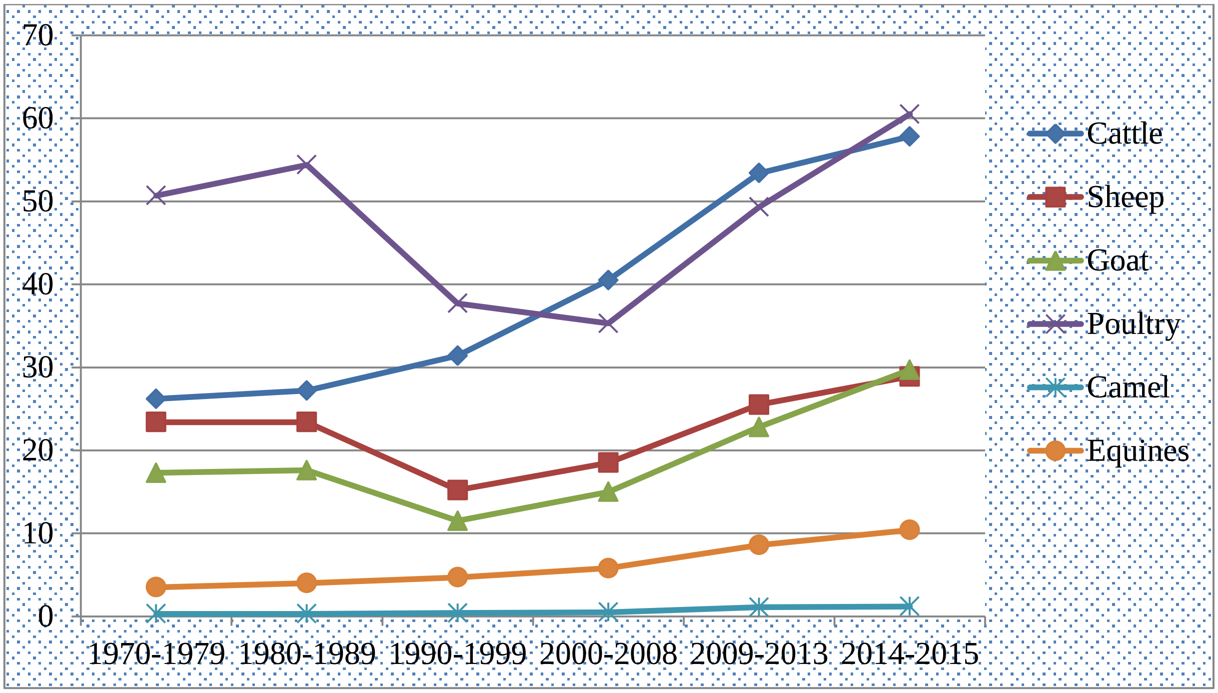

Figure 1.Cattle, sheep, goat, poultry, camel, and equines population growth trend in millions
Source: Own analyses using CSA data from 2005-2016 and FAO http://faostat.fao.org/

2.2.1. Utilization of Livestock products in Ethiopia

Despite, Ethiopia having large livestock populations; the overall contribution of livestock products to households' daily consumption is very limited. The average per capita annual consumption of meat and dairy products is just 4.6 kg and 16.7 kg, respectively (Kibrom Tafere & Ebrahim Worku, 2012). According to the survey report of CSA, (2020), from the total annual milk production, 50% is used for household consumption, 10% is sold, only 0.56% is used for wages in kind and the rest 39% is used for other purposes. Concerning the utilization of butter, 55% of the produce is used for household consumption although a considerable portion 39% is sold. Given recent income growth, there is potential for growth in the demand for livestock products. Using reasonable assumptions on income growth, urbanization, prices, and marketization, Abegaz Getachew *et al.*, (2018) projected that national animal source food consumption and commercial markets will increase by 165% and 192% by 2030 respectively and that the size of urban commercial markets will quadruple by 2030.

However, to convince that this enhanced local demand can be met by local supply, rather than imports. This implies more attention will be needed to be paid to livestock-related investments, such as increased adoption of improved animal husbandry practices and improved feeding cultivation, and the facilitation of an enabling environment that will allow for productive livestock markets (Abegaz Getachew *et al.*, 2018; Bimrew Asmare *et al*, 2016; Kibrom Tafere & Ebrahim Worku, 2012; Wondatir Zewdie *et al.*, 2015).

2.2.2. Constraints for livestock production in Ethiopia

Based on the reports of ARARI, (2018) farming system survey, livestock productions are constrained by the frequent occurrence of animal disease, lack of adoption of improved forage, lack of improved forage variety, lack of feed improvement technologies, training delivery is not based on gap assessment and also no ex-post assessment, high feed cost and lack of training, and shortage of pure water. Tibbo M, (2000) agreed, with ARARI, (2018) survey report, making through participatory rural appraisal method, that the overall livestock production problems expressed. In Ethiopia, as in many other countries, livestock productivity is constrained by the insufficient year-round availability of good-quality feed. This leads to inefficient production, overgrazing, environmental degradation, and low returns to producers, a sector that is unable to feed the livestock needed to meet demands for livestock products (ILRI, 2020).

2.3. Livestock fodder production in Ethiopia

Cultivated forages such as grasses, legumes forage and browse trees and shrubs are promising ways to properly and sustainably feed Ethiopia’s livestock. It contributes to food security, livelihoods, economic growth, and environmental policy goals (ILRI, 2020). The wide uptake of forage crops and grasses is held back by a lack of affordable quality-assured seeds as well as low market demand, especially from subsistence producers (Wondatir Zewdie *et al.*, 2015). According to the report of ILRI, (2014) and Getnet Assefa *et al.*, (2017) study, as the livestock sector becomes more commercial, demand for high-quality feeds will increase in response to demand for forages and business opportunities in the sub-sector. Introducing appropriate quality assurance mechanisms for forage technologies and seed is a key step in driving the uptake and use of forage crops and grass and will ultimately help stimulate a thriving forage seed sub-sector (Firew Tegegne & Getnet Assefa, 2015). Currently, the main sources of livestock feed are natural grazing pastures, poor-quality, and crop residues (Yenesew Abebe *et al., 2015*).

Major feed resources in Ethiopia include natural pasture, crop residues, collected fodders, agro-industrial byproducts, multipurpose trees and shrubs, stubble grazing, cultivated forage, and conserved forages. The contribution of these resources varies depending on agroecology, season, and farming system. Descriptions of some of the most common feed resources in Ethiopia are listed below in the Figure 2.

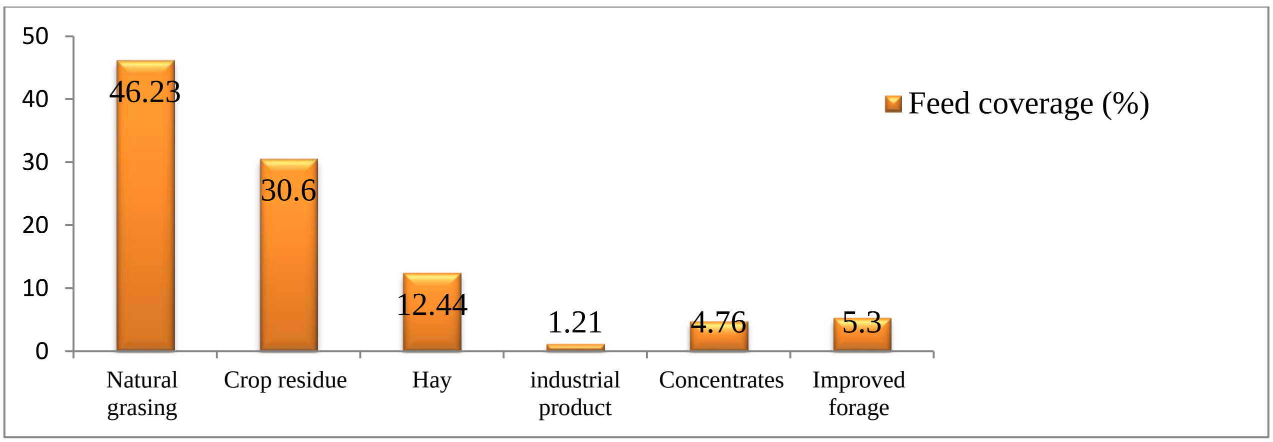

Figure 2**.** Coverage in proportion of animal feed resources in Ethiopia
Source: Shimelis Mengist, (2018)

2.4. Adoption of livestock fodder technologies in Ethiopia

The growing demand for milk products in Ethiopia is widely recognized, the dairy sector has not been able to produce adequate milk to satisfy this demand, mainly due to the low feed supply and its poor quality (Kebebe Ergano, 2015; ILRI, 2014). The use of technological inputs, such as the cultivation of improved forages and improved breeds of dairy cows is often seen as a prerequisite to increasing livestock productivity and resource use efficiency in the smallholder dairy sector (Kebebe Ergano, 2015b).

The use of cultivated fodder such as Napier grass, forage legumes, and multipurpose trees by small householders is an intervention in different stockholders and research institutions in Ethiopia to solve the feeding problem of livestock (Mulubrhan Balehegn, 2019). However, the adoption of such technologies has been low, despite numerous efforts to disseminate the technologies in the past. This poses a question as to why the majority of smallholders have not adopted livestock technologies in the Ethiopian highlands including the Amhara and SNNPR regions (Kebebe Ergano, 2015b). Adopting small-scale irrigation fodder technology may improve production, productivity, income, and access to food for farm households and also be used for forage production (Belete Belainew & Melak Surafel, 2018). However, evidence on the nutritional outcomes of small-scale irrigation fodder technologies is quite scant in Ethiopia.

2.5. Adoption of technology package versus single technology

In efforts to increase agricultural productivity, researchers and extension agents in developing countries have typically promoted a technological package consisting of several components such as variety, fertilizer, planting method, pesticide, insecticide, and weed control. Proponents of the package approach argue that a package is needed to capture the positive interactions between several components. A package may also provide a convincing effect to farmers by emphasizing the large yield difference between traditional and improved practices (Byerlee & Polanco, 1986).

However, because of capital scarcity and risk considerations, farmers are rarely in a position to adopt complete packages. Based on the study of Ayele Seife *et al.*, (2001) adoption is gradual may evolve starting from components to the full package as a whole depending on the farmer's knowledge, needs, and resource conditions. Experience also indicates that technology adoption is not a one-off static decision rather it involves a dynamic process in which information gathering, learning, and experience play pivotal roles particularly in the early stage of adoption (Ayele Seife, 2009). Farmers move from learning to adoption to continuous or discontinuous use over time. Aldana *et al*., (2011) the sequencing of adoption of a packaging technology has important implications for both the introduction of new technologies to the market and the industrial organization of the market for new technologies.

2.6. Emerging adoption challenges in the current livestock sub-systems of Ethiopia

Nowadays climate change/variability is one main emerging adoption challenge in the livestock production system in addition to feeding shortage, animal health, and adaptive breed. As indicated by Easter *et al.*, (2018) agricultural experts and farmers perceive climate change and stated that the temperature, rainfall pattern, groundwater table, and water recharges changed through time everywhere. They clearly understand late entry and early withdraw of rainfall, rainfall distribution reduction, and high rainfall intensity (Ashley *et al*., 2018). This is a constraint to adopt developed livestock technologies by extreme variation of climate/weather. Livestock production is likely to be increasingly affected by carbon constraints and environmental and animal welfare legislation (Thornton, 2010).

Daily market price fluctuation is also another challenge for adopting livestock farming technologies. Seasonal fluctuations in ingredients and compound feed prices and poor livestock marketing systems are common in Ethiopia (MoA & ILRI, 2013). This is because price fluctuation is mostly determined by brokers and their role is unrestricted. The price falls at the peak production period and rises at the slack production period; there is a wide price gap between peak season and slack season. Additionally, no more value addition on milk and milk products but is necessary, due to the absence of agro-processing industries. Market problems are also emanating from supply-side decisions. In general, there is a lack of channel marketing strategies and viable value propositions for new livestock technology adoption (https://www.farmprogress.com/irrigation-systems/challenges-opportunities-ag-techadoption).

Livestock production technologies developed by biological researchers response need to be assessed the economic feasibility before embarking on their large-scale dissemination to the farming communities. On-farm testing of animal production technologies in a participatory manner with the farming communities is critical to facilitate the adoption of available animal production technologies (MoA & ILRI, 2013). Likely, the reality may not as such and farmers will not be interested in these technologies if the relative advantage of the improved technologies is not economically feasible compared to farmers used previously.

In recent decades, there has been a rapid shift in livestock breeds used in developing countries, leading to a loss of local genetic resources. The introduction of high-performing livestock breeds might, however, offer opportunities to improve the income of poor livestock keepers. Animal diseases generate a wide range of biophysical and socio-economic impacts that may be both direct and indirect (Thornton, 2010). This means that the new technologies are most susceptible to diseases; this may be a challenge for adoption.

2.7. Introduction to basic issues of impact evaluation

2.7.1. Concept of impact evaluation

Several approaches can be used to evaluate programs. Monitoring tracks key indicators of progress throughout a program as a basis on which to evaluate outcomes of the intervention. The operational evaluation examines how effectively programs were implemented and whether there are gaps between planned and realized outcomes. In contradicting impact evaluation studies whether the changes in well-being are indeed due to the program intervention and not to other factors (Shahidur R. *et al*, 2010).

These evaluation approaches can be conducted using quantitative methods (that is, survey data collection or simulations) before or after a program is introduced. Ex-ante evaluation predicts program impacts using data before the program intervention, whereas ex-post evaluation examines outcomes after programs have been implemented. Reflexive comparisons are a type of ex-post evaluation; they examine program impacts through the difference in participant outcomes before and after program implementation. The main challenge across different types of impact evaluation is to find a good counterfactual namely, the situation a participating subject would have experienced had he or she not been exposed to the program (Shahidur R. *et al*, 2010).

An impact evaluation is a process of examining the extent to which a program has caused desired changes on the participants. It is concerned with sorting out the net impact of an intervention on the participants that can be attributable solely to that specific intervention (Mamo T, 2011). Programs and policies are designed to achieve a certain goal (Paul J. *et al*, 2016). The primary purpose of impact assessment is to determine whether a program has an impact on key outcomes, and more specifically to quantify how large that impact is (Takavarasha *et al.*, 2013). It is the act of assessing outcomes in the short, medium, or long term change due to an intervention.

2.7.2. Impact assessment of livestock technologies

Decision-making by everyone from national policymakers to international aid organizations looking to allocate scarce resources to meeting goals for global development will be confronted with a myriad of options (FAO, 2009; Paul J. *et al*, 2016). These goals are typically improved livelihoods, food security, and economic growth but also complementary aims related to gender, equity, and environmental sustainability (Bahta *et al.*, 2019). Key decisions often need to be taken about which goals to prioritize when they cannot be simultaneously achieved, and for whom. In livestock sector development, some investments may particularly favor capital intensive systems and large private sector interests, such as promoting livestock exports but may not be effective in reducing rural poverty or supporting gender equity (Bahta *et al*., 2019).

Ex-ante impact assessments of international agricultural and livestock research have transitioned from a somewhat narrow focus mainly on economic returns to better capturing of social goals related to poverty and hunger reduction, improved nutrition and health, employment generation, and climate action such as are embodied in the sustainable development goals (Bahta *et al*., 2019).

2.7.3. Impact evaluation approach

According to Mulubrhan Amare *et al*., (2012) estimation of the impact of technology adoption on household welfare outcome variables based on non-experimental observations is not trivial because of the need for finding counterfactual of intervention. The observed one is the outcome variable for adopters, in the case that they did not adopt. That is, we do not observe the outcome variables of households that adopt, had they not adopted, or the converse.

According to Ebrahim, (2019) improved technologies are not randomly distributed to the two groups of households as users and non-users, but rather to the household itself deciding to use given the information, it has, therefore the two groups may be systematically different. Estimation of the impact of improved technologies adoption on farm household nutrition based on non-experimental observations is significant because of the need of finding a counterfactual of intervention.

According to Minale Kassie, (2013), training material information's the soundness of the impact estimates depends on how justifiable the assumptions are on the comparability of participant and control groups, and the exogeneity of a program targeting across treated and untreated areas. How to evaluate impact then answered by randomized evaluations, matching methods, e.g., propensity score matching, double-difference, instrumental variable, regression discontinuity, design and pipeline methods, distributional impacts, structural and other modeling approaches. To address these missing counterfactual most scholars use propensity score matching (PSM), endogenous switching regression (ESR), and difference in difference methods for impact analysis.

Propensity Score Matching (PSM) approach: It is constructed a statistical comparison group by modeling the probability of participating in the program based on observed characteristics unaffected by the program. Participants are then matched based on this probability, or propensity score, to non-participants, using different matched methods.

The average treatment effect of the program is then calculated as the mean difference in outcomes across these two groups. On its own, PSM is useful when only observed characteristics are believed to affect program participation. The propensity score matching method is a commonly used non-experimental approach. It helps to control pre-intervention differences on the covariates. This theoretical procedure how impact estimate using PSM was stated by (Dehejia, 2005; Zhang *et al*., 2014; Zhou *et al*., 2017; Grilli *et al*., 2017).

As mostly stated in the underlying assumption is that conditional on the propensity score to overcome the potential source of bias, induced treated households and non-treated households become comparable (Abadie et al., 2003; Michels & Braunwald, 2002). However, the PSM approach has limitations like, selection on unobservable happens, geographic difference, different survey instruments, performs best in large samples, and treatment and control groups should have substantial overlap.

Difference in difference method: The estimator relies on a comparison of participants and non-participants before and after the intervention. For example, after an initial baseline survey of both non-participants and subsequent participants, a follow-up survey can be conducted of both groups after the intervention. From this information, the difference is calculated between the observed mean outcomes for the treatment and control groups before and after program intervention (Shahidur *et al*., 2010).

Based on the impact evaluation book written by Angrist, (2014); Takavarasha *et al*., (2013), when baseline data are available, one can thus estimate impacts by assuming that unobserved heterogeneity is time-invariant and uncorrelated with the treatment over time. This assumption is weaker than conditional exogeneity. The difference in difference estimate can also be calculated within a regression framework; the regression can be weighted to account for potential biases in difference in difference. However, one of the main limitations of this method is time-invariant selection bias is implausible for most impact programs. This is also more appropriate mostly for panel data rather than cross-sectional.

Endogenous switching regression: In impact estimation, recent econometric papers focused on estimating panel data models with unobserved individual-specific random effects. Endogenous switching regression of the adoption decision account the limitation of PSM that is, for the heterogeneity in the decision to adopt or not to adopt new technology and for unobservable characteristics of farmers and their farm by estimating a simultaneous equations model with endogenous switching by full information maximum likelihood estimation (Lokshin & Sajaia, 2004; Newson *et al*., 2004).

The ESR framework proceeds in two stages, the first stage is the decision to adopt improved technologies, and this is estimated using a binary model and in the second stage, an ordinary least squares regression with selectivity correction is used to examine the relationship between the outcome variable and a set of explanatory variables conditional on the adoption decision (Ana & Odejar, 2002; Miranda & Rabe-Hesketh, 2006). The limitation of ESR needs a large sample size; if the sample size is small it misleads the wrong conclusion.

2.8. Empirical review of the adoption of improved forage technologies

2.8.1. Demographic and socio-economic factors affecting adoption of forage technologies

Agricultural technologies adoption is affected by household demographic, economic, institutional, farmers attitude, and political factors (Tewodros Tefera *et al.,* 2016; Kebede Gezahegn *et al.*, 1990). Ndah *et al.*, (2017) said in their study of factors affecting the adoption of forage technologies in smallholder dairy production systems; the most common factor which affects the adoption of forage technologies in Africa are the farmers' attributes that either increase or reduce their likelihood to adopt new agricultural technologies. Factors in this group include the physical and social capital holdings of individual farmers and their educational achievements and demographic groups.

Education is a demographic factor that may affect the adoption of technologies whether positively or negatively depending upon the technologies. According to the results of the drivers for adoption study conducted by (Tewodros et al., 2013 and 2015) as cited by Yenesew Abebe *et al*., (2015) and Bereket Dindamo *et al.*, (2016) education level of the head of the household variable significantly affecting the adoption levels of forage technology specifically Rhodes and desho grass. Gebremedhin B. *et al*., (2003); Birhanu Yitayih *et al.*, (2017); Hailemariam Mekonnen *et al.*, (2010) also showed an educational level of the household head affecting dairy technologies including crossbreed, improved feed technologies, and improved management practice.

Worku Ayalew, 2019; Feyisa Bekele, (2020); Guye & Sori, (2020) explained on other technology adoption as forage adoption is encouraged when the household head is literate, this is because; literacy is important concerning access to information. In contrast, education may not always positively associate with adoption, probably because it may increase the opportunity cost of labor. The probit regression results revealed that education does not significantly affect the probability of adoption of improved forage technologies in the Wolita zone, Ethiopia (Bassa Zekarias, 2018). This is supported by the study of Rovere *et al.*, (2010); households headed by literates are relatively less likely to adopt improved technologies.

The age of farmers is another driving demographic factor and their experience in dairying is interrelated with technology adoption (Quddus Abdul, 2013). The review paper of Melisse Birhanu, (2018) showed that the age of the household head is a variable in explaining farmers' technology adoption behavior which plays an important role in influencing farmers' information access and shaping their ability to change the available information into action. Older farmers may have experience and resources that would allow them more possibilities for trying new technology. On the other hand, younger farmers are more likely to adopt new technology because they have had more schooling than the older generation.

The probit regression result revealed that age does not have a significant effect on the probability of adoption of improved forage technologies (Bassa Zekarias, 2018). But using general linear model analysis dairy technologies have a significant difference between the adoption (Hailemariam Mekonen *et al.,* 2010). According to Samuel Sebsibie & Wokineh Asmare, (2015), studies with the title of agricultural technology adoption and rural poverty, age has a negative and significant effect. On the other hand (Tigist Petros, 2010) revealed that age affects conservation tillage technology adoption positively. Simtowe et al., (2016) also showed that the age of the household head has a negative coefficient that is statistically significant at a 5 % level suggesting that older farmers are less likely to get exposed to the new pigeon pea varieties.

The gender gap in technology adoption remains for many agricultural technologies. Theis *et al.*, (2018) conducted research on gender and technology adoption, which largely focuses on reasons for low rates of female technology adoption, by shifting attention to what happens within a household after it adopts a technology. According to Ndah *et al.,* (2017) the rate at which a forage technology may be adopted by farmers depends on seven categories. Of which the household characteristics (i.e. if the farmers are rich/poor, literate/illiterate, young/ old, female/male) variables are a driver for adoption of forage technologies. In the study of adoption and continued use of improved technologies, comparing continuous users with those who discontinue, it is evident that the latter have more female family members (improved varieties traditionally require more male agricultural labor tasks) (Rovere *et al.*, 2010).

Likewise, male-headed households adopted a significantly higher number of dairy technologies such as crossbred animals, improved feed technologies, and improved management practices than female-headed households (Hailemariam Mekonen *et al.*, 2010). In contrast, sex has no significant effect on the probability of adoption of improved forage technologies which is done by Bassa Zekarias, (2018) in Wolita zone, Ethiopia. Njarui *et al*., (2017) also revealed that the adoption of forages is not influenced by sex in his study entitled of determinants forage adoption and production niches among smallholder farmers in Kenya.

Livestock holding shows that it has a negative significant effect on farmers' decisions to adopt agricultural technology (Feyisa Bekele, 2020b). The negative effect of livestock ownership on the intensity of use may be due to that livestock ownership increases households' access to manure which they use as a substitute for chemical fertilizer. On the other hand, Tigist Petros, (2010); and Hiko Muhammed, (2020) revealed that livestock holding has a positive and significant influence on the adoption of improved agricultural technologies. According to Bassa Zekarias, (2018) farmers with larger farm size also prepares private grassland by their own and have access to get crop residue and store it for the next drought periods to overcome feed shortages. Therefore the author concludes that this by itself negatively affects improved forage adoption.

The family size of the household head is a continuous variable that positively and significantly affects the probability of adoption of improved forage technologies at a 5% significant level (Bassa Zekarias, 2018). The study was done by Guye & Sori, (2020) using the Tobit model revealed that the probability of adoption and its intensity of malt barely technology package is affected by family size positively and significantly.

In most cases, a larger herd size was associated with greater adoption of precision dairy farm technologies (Gargiulo *et al.*, 2018). Multivariate analysis is used to investigate the associations, herd size for dairy farming decisions the likelihood of that technology being adopted (McDonald *et al.*, 2016). The extent of adoption of different dairy husbandry practices in the areas of feeding, housing, breeding, cleaning, and preventive and curing measures. Proper and better land size helps in developing good dairy and getting good returns too (Quddus Abdul, 2013). The author mentioned as reasons for non-adopting offered by included insufficient land for housing and grazing. According to Martínez-García *et al.*, (2013), herd size has a significant impact on adoption factors influencing the adoption of improved grassland management by small-scale dairy farmers in central Mexico and the implications for future research on smallholder adoption in developing countries.

Job *et al*., (2020) using multivariate probit regression results revealed that a unit increase in the years of experience in dairy farming by the dairy farmers' household head resulted in a decrease in the marginal effect of adopting the vaccination regime by 24 percentage points. McDonald e*t al.*, (2016) explained, experience using multivariate analysis is not significantly affecting the factors influencing new entrant dairy farmer's decision-making process around technology adoption. Similarly, a paper conducted by Martínez-García *et al.*, (2013), farmers experience, in the study of factors influencing adoption of improved grassland management by small-scale dairy farmers in central Mexico and the implications for future research on smallholder adoption in developing countries.

A variable found to affect the probability of farmers using artificial insemination among dairy technologies is the presence of an off-farm job (Howley *et al.*, 2012). The use of artificial insemination can be much more labor-intensive than using a bull to breed cows given the time required observing cattle to detect when cattle are in heat and the time required assisting artificial insemination techniques. Off-farm employment has a positive and significant effect for Teff and wheat but a negative effect for maize (Samuel Sebsibie & Wokineh Asmare, 2015).

Sample household's annual income is one of the important factors which define the adoption of agricultural technologies. Small-scale dairy systems and forage technologies development play an important role in providing income, employment, and nutrition. Based on the study of Martínez-García *et al.*, (2013) most farmers (92.5%) revealed strong intention to continue to use improved grassland (which requires active management and investment of resources); whereas 7.5% of farmers are undecided and showed weak intention, which is associated with farmers whose main income is from non-farm activities as well as with farmers who has only recently started using improved grassland.

2.8.2. Institutional and policy-related factors that affect the adoption of forage technologies

According to Dehinenet Gezie *et al.*, (2014) using Hackman's two-stage availability of dairy production extension services is positively associated with farmer`s likelihood to adopt dairy technology. This indicated that the good availability of dairy production extension services increased the probability of adopting dairy technology. Oppositely, Simtowe, *et al.*, (2016) revealed the proxy variables for access to government extension services distance to agricultural extension office has no significant effect on their study of adoption.

This seems consistent with the fact that government extension is no longer a major provider of information. On the other side, access to the extension has a positive and significant effect on the intensity of adoption which, maybe due to that access to extension is the major way through which farmers get technical information and other important services. Moreover, according to Mango *et al.*, (2018) results showed that awareness of water conservation practices within the study sites had a positive and significant influence on the adoption of small-scale irrigation farming. The utilization of saving institutions and cross breed cow availability are positively associated with farmer`s likelihood to adopt dairy technology. This is indicated that the utilization of saving institutions and cross-breed cow availability increased the probability of adopting dairy technology (Dehinenet Gezie. *et al.*, 2014). Saving institution utilization will be a better determinant variable than saving access.

The social linkages influence access to information on improved technologies. For example, membership in a social grouping such as a faith-based organization has a positive and significant effect on the propensity to get exposed to improved technologies (Worku Ayalew, 2019; Simtowe *et al.*, 2016; Tegegne, 2017). There also is a significant difference between farmer's research group (FRG) members and non-members in access to agricultural extension in the study of factors affecting diffusion and adoption of agricultural innovations among farmers in Ethiopia (Worku Ayalew, 2019). Based on the study of Duque-escobar, (2011) and Ndah *et al.*, (2017) most farmers belonged to one group or another, belonging to a group(s) or association(s) by small ruminant farmers can positively influence the adoption of new technology as they interact and share new ideas during group/association activities.

Similarly, participation in farmer groups increases the propensity to adopt irrigation. This is also supported by Nkonya *et al.,* (2020) participation in farmer groups increases the propensity to adopt irrigation. Farmer groups might also be an entry point for capacity building on irrigation; and groups to which farmers belong receive information on irrigation. This is also tending to support market participation, which is important to help address the challenge of economies of scale of small-scale irrigators.

Based on Quddus Abdul, (2013) the credit received significantly affecting the adoption of dairy farming technologies by smallholder farmers. The recent study was done by Guye & Sori, (2020) using the Tobit model revealed that the probability of adoption and its intensity of malt barely technology package were affected by participation in training, participation in the demonstration, and credit access positively and significantly, while the distance to nearest market had a negative and significant effect. However, sometimes farmers may hesitate to take credit even if there is access to it because of many reasons. Because of this, some studies used credit utilization rather than access to credit as a determining factor of the adoption of new agricultural technologies. Nowadays the credit access is everywhere, but most farmers are not utilized; so credit utilization is more preferable than credit access.

The first stage of the double hurdle model result indicated that cooperative, training, and demonstration influence the adoption of improved maize BH540 variety (Gedefaw Endeshaw *et al.*, 2020). Smallholder farmers' adoption decisions of multiple sustainable intensification practices in eastern and southern Africa. They developed a multivariate probit model using plot-level data gathered from maize-legume farming systems in Ethiopia, Kenya, Malawi, and Tanzania (Minale Kassie *et al.,* 2015). The adoption of SIPs is influenced by social capital and networks, quality of extension services, reliance on government support during crop failure, the incidence of pests and diseases, resource constraints, tenure security, education, and market access (Minale Kassie *et al.*, 2015).

Gebremedhin Berhanu *et al.*, (2003) mixed systems of the Ethiopian highlands; they found that household resource endowment, especially land and labor, and market integration and crop intensification are important factors encouraging adoption of an oats-vetch forage technology. The results imply that land-saving technologies such as high-yielding crop varieties or modern soil fertility management practices, the development of forage technologies that are complementary to food crops in land utilization, and the development of livestock markets can enhance the adoption of improved-forage-technologies.

The distance traveled to access the nearest market is another variable in their study that is thought to influence the adoption of small-scale irrigation farming. This is parallel, to the study results showed that the distance traveled to access input and/or output markets had a significant negative influence on the adoption of irrigation farming (Mango *et al.*, 2018). Access to training sessions and forage adoption among households may also positively relate. Training also has a positive influence on forage adoption, suggesting that an integral part of programs to promote the adoption of forage species should be the provision of training sessions to educate farmers on the benefits and methods of adoption of forage species (Abebe Alemayehu *et al.*, 2018).

Water sources are important drivers of irrigation technologies. Mango *et al.*, (2018) as expected, access to irrigation equipment influenced the adoption of small-scale irrigation farming positively and significantly at a 5% level. The odds of adoption are found to be 2.03 times greater for farmers with access to irrigation equipment compared to those without access. Access to irrigation equipment necessitates the adoption of small-scale irrigation farming. According to Nkonya *et al.*, (2020) acquiring land through the government or agricultural groups increases the propensity to use motor pumps and gravity irrigation. Bucket irrigation is not affected significantly by the method of land acquisition, and this could be due to its short-term nature, which does not depend on land rights. The author revealed land tenure also does not have a significant effect on the adoption of irrigation technologies. The religious institutions played important role in the provision of social infrastructures including the building of schools, hospitals, electricity, irrigation types of equipment, and farm credits for agricultural activities. The study established that many innovative approaches are being developed and adopted by farmers to enhance food security in the area (Ouma, 2014).

2.9. Empirical review of irrigated fodder impact on household farm income

Most impact assessment studies were cross-sectional data. But recently scholar's advice panel data is more appropriate to capture the time-invariant unobserved factors. Although, in this empirical review studies are included used whether cross-sectional or panel data as follows:

In a study by Muuz Hadush, (2021) the economic benefits of stall feeding adoption on a household's farm income and milk yield had a positive effect. He shows in his study adoption of stall feeding has a significant impact on milk production. These findings demonstrate the importance of stall feeding technology for enhancing livestock production in general and milk and milk products in particular in the study area of northern Ethiopia, the Tigrai region. This indicated that the adoption of irrigated fodder technologies might have a positive effect on milk production and household farm income.

A study by Ngeno, (2018), on the impact of dairy hub participation on-farm outcomes, including milk yield, using ESR results showed a positive and significant relationship between adoption and milk yields and farm net returns in Kenya. The study employed farm-level data taken from 826 Kenyan smallholder dairy farmers. Using ESR helps in estimating the true economic effect of dairy hub adoption by controlling the role of selection problem on adoption decisions.

According to the study by Fleming *et al*, (2020), feeding fodder beet to dairy cows in the early lactation period has recently been adopted by dairy producers despite the limited definition of feeding and grazing management practices. Normally this study was done in New Zealand. They used modeling rather than ESR to conduct to characterize changes of rumen pH, milk production, and total discomfort from feeding fodder beet and define practical feeding strategies of a mixed herbage and fodder beet diet.

Aryal *et al.*, (2020), conducted to assesses the factors affecting the adoption of laser land leveling and its impact on crop yields and net returns. It uses household survey data collected from 621 randomly selected farmers. This study was employed on rice technologies with irrigation and it seems to irrigate fodder technologies. Irrigated rice is a water-demanding crop, whereby large-scale laser land labeling adoption across the rice-wheat production system would potentially generate large public and environmental benefits in the study of India using the ESR model. Unbiased model results show that the adoption of laser land labeling has significant positive impacts on rice-wheat yields and net returns in the rice-wheat production system, thereby raising farmers' income substantially using the irrigation surface.

2.10. Conceptual framework of adoption of agricultural technologies

Adoption decisions and the impact of different technologies across space and time are influenced by different factors and their associations. Factors such as demographic, socioeconomic, institutional, and technology itself determine the probability of adoption of fodder technologies. The following conceptual framework showed that characteristics that influence the adoption of irrigated fodder technologies, adoption process, and final economic impact because of adoption. Adopting irrigated fodder technologies first improves livestock feeding. After improving the feeding system mainly milking cows produced better milk yield and quality. This leads to household farm income improvement.

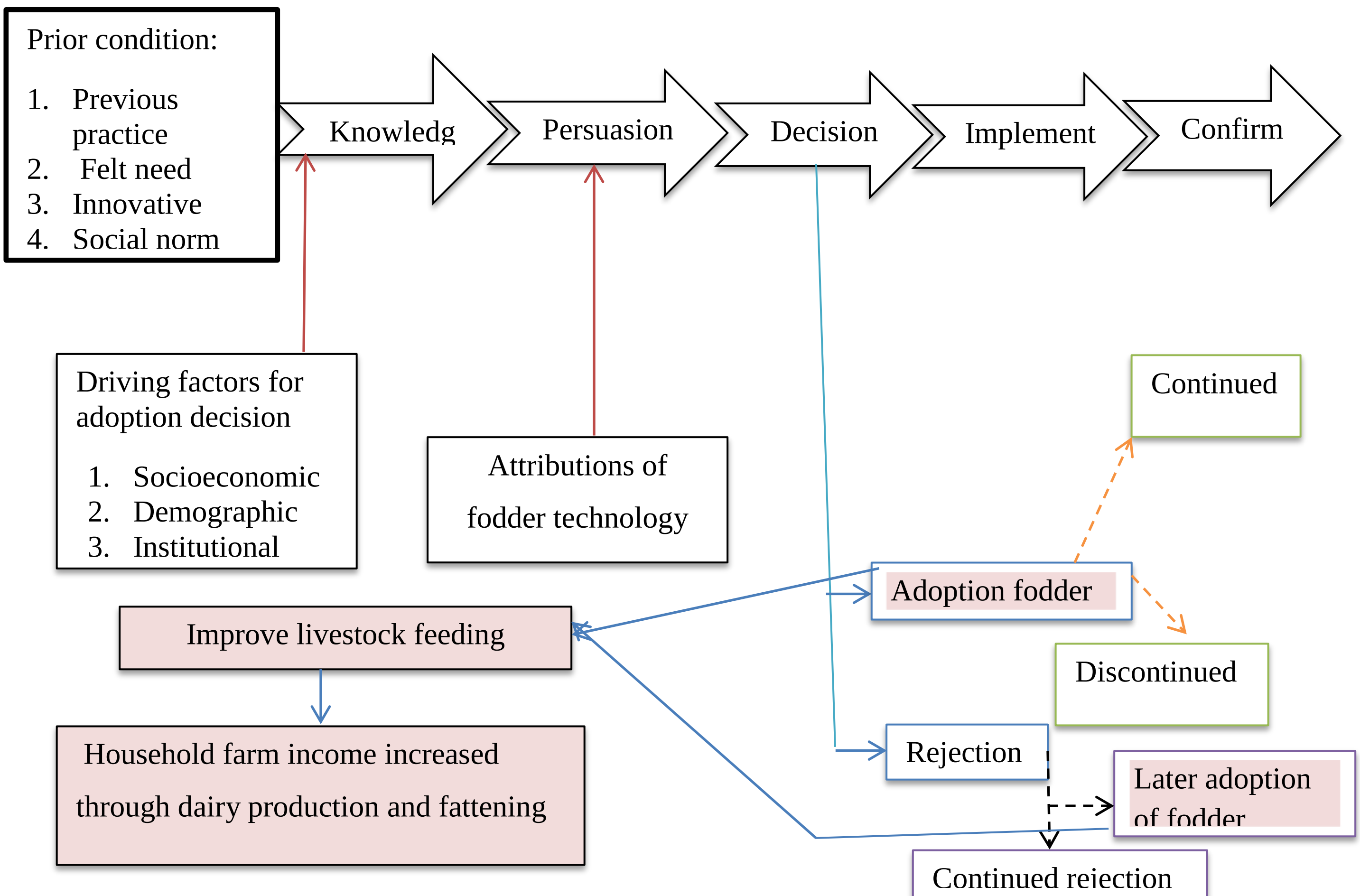

Figure 3. Conceptual frameworks

Source: Adoption decision process Rogers, (1983) and own computation, 2021

Chapter 3. METHODOLOGY

3.1. Description of the study area

The study was conducted in, where ILSSI irrigated fodder project is implemented by ILRI and its partners. Bahir Dar Zuria, and Lemo and Angacha districts are the intervention areas of irrigated fodder research and development work that has been conducted for several years (Figure 2).

Bahir Dar Zuria district: It is found in the west Gojjam zone of the Amhara region, where it is situated 560 km far from Addis Abeba. It is located within an altitude ranging from 1700-2300 meters above sea level and has a total area of 151,119 ha. The area receives an average annual rainfall of about 1035 mm and the minimum and maximum temperatures lie at 10ºc and 30ºc respectively (Anteneh Ayana, 2015; MoFED, 2010). The district has a livestock population of 152,772 animals (121,470 cattle, 14,322 sheep, 9,141 goats and 7,839 equines (Firew Tegegne & Getnet Assefa, 2015). Nearly 21% of the land in the district is cultivable and about 36% is covered with water.

The main source of water for irrigation in Bahir Dar Zuria is shallow well water. The water could not percolate into the ground and hence single water well may not serve throughout the dry period. As a result, many of the households have more than one water well. Despite the many rivers available, their contribution to irrigation is limited due to their short duration. Using irrigation impressively, khat has been introduced into the farming system and becomes the main cash crop and means of income source for almost all households in the district (Wondatir Zewdie *et al.*, 2015). Coffee and mango are other income sources next to khat produced by irrigation in the study area.

According to Asmare Zelalem *et al.*, (2017) in this district, communal grazing lands provide the major feed to cattle followed by crop residues and hay. The use of irrigated improved forages is not common in the district. So that feed shortage occurs year-round; however, the shortage was severe during the dry season (Asaminew Tassew, 2009). So to solve this problem, the communities have used hay and crop residues (Asaminew Tassew, 2009). In recent times the research institution and concerned projects mainly the ILRIs ILSSI project and ARARI promoting improved irrigated fodder technologies for the past continuous five years in the district.

Lemo district: This is another site of the study where located in between 7°22'-7°45'N latitude and 37°40' - 38°E longitude and covers an area of 38,140 hectares. Of which 91% covers woina-dega and moderately undulating land and 9% high altitude areas (Tesfaye Eyuel, 2020). The district is found around the capital of the Hadiya zone, Hosanna town, which is located 232 km away from the south of Addis Ababa. The district is bordered by Silte zone in the north, Kembata Tembaro zone in the south, Gombora woreda of Hadiya zone in the north-west, Ana Lemo woreda of Hadiya zone in the northeast, and Shashogo woreda of Hadiya zone in the East.

The dominant land feature in the district is gentle slope. There is a little portion of ups and downs in the western edges of the district. The land features of the district of 30% rugged land constitute the total area, while 70% is a plain or gentle slope (Yisehak Bekele, 2011). The types of crops grown and consumed by households comprised mainly wheat, maize, teff, cabbage, carrots, banana, and haricot beans, and moderate purchases of teff and maize (Bizimana, J. *et al*, 2020).

In the district, a livestock feed shortage of 88% is the major problem followed by a water shortage of 12% in the district. In addition to this, disease and low productivity were also identified as a constraint. Natural pasture 94% is the main feed resource during the wet season whereas crop residue 59% is in the dry season. Only 37% of respondents replied that there was communal grazing land in their area. The farmers start planted major forage species widely in the study area of the district are Desho grass, elephant grass, Guatemala grass, Sesbania, and tree lucerne (Salo S. *et al.*, 2017).

Angacha district: The third district where the study employed was Angacha which is one of the six districts in the Kambata Tambaro zone, SNNPR. It is located about 260 km southwest of Addis Ababa, the capital city of Ethiopia. The district is among the most densely populated area in the zone and has agro-ecology with mean daily minimum and maximum temperatures of 14 and 26 ^{0}c (Melkamu Bezabih *et al.*, 2016). The topography of the district is a mixture of plains, hills, and in some areas mountains. The vegetation coverage is moderate, with enset the main food crop around the homestead and eucalyptus and some indigenous trees planted along the roads and riversides (Lamedjo, 2019).

Agriculture, mainly composed of crop production and animal husbandry, is the main livelihood of the population in the district. The agricultural practice employed in the area is traditional oxen plow and hoe-culture practices. The main food crops grown in the district are wheat, teff, barley, maize, field peas, and broad beans (Mendel University, 2017). Livestock is an integral part of the agricultural production system and plays an important role in the economy of the district in general.

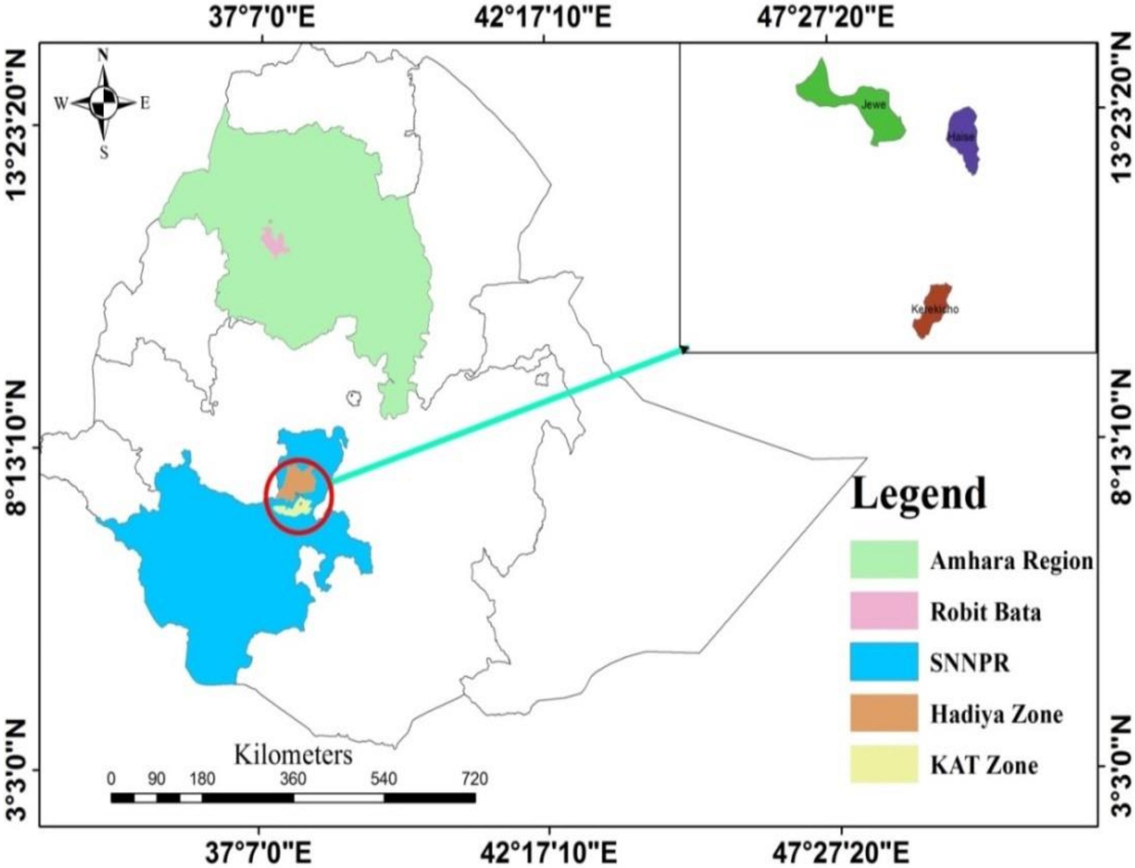

Figure 4. Location map of the study areas

Source: Own computation

3.2. Sampling technique and procedure

A purposive sampling technique with stratification was employed to select sample households. Simply the intervention of the ILSSI project sites was selected. This is because, at the project site, demonstrations, and pre-scaling up activities have been conducted on-farm by the project since 2015. Next, the selected sites were stratified based on irrigated fodder technologies' from the total household farmers in the intervention sites 26% of adopters and 74% of non-adopters. Finally, sample farm households were selected randomly from both stratifications (adopter and non-adopter) to represent the population.

3.3. Sample size determination

According to Kothari, (2004), there are two alternative approaches for determining the size of the sample. The first approach is to specify the precision of estimation desired and then to determine the sample size necessary to ensure it. The second approach uses Bayesian statistics to weigh the cost of additional information against the expected value of the additional information. The first approach is capable of giving a mathematical solution, and as such is a frequently used technique of determining sample size. The limitation of this technique however is that it does not consider the cost of gathering information versus the expected value of information (Kothari, 2004). The second approach is theoretically optimal, but it is seldom used because of the difficulty involved in measuring the value of information.

Hence, for this study, the first approach was more appropriate using the following formula Yaman, (1967) to determine the size of sample farmers.

$n = \frac{N}{1+N(e)2} = \frac{3804}{1+3804(0.06)2} = 258.84 \ldots\ldots\ldots (1)$ Where n is the sample size of household farmers, N is the size of household farmers in the project intervention kebeles, and e is the level of precision. While the minimum required sample size was 259 households, 351 farm households were taken in the survey to increase the dependability of the sample.

Table 1. Sampled households from site locations

No	Region	Zones	District	Sample Kebeles	Number of sampled households		Total Sampled households
					Adopter	Non-adopter	
1	Amhara	W/Gojjam	BD zuria	Robit bata	77	74	151
2		Hadiya	Lemo	Haysie	26	30	56
	SNNPR			Jawe	35	37	72
		KAT	Angacha	Kerekicho	43	29	72
Total sample households					**181**	**170**	**351**

3.4. Source and method of data collection

3.4.1. Data type and source

Quantitative and qualitative data were collected using primary and secondary data sources. Primary data was collected from sample farmers, major fodder growing areas, and sites where project interventions had been conducted. Besides, secondary data was collected from the office of agriculture like an overview of the farming system; constraints regarded feed problem, and socio-economic aspects such as population, fodder technologies grown, livestock breed type kept by farmers, etc. The research center was used as a source of secondary data collected like irrigated fodder technologies intervention and its progress, technologies promotion approach, dairy farm practice, and farmer’s perception regarded applicability of innovation of the technologies. The district's livestock office also was used as a source of data from the perspective of overall livestock improvement and fodder technologies development in the study area.

3.4.2. Method of data collection

Mainly household survey was used to collect primary data from farmers. Structured and open-ended unstructured questionnaires, focus group discussions, key informant interviews, and direct field observation methods were employed to collect primary data. Additionally, note-taking and photographs were made in the study districts to complement the data both qualitative and quantitative analysis, and for triangulation of the data reality

Field observation has conducted the processes including the feeding system that existed fodder technologies and a process of how the farmers applied irrigated fodder technologies in the area to assure the validity of acquired data. Data were collected with an observation about the types of adopted irrigated fodder technologies by smallholder farmers in the area and why they used those technologies rather than other options which are existed in the area. At the same time observation was done on how farmers to farmers, farmers to extension workers, and farmers and traders interacting including what type of information they shared.

Informal interviews were carried out frequently with the farmers met occasionally to get information to produce a semi-structured questionnaire. It was also used as a major tool for data gathering and to gain perceptions of smallholder farmers about irrigated fodder technologies for qualitative data. Key informant interview was also employed to collect valid data. Purposely district agriculture office experts, kebele extension workers, livestock fodder researchers, and elder farmers were taken as a respondent by expected might have better information about the technologies. The question was about the constraints and opportunities to adopt and popularize the irrigated fodder technologies.

Additionally, primary data was collected using focus group discussions with farmers comprised of different statuses (in terms of wealth from poor to rich, sex, age, education), and 8-12 farmers per one FGD was used, and there was one FGDs group per kebele. In the discussion, the question provided was what the major forage crop produced in the area before the new technologies intervention, is the yield of milk and milk-related product increased or not, prior constraints, and opportunities. Such type of discussion agenda included.

The major instrument used for data collection was a semi-structured interview with both open-ended and closed-ended questions which are carefully constructed. The data collected from the sampled population those selected based on the sampling technique. Five enumerators were selected for the collection of data through a semi-structured questionnaire. Enumerators were researchers who are employed in ARARI, SARI, and ILRI focal persons.

3.5. Method of data analysis

Descriptive statistics and/or inferential statistics, probit model, and endogenous switching regression (ESR) were employed as the main analytical techniques. The statistical package for social sciences (SPSS version-22) was used for data entry while stata 14.1 was used for data cleaning, editing, and analysis. Micro-soft excel was also employed for data cleaning and draw graphs. Before running a regression in the model, tests were executed to be confident. These were outliers checked using scatter plot, normality was checked using histogram and swilk test, gladder was employed for data transformation like (string variables to numeric variables), Breusch-pagan/cook-Weisberg test for heteroskedasticity, and VIF for multi-collinearity was employed. After doing all the necessary operations, the researcher analyzed the cleaned and organized data using stata 14.1.

3.5.1. Descriptive and inferential statistics

Descriptive statistics were employed to present the data obtained from the sampled farmers among locations. This was useful to provide a summarized glimpse of the characteristics of the sampled smallholder farmers. The analysis was employed to analyze the survey data using measures of dispersion such as percentage, frequency, variance, and standard deviation and measures of central tendency such as mean. Both parametric (t-test) used to compare mean difference for continuous variables and non-parametric (chi-square test) were used to check the association between dummy variables for adopters and non-adopters of the irrigated fodder technologies.

3.5.2. Econometric analysis

The binary probit model was used to analyze the driving factors affecting the adoption decision of households towards irrigated fodder technologies. The endogenous switching regression (ESR) model was also employed to analyze the irrigated fodder technologies adoption impact on household farm income. The ESR is selected since it considers both observable and unobservable characteristics and heterogeneity.

I. Probit model specification

Agricultural technology adoption is a voluntary decision, farmers themselves decide to adopt or not to adopt, based on the information they have (Muuz Hadush, 2021). Adoption studies based upon dummy regression models have been employed to explain the probability of willingness to use new technology versus non-use (Adeoti, 2008; Chuchird *et al.*, 2017). Mostly in such studies on the willingness of adoption of the decision-maker can be captured using the dependent variable defined as dummy having a value of one or zero *(Alabi et al.*, 2014; Rahman & Daniel Chima, 2015). Binary choice models are fit when the choice between two alternatives depends on the characteristics of the problem, the farmer's decision to use or reject the new technologies.

In this case, decision-making on irrigated fodder technologies adoption was a binary variable. ILRIs ILSSI project has demonstrated different fodder varieties using small-scale irrigation since 2015. The decision for adopting at the household level depends on demographic, socioeconomic, and institutional characteristics. In this study, the researcher aimed to determine driving factors affecting the decision of the farmers to produce irrigated fodder technologies. Hence probit and logit model is more appropriate to determine the factors driving whether to adopt or not. Adopters in this study were defined as smallholder farmers who planted fodder technologies using small-scale irrigation for two continuous years since 2015.

The Probit model is a discrete choice model, which is characterized by the fact that the dependent variable takes only two values 0 and 1, which correspond to each of the two possible alternatives in this study 1 adopt and 0 did not adopt irrigated fodder technologies. Mostly, such variable values were estimated using probit or logit regression through the maximum likelihood approach. Its normal distribution error was assessed using the probit model and logistic distribution of the error term was done by using the logit model since the parameters show consistency (Ravallion, 2001).

Following Maina *et al*., (2020); Alabi *et al*., (2014); Yeneayehu *et al*., (2018); Bassa Zekarias, (2018) the probit model adoption of irrigated fodder technologies were specified as follows:

$$F(x'\beta) = \emptyset(x'\beta)\int_{-\infty}^{x'\beta} \varphi(z)dz \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where F = probability that the i[th] farmer uses the irrigated fodder technologies and 0 otherwise x= vector of the explanatory variables z = standard normal variable β = vector of the coefficients estimated. $\emptyset$ = distribution function for the standard normal random variable.

It is assumed that the latent variable Y* can be specified as follows:

$$\text{Yi} * = \beta 0 + \sum_{n=1}^{N} \beta nxni + ui \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

And

$$\text{Yi} = \begin{cases} 0 \text{ if farmers not adopted irrigated fodder} \\ 1 \text{ if farmers adopted irrigated fodders} \end{cases} \ldots\ldots\ldots\ldots\ldots. (3.3).$$

Where xi represents a vector of explanatory variables, ui is a random disturbance term, N is the total sample size, and β is a vector of unknown parameters to be estimated by the method of maximum likelihood.

Due to the non-linearity of the probit model, the parameters are not necessarily the marginal effects of the various independent variables. The marginal effects of the coefficients are more informative and useful for policy decision-making. Thus the marginal effect is estimated based on the following equation as follows:

$$\frac{\partial Yi}{\partial xi} = \varphi(\beta' xi)\beta i \ldots\ldots\ldots\ldots .3.4.$$

Where φ is represented the probability density function of the standard normal distribution. The empirical specification of the probit model for the study included 18 variables which are selected based on the intuition and scoping review.

II. Endogenous switching regression (ESR)

The average treatment effect on the treated (ATT) has estimated the average difference in outcomes of the adopter (treated group) and non-adopter (control group) of the technologies.

However, most commonly used methods using non-experimental data to calculate ATT such as PSM fail to capture observable and unobservable factors that affect the adoption and outcome variables (Million Sileshi *et al.,* 2019; Hichaambwa, 2015). For example, instrumental variables capture only unobserved heterogeneity, but the assumption is that the parallel shift of outcome variables can be considered as a treatment effect (Bekele Shiferaw *et al.*, 2014). In contradiction, using regression models to analyze the impact of a given technology using pooled samples of adopters and non-adopters might be inappropriate because it gives a similar effect on both groups (Menale Kassie, 2015). A simple comparison of treated and control groups can provide misleading results that attribute differences in the irrigated fodder producers.

To overcome such limitations, a researcher uses an endogenous switching regression (ESR) model to estimate the parameters. A survey of the recent literature shows that many impact assessment studies based on cross-sectional data have moved towards endogenously switching regression models (Million Sileshi *et al.*, 2019; Bekele Shiferaw *et al.*, 2014; Girma Kassie, 2013; Muuz Hadush, 2021; Menale Kassie, 2015; Sulfh *et al.*, 2017). ESR model is a more appropriate model to reduce the selection bias and validate the consistency of results by capturing both the observed and unobserved heterogeneity that affect the outcome variable as well as the adoption decision (Million Sileshi *et al.*, 2019; Menale Kassie, 2015).

Estimation of the economic gain of adoption of irrigated fodder technologies based on non-experimental observations requires finding a proper counterfactual to treatment is the main challenge (Menale Kassie, 2015). When comparing adopters with non-adopters, adopters might differ on additional unobservable characteristics such as ability, awareness, information, or motivation that could have a direct effect on the outcomes beyond adoption (Muuz Hadush, 2021; Asfaw Solomon & Bekele Shiferaw, 2010). It is important to use instrumental variable methods to identify the second-stage equation from the first-stage equation of the ESR model (Million Sileshi *et al.*, 2019). The instrumental variable should affect the adoption of irrigated fodder technologies but not the outcome variable which is household farm income in this case. Although, that the selection of instrumental variables is empirically challenging. In most literature distance to FTC is employed as an instrumental variable regarded to forage production and dairy cooperative development impact on income. For this study, distance to FTC was an instrumental variable used. The validity of the instrument variable was checked by using a falsification test.

Following Muuz Hadush, (2021); Million Sileshi *et al.*, (2019); Hasen Musa *et al.*, (2017); Menale Kassie, (2015); Bekele Shiferaw *et al.*, (2014), ESR has two steps: the first step in the ESR is to specify the selection model to determine factors driving irrigated fodder technologies adoption based on a probit function explained above. This is written as follows:

$$\text{Regime 1}: \mathrm{Y_{1i}} = \theta 1 \mathrm{Z_{1i}} + \varepsilon_{1i}, \quad \text{if I} = 1 \quad (3.5a)$$

$$\text{Regime 2}: Y_{2i} = \theta 2 Z_{2i} + \varepsilon_{2i}, \quad if\ I = 0 \quad (3.5b)$$

where Y_i represents outcome variable of household farm income for adopters and non-adopters, Z_i is a vector of demographic, socio-economic, and institutional characteristics of a household that affects outcome variables, and θ_i is a vector of parameters to be estimated.
The error terms are distributed to be trivariate normal, with mean zero and a non-singular covariance matrix:

$$cov(\varepsilon_1, \varepsilon_2, v) = \begin{bmatrix} \sigma_1{}^2 & \sigma_{12} & \sigma_{1v} \\ \sigma_{21} & \sigma_2{}^2 & \sigma_{2v} \\ \sigma_{v1} & \sigma_{v2} & \sigma_v{}^2 \end{bmatrix} \ldots\ldots\ldots\ldots.. \quad (3.6)$$

where σ_{21}, σ_{22}, and σ_{2v} are the variance of the outcome function of regimes 1 and 2, as well as the selection equation, respectively, σ_{12}, σ_{1v} , and σ_{2v} represent the covariance of ε_{1i}, ε_{2i}, and v_i. The variance of selection question (σ_{2v}) is assumed to be equal to 1 since the coefficients (β) are estimable only up to a scale factor.

The expected values of the error term of the second stage are non-zero because of the error term of the first stage (v_i) and second stage (ε_{1i} and ε_{2i})) are associated with each other. The expected value of error terms of the question (3.4a) and (3.4b) can be expressed as follows:

$$E(\varepsilon_{1i})\ /Y_i = 1) = \sigma_{1v} \, {}^{\emptyset(\beta X_i)}\!\Big/_{\Phi(\beta X_i)} = \sigma_{1v}\lambda_{1i} \ \ldots\ldots\ldots\ldots\ldots.. \quad (3.6a)$$

$$E(\varepsilon_{2i})\ /Y_i = 0) = \sigma_{2v} \, {}^{\emptyset(\beta X_i)}\!\Big/_{1-\Phi(\beta X_i)} = \sigma_{2v}\lambda_{2i} \ \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.6b)$$

Based on the above context, comparing real and counterfactual scenarios of expected values of the outcomes of adopters, the average treatment effect on the treated (ATT) can be obtained. Similarly, the average treatment effect on the untreated (ATU) also can be calculated by comparing the expected values of the outcomes of non-adopters in truth and not. Following (Aryal *et al.*, 2020; Asfaw Solomom & Shiferaw Bekele, 2010; Gaither & Cavazos-Gaither, 2020; Hasebe, 2020; Khanal & Gillespie, 2013; Kumar *et al*., 2018; Mojo *et al*., 2017; Ngeno, 2018; Otieno, 2020; Tesfay Menasbo, 2020) the expected values of the outcomes of both adopters and non-adopters in reality and the counterfactual can be described as follows:

Adopters with the adoption of irrigated fodder technologies (truth):

$$E\left(\frac{Y_{1i}}{X}, I = 1\right) = \theta_1 X_{1i} + \sigma_{1v}\lambda_{1i} \dots\dots\dots\dots \quad (3.7a)$$

Non-adopters without adoption of irrigated fodder technologies (truth):

$$E\left(\frac{Y_{2i}}{X}, I = 0\right) = \theta_2 X_{2I} + \sigma_{2v}\lambda_{2i} \dots\dots \quad (3.7b)$$

If adopted had non-adopted irrigated fodder technologies (counterfactual):

$$E\left(\frac{Y_{2i}}{X}, I = 1\right) = \theta_2 X_{1i} + \sigma_{2v}\lambda_{1i} \dots\dots \quad (3.7c)$$

If non-adopted had adopted irrigated fodder technologies (counterfactual):

$$E\left(\frac{Y_{1i}}{X}, I = 0\right) = \theta_1 X_{2i} + \sigma_{1v}\lambda_{2i} \dots\dots \quad (3.7d)$$

Finally, the ATT of adopters is computed as the difference between (3.7a) and (3.7c) and similarly, ATU of non-adopters is computed as the difference between (3.7b) and (3.7d).

3.6. Definition, measurement, and hypothesis of the study variables

3.6.1. Description of the dependent and outcome variables

The dependent variable is irrigated fodder technologies adoption binary taking the value of 1 if the farmer has adopted the irrigated fodder technologies and 0 otherwise. In the intervention areas before the project engaged farmers mostly produced khat, but after the intervention, they were shifting to fodder production. The outcome variables are dairy income and household farm cash income for the rural smallholder farmers that have adopted irrigated fodder technologies and those that did not have irrigated fodder technologies.

Dairy income: This is defined as household farmers may have local or crossbreed and /or both dairy cattle might start from one and above in number but their livelihood was not depending on only in dairy farm and but, taken it as an additional income source. Dairy income (ETB/year) was calculated as the sum of the average amount of milk sold (lit) multiply by average price (ETB/lit), amount of butter (kg) multiply by average price (ETB/kg), and amount of sold cheese (ETB) multiply by average price (ETB/kg) of the dairy products. It is measured by ETB.

Household farm cash income: Farm households, aside from their ownership of a business, also rely on a variety of income sources. Farm household income originates from farms and sources. In the study area, almost all sampled farmers produced for household consumption. In this study the farm source includes cash crop income, livestock sold income, forage sold income, and dairy income. So the household farm income is calculated by summing of those sources and measured by ETB.

3.6.2. Description of explanatory/independent variables

Household farmers' adoption decisions of irrigated fodder technologies were driven by the demographic, socio-economic, and institutional factors of the household. Because of that, the selected variables are defined contextually based on intuition, and the scoping literature review is as follows.

Sex of the household head: This is a dummy variable that takes a value of 1 if the household is male-headed and 0 if a household is female-headed. Female-headed households are highly engaged in livestock keeping and feeding in the rural area of Ethiopia. Although, mostly females are busy with housework than males and may have no information about fodder technologies and other extension actives implemented in the area. As a result, the researcher hypothesized that male-headed households have better opportunities in participating in irrigated fodder technologies than female-headed households in the area. This is supported by the finding regarded to forage technologies by (Nkonya *et al*., 2020; Muuz Hadush, 2018; Aditya R. Khanal & Gillespie, 2013; Lambrecht *et al*., 2019).

Age of the household head: It is a continuous variable measured with years. The age of the farmers may affect the adoption of irrigated fodder technologies whether positively or negatively. This is because; mostly if farmers are aged he/she accumulate more knowledge than younger ones from the extended time of experience they gain through their lifetime. Age was positively hypothesized by Mango *et al.*, (2018) in their study of small-scale irrigation adoption. On the other hand, if the farmers are too old less likely to take risks than young farmers (Ouma, 2014). So that, the researcher hypothesized this variable could have a positive or negative effect on irrigated fodder technologies adoptions.

Dependency ratio: It is a measure of the number of dependents aged zero to 14 and over the age of 65, compared with the total population aged 15 to 64. This demographic indicator gives insight into the number of people of non-working age, compared with the number of those of working age of irrigated fodder technologies. A farmer has near to one engaged in irrigated fodder technologies is more likely to be in a position to try to continue using technologies. Therefore, a large dependency ratio would be able to provide the labor that might be required by the irrigated fodder technologies. Mostly, farmers who have children may have several livestock numbers and improved feeding practices but if the farmers have no children, feeding practice might less b/c of need labor engaged. This is similarly positively hypothesized by (Quddus Abdul, 2013; Bassa Zekarias, 2018; Kumar *et al.*, 2018). On the other hand, farmers may adopt irrigated technologies if the family size is small in number. This is because farmers shift totally from crop production and keeping the livestock and engaged in dairy production by renting/sharing out the land owned. This is supported by Yenesw Abebe *et al.*, (2018); Hailemariam Mekonnen *et al.*, (2010) who studied the adoption of fodder technologies and dairy production. Thus, the dependency ratio is near to one and zero expected to increase the probability of adopting irrigated fodder.

Education level (year of schooling): It is a continuous variable measured with a year of schooling. If the farmers are more educated the ability to analyze benefits and cost, interpret and decide the better option of the fodder technologies provided by the ILRIs ILSSI project and other stakeholders. In this study, the variable education data collected by the researcher is the farmers who are illiterate as grade zero, basic education (year of schooling), and formal education (year of schooling) were taken and measured by a year of schooling. This variable was hypothesized to have a positive relationship with irrigated fodder technologies adoption. This is supported by Mango *et al*., (2018); Quddus Abdul, (2013); Birhanu Mulugeta *et al*., (2017).

Livestock's Ownership: This variable is continuous shows the number of livestock owned by the household measured in TLU. Livestock is considered an asset that could be used in the agriculture production process and transportation. Small ruminates are also used as cash income or be exchanged for other productive assets. So the farmers have much livestock, farmers may develop different strategies to feed the theme of which irrigated fodders may be one of the strategies (Birhanu Mulugeta *et al*., 2017). On the other hand, if the number of livestock is small in number the technologies might adopt by expecting to feed them the improved fodder to gain better quality. Similarly, if the livestock number is high the probability of having irrigation access is disturbed by animals; this is negatively affecting the irrigated fodder technologies. Because of those reasons, the variable livestock ownership hypothesized either positive or negative effects on the adoption of the technologies.

Irrigated land size: This is a continuous variable measured by hectare. This refers to the total irrigated land size cultivated by a household that has a direct relation with crop and fodder production. A larger size of irrigated cultivated land implies more irrigated fodder technologies and the availability of livestock feed increased. Hence, the size of irrigated land size is expected to have a positive impact on household irrigated fodder technologies. The irrigated land size was hypothesized to have a positive effect on irrigated fodder technologies adoption in this study. This hypothesis is supported by (Nkonya *et al*., 2020; Zeweld woldegebrial *et al*., 2015).

Dairy farm experience: This is a continuous variable measured with a year. The framers had experienced with dairy farm the awareness about the technology of fodder importance increases. This is because farmers know the improved fodder technologies' advantage on milk production and quality. Hence it was hypothesized that the dairy farm experience has a positive effect on irrigated fodder technologies adoption. This hypothesis is supported by the study by Quddus Abdul, (2013); Bayan, (2018) regarded the adoption of dairy farming technologies by smallholder farmers.

Distance to FTC/DA office: It is a continuous variable measured by kilometer. Distance from the farmer's residence to the farmer training center/office of development agents (in km) short farmers can get information easily. The longer is the distance, the lesser the probability of getting information, input, and adopting new technology. But the farmer's residence is near to FTC every morning and evening might see the demonstration of technologies done by development agents. This hypothesis is in line with the study of (Quddus Abdul, 2013). Hence, a negative relationship is expected in the study area.

Livestock extension service received: This is a dummy variable that takes 1 if the farmers received extension advice about livestock and fodder technologies and 0 if farmers were not received. Now a day's access to extension services provided by the government at all levels represents the major source of information for farmers. The variable representing extension advice for the farmers by extension experts influences farm households' irrigated fodder technologies. The more advice received the farmers will have better information/knowledge and then use the technologies based on the information they have. Hence, advice received from extension agents is hypothesized to affect farmers' irrigated fodder technologies adoption. This is also hypothesized by (Quddus Abdul, 2013).

Member of water use association (WUAs): This is a dummy variable taking 1 if the household head was a member of water use association and 0 if the farmers, not a member. Farmers have no private irrigation access they may be joined to the association. This might affect the adoption of irrigated fodder positively. However, the farmers might not be interested in a common property to use every time and might have a conflict among members. This leads the farmers are not to adopt irrigated fodder technologies. Hence members of the water use association might positively or negatively affect the adoption of irrigated fodder. This is supported by Chuchird *et al*., (2017); Eefje Aarnoudse, (2018).

Dairy cow breed type: This is a dummy variable taking 1 if farmers had a crossbreed cow and 0 if the farmers had only a local milking cow. Mostly, farmers perceived that breed milking cow needs more improved feed than that of local milking cows to produce a better amount of milk quantity and quality. This might lead to having farmers who had a crossbreed more probability to adopt irrigated fodder technologies than local milking cow owned. This is supported by the study of Bayan, (2018); Ghosh, (2004) which was about the impact of the dairy cooperative on household income. As a result, it was hypothesized that a crossbreed milking cow ownership affects the adoption of the technologies positively than the owner of a local milking cow.

Forage seed access: This is a dummy variable taking 1 if the respondent had access to forage seed and 0 otherwise. Improved forage seed access combined with appropriate management handling practices is believed to solve some of the critical feed shortages and quality problems. For farmers who get improved seed, the probability of adopting the irrigated fodder technologies might more. This is the reason that the farmers expect to produce better and quality grass; this is directly linked to better livestock production. Additionally, expected improved seed grass is very suitable for dairy farmers who practice a cut and carry system. This is supported by Bayan, (2018). Thus, it was hypothesized that forage seed access positively influences the adoption of irrigated fodder technologies.

Membership of a dairy cooperative: This is a dummy variable taking 1 if the respondent is a member of a dairy cooperative and 0 otherwise. It might contribute towards improving yields of dairy production. If the farmers become a member, the probability of getting forage seed access, credit, and other relevant information might be increased regarded irrigating forage. This might be activating for the adoption of irrigated fodder technologies. This hypothesis is in line with the study of (Kumar *et al*., 2018). Hence, it was hypothesized to have a positive effect on the adoption of irrigated fodder technologies.

Livestock market information access: This is also a dummy variable taking 1 if the farmers have information access about milk market and forage production-related issues while taking 0 if no access to milk and forage market information. This might affect the adoption of the technologies directly. If the farmers have information about forage market/field price, milk and milk product price, livestock market/field price decided to adopt the technologies to share the importance of the coming new technologies. As a result, the researcher hypothesized it has a positive effect on the adoption of irrigated fodder technologies.

Credit utilization: This is as a dummy variable taking 1 if the farmers utilize the credit and 0 otherwise. Nowadays credit institutions are everywhere both formal and informal mainly microcredit institutions. As a result, the researchers have taken the utilization rather than access because farmers might not take credit due to frustration, and credit institutions regain farmers to provide collateral. However, if the farmers borrowed money the probability to buy farm input and apply on the targeted technologies; this is positively influenced the adoption of technology. Therefore, credit utilization was expected to increase the probability of adopting irrigation fodder.

Grazing land size holding: This is a continuous variable measured in hectares. Most farmers have their grazing land. But, currently, the land shortage is for agricultural activity mainly for youths. As a result, youth farmers are plowing the grazing land and keeping the cows with the house by feeding crop residue. This might be affecting the fodder adoption positively but in most cases, if farmers graze land more the adoption of the technologies declines. Thus, this was hypothesized that grazing land size affects negatively.

Number of milking cows: It is a continuous variable measured by number. If the numbers of milking cows increase the probability of adoption might be increased by thinking to producing more milk. This is including both local and crossbreed milking cows. Then it is hypothesized that if farmers had a great milking cow in number the adoption of the irrigated fodder technologies increased positively. This was supported by Muuz Hadush, (2021).

Irrigated fodder production training: This was as a dummy variable taking 1 if the farmers who take training and 0 otherwise. Irrigated fodder technologies were not practiced in farming in most of the country. Mainly in most irrigated areas khat and other horticultural crop were produced; to introduce and popularize the irrigated fodder production training was important regarded to forage production, management, its importance, its economic return, and nutritional value advantage. As a result, the researcher hypothesized the farmers who gain training was increased the probability of adoption of irrigated fodder than those who did not take the training.

Table 2. Summary of variables, description, expected sign, and their measurements

Variables	Description	Measurement units	Expected sign
Adoption of irrigated fodder technologies	Dependent variable	1 for the adopter, 0 otherwise	
Household farm income	Outcome variable	Annual growth cash income	
Dairy income	Outcome variable	Annual growth milk income	
Independent variables			
Sex	Sex of the household head	1 if male, 0 otherwise	(+)
Age	Age of the household head	Number of years	(+/-)
Dependency ratio	Measure of the number of dependents compared with the active age of the households	Dependency ratio	(+)
Educational level	The educational level of the household	Year of schooling	(+)
Irrigable land size	Average irrigable land size	Size in hectare	(+)
Livestock ownership	Livestock ownership of the household	Tropical livestock unit (TLU)	(+/-)
Dairy farm experience	Farmers engaged in dairy farm	Number of years	(+)
Distance to FTC	Distance of residence to FTC	Kilometer	(-)
Extension service	Livestock extension service received	1= received ,0= not received	(+)
Forage seed	Forage seed access	1= has access, 0= no access	(+)
Dairy cooperative	Membership of dairy cooperative	1= member, and 0 =otherwise	(+)
Dairy breed type	Ownership of dairy breed type	1= crossbreed, 0 otherwise	(+)
Water use association	Member water use association	1= member, 0 = non-member	(+/-)
Credit utilization	Farmers utilized credit	1=utilized, 0 =non-utilized	(+)

Market information	Livestock market information	1= Yes ,0 = No	(+)
Grazing land	Average grazing land size	Hectare	(-)
Milking cow	Number of milking cow	Numbers	(+)
Training	Irrigated fodder production and management training	1=Yes, 0 = no	(+)

Chapter 4. RESULT AND DISCUSSIONS

This chapter presents the results and discussion section of the study. Descriptive and inferential statics results are presented to describe the socio-demographic and institutional characteristics of sampled households. Reasons why adopters are adopting and non-adopters not adopting the technologies are presented. Then, the econometric analysis, the driver of adoption of irrigated fodder, and its impact on households' farm cash income are presented in the chapter.

4.1. Socio-demographic, and institutional characteristics

In this sub-section, socio-demographic, and institutional characteristics of sample households are presented. Households' socio-demographic characteristics such as sex, age, educational level, irrigated landholding size, livestock ownership, grazing land size; number of milking cows, and dairy breed cow's type were discussed. Besides, livestock extension service received, livestock market information, dairy cooperative participation, and credit utilization were presented by comparing improved fodder adopters with non-adopter groups. Similarly, irrigation and water access statistics such as water use association, irrigated fodder training, and forage seed access are described.

4.1.1. Socio-demographic characteristics of sample households

Sex of the household heads: Among the sample respondents 80.06% were male-headed and 19.94% were female-headed households at project sites from 351 total sampled populations (Table 3). From the total adopter of irrigated fodder technologies, 44.16% respondents were male-headed households while 7.41% were female-headed households (Table 3). Among the non-adopter sampled population 35.90% were male-headed and 12.54% were female-headed households at project intervention areas (Table 3).

The chi-square test result showed a significant association between sex of the household and adoption of irrigated fodder cultivation at project intervention areas. The chi-square test result is similar to Hailemariam Mekonnen *et al*., (2010) and contradicted Muuz Hadush, (2021); Mango *et al*., (2018).

Age of the household head: The descriptive statistics result showed the average age of the total sample household heads was 44.57 in project intervention areas (Table 4). The average age of the sample household head of adopters is 42.91 years while it is 46.34 for those who didn't adopt irrigated fodder cultivation (Table 4).

Age plays a key role in household decisions for the adoption of irrigated technologies. This is proved by the t-test result that there is a significant mean difference between the adoption groups in the study areas. The t-test result is in agreement with other studies such as (Quddus Abdul, 2013; Agerie Nega, 2017). However, the finding also contradicts with other studies by Khanal *et al.,* (2010) on forage adoption technologies packaged for milk production.

Dependency ratio: The dependency ratio of the sample households on average adopter is 0.76 while it is 0.78 for those who did not adopter irrigated fodder technologies in the project intervention areas (Table 4).

Level of education: Adopters of irrigated fodder are better-off in their level of education with a mean of 4.59 while 2.29 years of schooling for those who did not adopt irrigated fodder technologies (Table 4).

The independent t-test results show that there is a statistically significant mean difference between the educational level (year of schooling) of the household head and adoption status of irrigated fodder technologies. The possible reason might education plays the most important role in any decision. The result is coincided with (Kebebe Ergano, 2015b). This is similarly reported by Melkamu Bezabih *et al.*, (2020) in the ILRI discussion paper.

Dairy farm experience: The total sampled households that the mean dairy farm yearly experience of adopters is 12.37 years while it is 7.75 years of experience for those who do not adopt irrigated fodder cultivation (Table 4). The t-test showed there is a significant mean difference between the two groups in terms of dairy farm experience in years. This is supported by the study of (Bayan, 2018; Quddus Abdul, 2013).

Irrigable land holding: At across regions, the average size of irrigable landholding of adopters and non-adopters of irrigated fodder cultivation is about 0.27 and 0.19 ha respectively (Table 4).

The t-test result revealed that irrigation land size has a statically significant mean difference between adopters and non-adopter of irrigated fodder. This is because the land is the basic asset of Ethiopian farmers in general and irrigation user farmers in particular as most investments in the agricultural sector require land and to produce two or more times within a year. This implies higher irrigated land size ownership households participating in irrigated fodder cultivation. This is nearly supported by the study of (Melkamu Bezabih *et al.*, 2020; Ejeta Tadesse *et al*., 2019).

Livestock ownership: The descriptive statistics result showed that average numbers of livestock in terms of TLU owed by households were 4.82 TLU for adopters while it is 4.35 TLU for those who did not adopt irrigated fodder in the intervention areas (Table 4).

Ownership of livestock between the two groups in the sample households showed a disparity. The t-test showed that there is statically a mean significant difference between adopter and non-adopter. This is supported by (Salo Sefa *et al.*, 2017). In the current subsistence form of Ethiopian agriculture, it is impossible to think of farming without animals. However, the livestock population holding per household is at a decreasing rate due to the introduction of natural resource management and protection of communal grazing land from animal contact. This is forced smallholder farmers to exercise stall feeding, irrigated fodder production, and promote zero-grazing. Adopter of irrigated fodders technologies kept livestock mainly cows used as a major source of milk and butter which are in turn sources of cash. Besides, small ruminants in the area are kept mainly for income supplementation of households. Thus, household farmers produced livestock forage integrated with small-scale irrigation and dairy farm is important to increase option of income sources.

Dairy cow breed type: Based on the result of the descriptive statistics the sample household head at sites 43.02% kept cross-breed cows while 56.98% owned local cows (Table 4). Of the total adopters, 29.63% kept a crossbreed dairy cow while 21.94% of adopters kept a local dairy cow (Table 4). Similarly from the total non-adopter of the irrigated fodder technologies, 13.39% of sample households kept breed cows but 35.04% kept local dairy cows (Table 3).

In most cases, the farmers produced the improved forage who kept a breed cow rather than the local milking cow by expected breed cow produced quality and quantity milk and milk product. Chi-square association is in line with Muuz Hadush, (2021) studied in the Tigrai region, Ethiopia regarding stall feeding practice; adopters had improved breed cows than non-adopters. Duque-escobar, (2011) in his study also concluded that adoption of fodder technologies is determined by types of livestock breed type kept by farmers.

Number of milking cows: The average number of milking cows owed by adopters is 1.58 while the non-adopters are 0.89 in number at project sites (Table 4).

The headcount milking cows owned/kept by sample adopters and non-adopter indicates that there is a disparity between the two groups in the sample households. The result of the t-test showed that there is statically a mean significant difference between adopters and non-adopters in terms of the ownership of the number of milking cows.

Table 3. Categorical socio-demographic characteristics of sample households

Variables	Category	Adopters (N=181)		Non-adopters (N=170)		Total (N=351)		$\chi 2$-test
		N	%	N	%	N	%	
Sex	Female	26	7.41	44	12.54	70	19.94	7.28***
	Male	155	44.16	126	35.90	282	80.06	
Dairy cow breed type	Local	77	21.94	123	35.04	200	56.98	31.78***
	Breed	104	29.63	47	13.39	151	43.02	

***, means significant at the1%, probability level

Source: Own survey result, 2021

Table 4. Continuous socio-demographic characteristics of sample households

Variables	Total sample households (N=351)		Adopters (N=181)		Non-adopters (N=170)		T-test
	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	
Age	44.57	12.73	42.91	11.99	46.34	13.28	2.53***
Education	3.78	3.11	4.59	3.12	2.92	2.87	-5.17***
Dependency ratio	0.77	0.38	0.76	0.23	0.78	0.38	0.68
Irrigated land size	0.23	0.10	0.27	0.12	0.19	0.07	-6.47***
Dairy experience	10.09	9.35	12.37	9.49	7.75	8.62	-4.57***
TLU	4.59	2.10	4.82	2.10	4.35	2.08	-2.10**
Grazing land size	0.12	0.17	0.13	0.18	0.12	0.16	-0.52
No milking cow	1.24	0.97	1.58	0.88	0.89	0.93	-7.11***

***, ** and *means significant at the 1%, 5%, and 10% probability levels, respectively.
Source: Own survey result, 2021

4.1.2. Institutional and policy aspects of sample households characteristics

Institutional variables are also having an important role in influencing the behaviors of farmers in the adoption of technologies. Based on the descriptive analysis results, most institutional variables had statically significant association and mean differences between adopters and non-adopters of irrigated fodder cultivations and described as follows.

Livestock extension service received: From the total sample household respondents 71.23% were received extension service from development agents and 28.77% of the household respondents were not received. Among those households who received extension service, 42.45% were adopters and 28.77% were non-adopter of irrigated fodder technologies (Table 5). From households headed who did not receive the extensions service 9.12% were adopters and the remaining 19.66% were non-adopters of irrigated fodder technologies (Table 5).

In each of the kebeles of the districts, there is an extension agent's office as a country. However, there is a significant association between irrigated fodder technologies and household adoption status in livestock extension service received by extension agents between the two group’s intervention areas. Farmers used agricultural extensions services received livestock production, irrigated forage production methods, and technologies that increase the probability of adopting improved irrigated forage technologies. This is in agreement with the study by Walisinghe *et al.*, (2017) in the country of Sir Lanka regarding the importance of agricultural extension services promoting technology adoption.

Credit utilization: From the total sample of household respondents 27.35% are utilized credit services while 72.65% of the respondents are not used credit services (Table 5). Among adopters of irrigated fodder technologies, 17.66% utilized credit services and 33.90% were not used. Similarly from the total non-adopters, 9.69% utilized credit services while 38.75% were not used the access (Table 5).

Nowadays access to credit is everywhere but farmers may not utilize it as they want. Because farmers might be frustrating to lend, and credit institutions need collateral. Despite farmers utilizing the credit to facilitate dairy production through expanding the forage with small-scale irrigation. This is supported by (Dehinenet Gezie. *et al.*, 2014; Quddus Abdul, 2013; Guye & Sori, 2020; Ejeta Tadesse *et al*., 2019).

Livestock market information access: From the total sample households 84.90% of the respondents have information of which 45.30% and 39.60% were adopters and non-adopter of irrigated fodder cultivation respectively (Table 5). Similarly, the descriptive statistics revealed that 15.10% of respondents have no information about the livestock market (Table 5). Of those 6.27% were adopters while 8.83% were non-adopter of irrigated fodder technologies at project sites (Table 5)

Information on market prices and channels is one of the important aspects of the adoption of new technologies. Based on the focus group discussion participants' lack of market information directly affects farmers to obtain a reasonable and better price for their product mainly milk and milk product price. Most respondents obtained information from kebele development agents and neighbors. This indicated that farmers exchange any information include market-related issues with their neighbors and colleagues about agricultural activities and markets. Additionally, they shared information on how they plow and frequency of plow, method of feeding their animals, harvesting of forages, and other particular activities in general. As a result, livestock market information has an impact on the adoption of irrigated fodder technologies. This is supported by the study of (Agerie Nega, 2017).

Member of a dairy cooperative: From the total sample respondents 45.58% were membership and the rest 54.42% were not the membership (Table 5). The descriptive results showed that 30.77% adopters were members of a dairy cooperative while 20.88% of adopters of irrigated fodder technologies were not members of the intervention sites (Table 5). From the total non-adopter sampled households 14.81% were members and the rest 33.65% non-adopter, not a member (Table 5).

General cooperatives play a significant role in the adoption of innovative agricultural technologies. At the same time, dairy cooperatives contribute for dairy farmers to adopt the related technologies. As a result, the inferential statics shows that a significant association between adopter and non-adopter irrigated fodder technologies. Member farmers can save money and enjoy a range of benefits, such as buying inputs or transporting milk in bulk and gain access to new technologies, loans, and inputs. They can also earn higher profit by negotiating directly with buyers and suppliers. The result is in line with the study by Kumar *et al*., (2018); Muuz Hadush, (2021).

Member of water user association (WUAs): Among 351 sampled household respondents only 12.82% are members of a water user association and 87.18% of the respondents were not a member of a water user association (Table 5). The descriptive result showed that from the total member of water use association 2.28% adopters were a member and 10.54% non-adopters were not a member of water use association (Table 5). Among the total non-membership, 49.29% were adopters while 37.89% were non-adopter of irrigated fodder technologies (Table 5).

The variable water use association chi-square result is supported by (Chuchird *et al*., 2017). Based on the respondent's information each member farmer had a function and made his/her contribution. The association was an informal, user-based organization, and members have the right to use water from irrigation systems based on the association governance. Even the

WUAs representatives/committee was elected by members and the selected committee was called the father of water. However, there is a conflict to use the water and most farmers resign from the membership.

Forage seed access: From the total sample of household respondents 79.49% used improved forage seeds and 20.51% of the respondents did not use improved forage seed (Table 5). Among farmers who accessed forage seed, 49.86% were adopters of irrigated fodder technologies while 1.71% of respondents were non-adopter of the technologies (Table 5). Besides, from the total farmers who are not access improved forage seed, 29.63% were adopters 18.80% were non-adopters of irrigated fodder technologies at intervention areas (Table 5).

The chi-square result showed that the association between adopters and non-adopters is significant. Based on the focus group discussion information, feed shortages and the poor quality of available feed are the major constraints to increased livestock productivity in the study area. Mainly, dairy farmers need green forage to produce more and quality milk. To improve the quality and quantity of green forage use of improved forage cultivars is important. Otherwise, it is hindering facilitating the adoption of irrigated fodder technologies. The result is supported by (Jones & Hanson, 2018; Tekalign, 2014).

Irrigated fodder production training: The total farmers who took training 51.57% among that 37.32% were adopters and 14.25% were non-adopters of irrigated fodder technologies at project intervention sites (Table 5). Similarly, from the total sample household who did not take irrigated fodder training, 14.25% were adopters and 34.19% were non-adopter of irrigated fodder technologies (Table 5).

Training is one of the means for technology adoption. Farmers participating in training influence the adoption positively. The result of the study showed sample household adopters who took training about irrigated fodder management and cultivation while non-adopters had nothing less. This implies that training was conducted about the overall irrigated fodder production and livestock management such as production, management, feeding of irrigation fodder, dairy cow handling, and health management for most adopters. The result is in line with Dagninet Asrat & Adugnaw Anteneh, (2019; Agerie Nega, (2017).

Table 5. Categorical institutional and policy characteristics of sample households

Variables	Category	Adopters (N=181)		Non-adopters (N=170)		Total (N=351)		χ2-test
		N	%	N	%	N	%	
Dairy cooperative	No	73	20.80	118	33.62	191	54.42	29.88***
	Yes	108	30.77	52	14.81	160	45.58	
Extension service	No	32	9.12	69	19.66	101	28.77	22.44***
	Yes	149	42.45	101	28.77	250	71.23	
Credit utilization	No	119	33.9	136	38.75	255	72.65	8.96***
	Yes	62	17.66	34	9.69	96	27.35	
Market information	No	22	6.27	31	8.83	53	15.10	2.52*
	Yes	159	45.30	139	39.60	298	84.90	
WUAs member	No	173	49.29	133	37.89	306	87.18	23.59***
	Yes	8	2.28	37	10.54	45	12.82	
Forage seed access	No	6	1.71	66	18.80	72	20.51	67.78***
	Yes	175	49.86	104	29.63	279	79.49	
Training	No	50	14.25	120	34.19	170	48.43	64.79***
	Yes	131	37.32	50	14.25	181	51.57	

***, and * means significant at 1%, and 10% probability level respectively.
Source: Own survey result, 2021

Distance from farmer's residence to FTC: The descriptive result shows that adopters were far from the center to their residence an average of 1.23 km while non-adopter 1.92 km at intervention areas (Table 6).

The independent t-test result shows that there is a statistically significant mean difference between adopters and non-adopters of irrigated fodder technologies in terms of the average residence distance in kilometer at 1% ($p<0.01$) significant level.

Table 6. Continuous institutional and policy characteristics of sample households

Variables	Total sample households (N=351)		Adopters (N=181)		Non-adopters (N=170)		T-test
	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	
Distance to FTC	1.56	1.26	1.23	1.10	1.91	1.32	5.23***

*** means significant at the1% probability level

4.2. Irrigated fodder technologies adoption

4.2.1. Type of irrigated fodder technologies delivered by ILRIs ILSSI project

Based on the survey conducted, the ILRIs ILSSI project demonstrates and scale-up fodder technologies cultivated by small-scale irrigation to stallholder farmers. These fodder technologies were produced and adopted by sample households such as elephant grass, desho grass, Rhodes grass, and desmodium, alfalfa, and Susbania susba. Of which, desho grass, and elephant grasses were adopted by 42.74% and 36.29% sample farmers relative to the rest of fodder technologies respectively (Table 7).

Table 7. Cultivated fodder technologies with irrigation

No	Irrigated fodder technologies	Adopters		Non-adopters	
		N	%	N	%
1	Elephant grass	127	36.29	223	63.71
2	Desho grass	150	42.74	201	57.26
3	Rhodes grass	51	14.53	300	85.47
4	Desmodium	56	15.95	295	84.05
5	Alfalfa	38	10.83	313	89.17
6	Susbania susba	27	7.69	324	92.31

Source: Own survey result (2021)

4.2.2. Reason for adoption and non-adoption of irrigated fodder technologies

A. Reasons why adopters adopting irrigated fodder technologies

As explained in figure 4.1 from the total sampled households 51.57% were adopters. Based on focus group discussion results adopters had reasons for adopting the irrigated fodder technologies. First, the farmers were asked to list the reason why they adopt the technologies using a checklist and focus group discussion. Then most prominent reasons were provided by participants and summarized into seven main reasons, which were included in the survey tool. During the individual interview, respondents were asked to rank (1-7) the reasons based on their importance.

Firstly, based on the survey results 45.14% of respondents adopting irrigated fodder used as feed sources during the dry season (Table 8). Respondents explained that the rainy season is now a day that enters later and the dry season is often extended. In such cases, the irrigated fodder technologies are used as a coping strategy to feed cattle mainly milking cows. This is in agreement with the study by (Wondatir Zewdie *et al.*, 2015a; Wondatir Zewdie & Damtew Elias, 2015b). However, less water availability from shallow wells dries soon after the onset of dry seasons is also a challenge for adoption.

Secondly and thirdly 42.29% and 29.71% of adopters adopted the technologies by expecting better milk yield and quality respectively when feeding the milking cows green forage produced by irrigation throughout the year (Table 8). This showed that small-scale irrigation fodder production is the best option beyond increasing feed availability at the household level and as a result contributes to increasing milk products and quality. This is similarly explained by the study of (Ghosh, 2004; Melku Muluye *et al*., 2017; Yilma Zelalem *et al.*, 2011)

In the fourth rank, 34.69% (Table 8) of respondents from the total adopters were responding the reason why adopting the technologies; because of participating in the learning and training process and understanding how much it is important. Training on the production of irrigation fodder, dairy cow handling, and health management was given by ARARI and SARI. Some farmers were also participated in the demonstration, pre-scaling up activity, and filed day organized by stakeholders mainly, ILRI collaborated with ARARI and SARI. This showed that training and awareness creation conducted is important for the adoption.

Farmer to farmer extension contact was also another reason for adopters to adopt the technologies. This is because learning new technologies is a complex process; farmers may need to rely on multiple sources of information before they adopt a new technology from their colleagues, neighbors, and friends. As a result, major respondents were taken it as the fifth rank as a reason for adopting the irrigated fodder technologies by observing from their peers.

Adopters were motivated to expand dairy farm production. Thus, 18.97% of adopters were adopting irrigated fodder technologies to produce a year-round green feed supply for milking cows (Table 8). This is supported by (Kebebe Ergano, 2015; ILRI, 2014). This implies that the feeding system is an issue for intensive dairy farm systems. Finally, based on survey results 20% of adopters were adopting the irrigated fodder technologies because of having water access (Table 8).

Table 8. Reasons for adopted irrigated fodder technologies (only adopter)

	Rank (1-7) based on importance						
Reason of respondents	1	2	3	4	5	6	7
Feed source during dry season	45.14	21.14	14.86	8	5.71	4	1.14
Expecting higher milk yield	33.14	42.29	17.14	5.71	1.71	0	0
Expecting higher milk quality	3.62	26.09	29.71	23.19	10.14	4.35	2.9
Learning and training	8.16	4.08	14.29	34.69	25.51	10.2	3.06
Observation of peers	5.17	6.03	16.38	23.28	27.59	18.97	2.59
Motivation to expand dairy	13.33	6.67	22	19.33	17.33	15.33	6
Good access to water	4.81	6.73	15.38	17.31	18.27	12.5	25

Source: Own survey result, 2021

B. Reasons why non-adopters not adopting irrigated fodder technologies

The total sample households of the non-adopter were 48.43% (Figure 4.1). To increase livestock production and alleviating feed constraints access to improved forage varieties is necessary. Thus, the researcher asked non-adopters using a checklist of questions through focus group discussion. The main reasons provided by non-adopters respondents have been summarized into seven and included in the main survey tool. Then, non-adopter household respondents were asked to rank the reasons why not adopting irrigated fodder cultivation.

About 41.54% of non-adopter responded that access to irrigation water was the first constraint for adoption in the study area (Table 9). About 41% of non-adopter respondents mentioned shortage of land and unsuitability of the available land for irrigation as a constraint for adoption (Table 9). This is supported by (Melkamu Bezabih *et al.*, 2016). Secondly, 41.05% of respondents from the total non-adopter, shortage of land, and unsuitability are taken as a challenge for adoption (Table 9).

Thirdly, 32% of non-adopters were not convinced by the benefit of the irrigated fodder technologies comparing it with khat income. According to focus group discussion results, due to better milk price irrigated fodder-based dairy production is profitable. But in some periods of the year the demand for milk products declines, especially during fasting months, during which they used milk only for home consumption. In times of fasting and disagreements with milk processing enterprises, the business has been challenged. Transforming the dairy cooperative into the processor level and creating effective market linkage with milk factories would solve the problem. But in challenging conditions irrigated fodder-based dairy production would not be economically feasible as the cost of irrigation fodder is high.

Fourthly, 30.49% of respondents reported shortage of labor as a challenge for adopting irrigated fodder technologies (Table 9). Based on the information, small-scale irrigation fodder development is a labor-intensive task; there is a high demand for labor in the area. But, non-adopter farmer's priority was to engage the available labor for harvesting cash crops. Fifth, for non-adopters who had no cross-breed cow, the irrigated fodder technologies were not implemented. 16.67% of respondents of the non-adopter puts crossbreed owner lead to adopting irrigated fodder. This is in line with the study by (Muuz Hadush, 2021; Duque-escobar, 2011). This shows that farmers adopted the irrigated fodder cultivation to increase milk and milk products. Finally, in this study, the non-adopters raised limitation of forage varieties access and training and information also a problem in the study area for adoption.

Table 9. Reasons for not adopting irrigated fodder cultivation (only non-adopter)

	Ranks (1-7) based on importance						
Reason for not adopting	1	2	3	4	5	6	7
Lack of access to IFV	33.33	30.48	18.1	10.48	4.76	1.9	0.95
Land shortage	37.89	41.05	12.63	6.32	2.11	0	0
Water shortage	41.54	35.38	17.69	2.31	3.08	0	0
Lack of access to training	20.17	21.85	31.09	17.65	7.56	1.68	0
Shortage of labor	13.41	13.41	21.95	30.49	10.98	8.54	1.22
Not convinced about the benefits	7.55	13.21	32.08	26.42	7.55	7.55	5.66
No crossbreed cow	14.81	11.11	18.52	25.93	16.67	3.7	9.26

Source: Own survey result, 2021

4.3. Income generated from sample farmers

The descriptive result showed that adopters of irrigated fodder total household farm cash income on average per year had 71,765.29 ETB while non-adopters had 55,616.88 ETB (Table 10). This total household income is calculated from the sum of forage income, cash crop income, livestock sold income and dairy income (Table 10). Household farmers who are adopting irrigated fodder are produced better milk per cow and generated more income.

However, at this level, it was difficult to conclude that adopting irrigated fodder technologies have an impact on this selected outcome variable. As a result, an impact assessment is a necessary task to determine this outcome variable affected by irrigated fodder adoption. This is conducted by controlling the observed and unobserved heterogeneity that affect the adoption decision and outcome variable.

Table 10. Cash income generated from sample farmers

Farm income	Total sample households (N=351)		Adopters (N=181)		Non-adopters (N=170)		T-Value
	Mean	SD	Mean	SD	Mean	SD	
Forage income	651.82	2712.59	908.83	3588.59	378.17	1173.25	-1.83**
Dairy income	10578.06	3049.05	11667.96	3691.929	9417.64	1452.33	-7.42***
Livestock sold income	10643.97	15902.48	12328.56	17673.06	8850.36	13593.82	-2.05**
Cash crop income	42070.27	18880.82	46859.93	20946.9	36970.69	43077.29	-1.01
Total HH farm income	63944.12	34470.59	71765.29	23153.1	55616.88	46839.66	-1.60*

*, and *** means significant at 1%, probability levels Source: Own survey result, 2021

4.4. Drivers of irrigated fodder technologies adoption decision

The binary probit model was used to identify significant driving factors that determined households to adopt irrigated fodder technologies. At the pooled analysis of the project intervention areas, 12 variables significantly determined the adoption of fodder technologies. These variables are age, education, distance to FTC, irrigated land size, livestock extension service received, member of dairy cooperative, dairy farm experience, water use association, forage seed access, the number of milking cows, irrigated fodder training, and dairy cow breed type. In this sub-section, the result of each significant variable was discussed based on the model result.

Age: The age of household head negatively affected the probability of adopting irrigated fodder technologies in the study sites. As the age of the household head increases by a year, the probability of adopting irrigated fodder technologies would decrease on average by 3.4% at ($p<0.01$) level of significance in the intervention areas, keeping other variables remain constant (Table 11).

The result is intuitive that as the age of the household head increases, the household decides not to use irrigated fodder technologies. This might be linked to the low motivation of aged farmers to try new technologies. In other words, the younger the household head is, and the more likely will be the probability of using irrigated fodder. This result is in agreement with the study by Aditya & Gillespie, (2013); Ergano Kebebe, (2015b) about the adoption and productivity of breeding technologies. This is also similar to the negative effect of age on the adoption of small-scale irrigation farming as climate-smart agriculture (Mango et al., 2018). By contrast, Gebremariam Yihdego, (2010); Martínez-García *et al*., (2016) showed that age has a positive significant effect on adopting micro-irrigation and forage production.

Education: The probit model result showed that as the level of education of the household head increases by one year of schooling, the probability of adopting irrigated fodder technologies increase on average by 4.85% at ($p<0.01$) level of significance, keeping other variables remain constant (Table 11).

Education level of the household head positively encouraged his/her decision of using irrigated fodder. This might be because farmers with higher education levels are good at communication, information searching, negotiation, and undertaking transaction which helps them to easily contact the development experts, seed traders and sell their products like dairy products and forage. This is in line with a study by Bayan, (2018) on the impact of dairy cooperatives on smallholder dairy farmers. Irrigation technology adoption is also affected by education level and coincides with the study by (Gebremariam Yihdego, 2010).

Irrigable land size: The model result indicated as the irrigable land size increase by a unit, the probability of adopting irrigable fodder technologies increased on average by 40.22% at ($p<0.01$) level of significance in the intervention areas, *ceteris paribus* (Table 11).

The land size owned allocated to irrigation is found to be an important factor in determining the adoption of irrigated fodder technologies in the study area. It is supported by Martínez-García *et al*., (2013); Bassa Zekarias, (2018). Mapiye *et al*., (2006) showed that land shortage was identified as one of the factors affecting forage adoption. Similarly, this is also supported by (Yeneayehu Fentahun *et al*., 2019). This is because forage production competes with food crop production and farmers may not want to take land away from food production for other uses.

Livestock extension service received: As the binary probit model result showed that, it means that households who obtained extension received has 26.64% at ($p<0.01$) level of significance higher probability to participate in the production of irrigated fodder technologies than farmers who did not service in the intervention areas *ceteris paribus* (Table 11).

Livestock extension service received has a significant and positive effect on the probability of adoption decision of using irrigated fodder technologies. This is supported the studies by (Alemayehu Abebe *et al*., 2018; Dehinenet Gezie *et al.*, 2014; Endeshaw Gedefaw *et al.*, 2020). In the mixed crop-livestock production system like the study area, the household’s main objective is subsistence farming. Thus, to think beyond subsistence farming and engage in cash livestock production, awareness plays a key role. In this regard in the project intervention areas, extension service and farmer's to farmer’s extension play a significant role in enhancing the knowledge of farmers about the use of irrigated fodder technologies and dairy production.

Distance to FTC: The model results showed that distance to FTC significantly and negatively affected adoption of irrigated fodder technologies. As the distance increased by one kilometer the marginal effect of the adoption decreased by 26.04% ($p<0.01$) level of significance keeping other variables remain constant (Table 11).

The assumption was that farmer's residents going far from FTC harmed the adoption of irrigated fodder. This is because FTC tends to be important to get information regarded any improved technologies. This result is supported studies by Alemayehu Abebe *et al*., (2018) and Bassa Zekarias, (2018) regarding determinants of improved forage adoption in Ethiopia.

Forage seed access: The binary probit model results regarded to forage seed access showed that households who obtained forage seed access have increased by a probability of 32.70% at ($p<0.01$) level of significance than did not access forage seed at project intervention areas, *ceteris paribus* (Table 11).

The main problem with the adoption of irrigated fodder technologies in the smallholder farming sector is the poor/limited availability of improved seed varieties. In addition, farmers could able to realize income from the sale of forage seed, which creates a possible condition to boost their income sources and diversity of farm activities. Based on the focus group discussion sometimes in the study area, farmers are bought fodder root splits/planting materials from IFV adopter farmers.

Dairy cow breed: The regression result showed that households who kept a crossbreed milking cow have increased by 30.72% at ($p<0.01$) probability to participate in the production of irrigated fodder than farmers who kept local milking cow *ceteris paribus* (Table 11).

A high level of technology adoption has a direct impact on milk yield and household income generation as well as dairy development. Farmers need crossbreed cows than local milking cows for milk production in the study areas. As a result, irrigated fodder production is associated with higher milk yield. The result is supported by (Dehinenet G. *et al*., 2014).

Membership in water use association: Membership in water use association significantly and negatively affected the probability of cultivating the irrigated fodder technologies at project sites. It means that WUAs households probability to participate in irrigated fodder decreased by 32.14% at ($p<0.05$) level of significance than that did not a member of WUAs of households keeping other variables remain constant (Table 11).

The probit model result of water use association variable is consistent with a study by Chuchird *et al.*, (2017) about the adoption of irrigation by a water pump. Though, its importance most common property is not used as a private resource so; a variable member of the water use association affects the adoption of irrigated fodder technologies negatively if not has private irrigation water accessed. This is because the association is governed by an informal way and disputes happened to use water. As a result member farmers resign from a member and neglect usage of irrigation technologies.

Irrigable fodder Training: As the binary probit model result showed that it means that households who obtained training the probability of participation in irrigable fodder increased by 30.26% at ($p<0.01$) level of significance than farmers who had not to access training *ceteris paribus* (Table 11).

Irrigated fodder technologies have a positive significant effect on the participation decision of the household in using irrigable fodder cultivation in the study areas. This is supported by (Salo Sefa *et al.,* 2017). This is also consistent with the study by Chuchird *et al.,* (2017) farmers who have access to training in agricultural water management will take the principles of agricultural production under sustainability and how the lifting of water used taking under consideration.

Number of milking cows: As the number of milking cows increased by one, the probability of adopted irrigable fodder technologies increased on average by 14.88% at ($p<0.01$) level of significance, keeping other variables remain constant (Table 11). It has a positive significant effect on the participation decision of the household in using irrigable fodder cultivation.

This is supported by (Salo Sefa *et al.*, 2017). This might be because later on a serious feed shortage especially during the dry season became a serious bottleneck to sustain their dairy farming and on another hand, the demand for milk and milk products increases from time to time. As a result, farmers increased milking cows in number to widespread the income source throughout the year and used irrigable fodder technologies. It helps to provide fresh/green grass during the dry season that has a great contribution to dairy animals' health as it is highly palatable and digestible.

Membership in dairy cooperative: The binary probit model results imply that participating as a member of the dairy cooperative the probability of adopting irrigated fodder increased by 35.18% at ($p<0.01$) level of significance than who were not a member in the project intervention areas, *citrus paribus* (Table 11).

Participation in dairy cooperatives had a positive influence on the adoption of irrigated fodder technologies at 1 % level of significance in the national level of the study area. Organizing of farmers to be a member of cooperative society would help to facilitate access to credit, access to extension information and market access and information. This result is consistent with Feyisa Bekele, (2020a) regarded the adoption of agricultural technologies.

Dairy farm experience: It was significantly and positively affects the probability of adoption in using irrigable fodder technologies in project intervention areas. As the dairy farm experience of the household head increases by a year, the probability of adopting irrigated fodder technologies increased on average by 1.03% at ($p<0.01$) level of significance at project sites, taking other variables held constant (Table 11).

Dairy farm experience plays a great role in the adoption of dairy-sector technologies. Thus, the probit regression result showed a positive and significant effect on the adoption of irrigated fodder technologies. Because awareness about the technology of fodder production increases the probability of using irrigated fodder technologies. It also increases the risk-taking capacity of the farmers and will give them the capacity to calculate costs and benefits which is very important in the participation decisions of the production of irrigable fodder technologies and other comparative scenarios. This coincides with a study by Gebremedhin Bruk *et al*., (2003); Njarui *et al*., (2017) on the determinants of improved forage technology adoption in Ethiopia.

Table 11. Drivers of households' decisions to adopt irrigable fodder: Probit model.

Variables	**Coefficients**	**Marginal effect (dy/dx)**	**Standard error**
Sex	0.27979	0.11092	0.24648
Age	-0.01882**	-0.00750	0.00856
Education	0.12178***	0.04858	0.03315
Dependency ratio	-0.08328	-0.03322	0.12866
Irrigable land size	1.00839***	0.40228	0.37503
Grazing land size	-0.28951	-0.11549	0.56932
Livestock ownership	-0.07667	-0.03058	0.05229
Extension service	0.67105***	0.26042	0.22217
FTC-distance	-0.41266***	-0.16462	0.08908
Dairy coop	0.91352***	0.35180	0.20589
Dairy experience	0.02599***	0.01036	0.00921
Credit utilization	0.16754	0.06669	0.21849
Mkt information	0.44115	0.17270	0.29417
WUAs member	-0.87176**	-0.32144	0.34884
Forage seed access	0.85743***	0.32707	0.23162
Dairy breed type	0.79183***	0.30728	0.20730
Fodder training	0.77770***	0.30260	0.19481
No milking cow	0.37183***	0.14833	0.10203
Constant	-2.31961***		0.60635
Sample size (N)	351		

*, ** and *** represents significant at 10% (P<0.1), 5% (P<0.05) and 1% (P<0.01) respectively

Source: Own estimation result, 2021

4.5. Impact of irrigated fodder technologies adoption

One of the basic objectives of this study was to analyze the impact of adopting irrigated fodder technologies on household income with ETB. The endogenous switching regression (ESR) model was employed to answer this objective. In the above two sections mainly, the driving factors of adoption and descriptive statics of this study are discussed. In this section, the impact part of the study has analyzed. In the first regime of the endogenous switching regression model, estimated the driving factors of the adoption decision of households discussed in subsection 4.4. The second stage of the ESR model is used to estimate the impact on dairy income and household farm income for both adopters and non-adopters of irrigated fodder technologies in the intervention sites of ILSSI project (Appendix Table 1 and 2).

The selection equation after the adoption equation incorporates all the variables in the adoption equation and instrumental variable to improve identification. The falsification test was used to check whether the proposed instrumental variable can be a good instrument for the adoption of irrigated fodder technologies. This instrumental variable used in the model was a distance from residence to FTC measured in km. The test variable was found to affect the adoption of irrigated fodder technologies significantly but has no direct effect on dairy and household farm income. Thus, the selected variable fulfilled the criteria to be the instrumental variable. Using endogenous switching regression model, the researcher estimated the outcome variable for both adopters had they adopted (ATT), and non-adopters had they adopted (ATU) (Table 12) showed below including transitional heterogeneity and treatment effect in the intervention sites of ILSSI project.

Table 12, revealed that the average treatment effect on dairy income for the treated/adopter of irrigated fodder technologies had increased by 3,975.082 ETB because of adopted the irrigated fodder in the study sites. This indicated that if adopters of irrigated fodder technologies did not adopt, the income generated from dairy products would have decreased by 3,975.082 ETB. For non-adopters of irrigated fodder technologies, the average treatment effect in terms of dairy income was 3,044.411 ETB. The results suggest that if non-adopters had adopted, dairy income could have increased by 3,044.411 ETB.

The transitional heterogeneity effect is positive in terms of dairy income. This indicated that the impact of irrigated fodder technologies on dairy income was significantly greater for farmers who real adopted compared to counterfactual at intervention sites. This result was supported by the study of Angrist & Krueger, (2001); Bayan, (2018) about the impact of a cooperative member on dairy income and milk yield.

Table 12, revealed that the average treatment effect on household farm income for the treated/adopter of irrigated fodder technologies was 10,427.20 ETB at intervention sites. This indicated that if adopters of irrigated fodder technologies did not adopt, the income obtained from the farm would have decreased by 10,427.20 ETB. For non-adopters of irrigated fodder technologies, the average treatment effect on household farm income was 35,994.58 ETB. The results suggest that if non-adopters of irrigated fodder technologies had adopted irrigated fodder technologies, farm income could have increased by 35,994.58 ETB.

The transitional heterogeneity effect was significantly negative in terms of household farm income. This indicated that the impact of irrigated fodder technologies on farm income of the counterfactual is significantly greater compared to farmers who really did adopt irrigated fodder technologies at a national level of the study area. This is similar to the study of the adoption impact of different technologies on household income (Khan *et al*., 2013; Lambrecht *et al*., 2019; Moti Jalet *et al*, 2015; Muuz Hadush, 2021).

This is also supported by the studies of Muuz Hadush, (2021); Muuz Hadush, (2018) regarding the impact of stall feeding practice on milk production and farm income in northern Ethiopia. This is also similar to the study that regarded forage technology adoption's impact on milk and milk product results in Kenya (Ngeno, 2018; Otieno, 2020). This is directly linked to adopters of irrigated fodder technologies increase the dairy income because milk productivity increased including butter and other milk products relative to non-adopters. This is also explained by the study of Angrist & Krueger, (2001); Bayan, (2018) about the impact of a dairy cooperative member on household income.

Table 12. Average treatment effects using the endogenous switching regression model

Outcome variables	Category	Decision stage		Average treatment effect
		To adopt	Not to adopt	
Dairy income	ATT	(a) 11,667.73	(c) 7,692.65	(I) 3,975.08***
	ATU	(d) 12,472.88	(b) 9,428.46	(II) 3,044.41***
	HE	(e) -805.15	(f) -1,735.81	(III) 930.67***
Household farm income	ATT	(a) 73,015.24	(c) 62,588.04	(I) 10,427.20***
	ATU	(d) 90,545.32	(b) 54,550.75	(II) 35,994.58***
	HE	(e) -17,530.08	(f) 8,037.29	(III) -25,567.38***

***,1% level of significance; ATT=Average treatment effect on treated; ATU=Average treatment effect on untreated Note: (I) = (a)-(c) (II) = (d)-(b) (III) = (e)-(f) HE =ATT-ATU
Source: Own survey result (2021)

Chapter 5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary and conclusion

In Ethiopia, livestock production is largely constrained by feed shortage. The main sources of feed are crop residue and grazing land. However, the introduction of improved forage for livestock producers was attempted by different organizations but, their adoption and economic contribution remained low. ILRIs ILSSI project is one of the research institutions that delivered the irrigated fodder technologies to final users since 2015.

Thus, the study aims to identify factors that influence the adoption of irrigation fodder technologies and the impact on household income using cross-sectional survey data. Descriptive statistics and inferential statics were employed. The binary probit model was used to analyze the driving factors for the adoption. The endogenous switching regression model was also employed to minimize the error that happened due to observed and unobserved factors for the outcome variable. The study involved an analysis of data collected from a total of 351 households at ILSSI project intervention sites. The primary data were gathered through various means for triangulation of data reality.

Based on the results of descriptive statistics most variables showed a significant association and mean difference except dependency ratio and grazing land size. Dairy income and household farm income were outcome variables in this study. Its statistics showed that the adopters of irrigated fodder technologies were significantly higher than non-adopters. Despite this, the finding was not enough to conclude that the adopter of irrigation fodder is beneficial than non-adopter without catch-up both observed and unobserved factors. As a result, ESR model was run to estimate the average treatment effect for both treated and untreated households.

From the total 351 sample households, 51.57% were adopters while 48.43 were non-adopters of irrigated fodder technologies. Among the main reason why people adopt irrigated fodder technologies are used as a coping strategy during the dry season and shortage of water was the main reason for not adopting the technology.

The probit model results showed that 12 variables were a prominent determinant for the adoption of irrigated fodder technologies. These variables were age, distance to FTC, member of water use association, irrigated land size, livestock extension service, membership to a dairy cooperative, forage seed access, dairy farming experience, credit utilization, number of milking cows, irrigated fodder training, and dairy breed kept type.

The endogenous switching regression model showed that in terms of dairy income adopters were increased by 3,975.08 ETB at project intervention areas because of adopted the technologies. Non-adopters of irrigated fodder technologies decreased by 3,044.41 ETB because of not adopting the irrigated fodder technologies. In terms of total household farm income, the average treatment effect of the treated/adopter of irrigated fodder technologies is increased by 10,427.20 ETB at project intervention areas because of the cultivation of fodder technologies while the non-adopters of irrigated fodder technologies household farm income was decreased by 35,994.58 ETB because of not adopting the irrigated fodder technologies. Based on this, we can conclude that irrigated fodder technologies adoption contributes to improving dairy income and total household farmer's income in the study sites.

5.2. Recommendation

Since irrigated fodders technologies adoption is extremely important towards improving the household income, the following recommendations are formulated based on findings for policymakers, development intervention activities, and future research.

The results of the probit model revealed that a dairy cooperative member can play an important role in the adoption of irrigation technologies in the study sites. It could play an effective role in supporting member farmers by supplying the price information, capital, and transportation that smallholder farmers often lack. However, the dairy cooperative in Ethiopia is not yet well-developed and needs to be strengthened its management capabilities and promote the expansion of dairy cooperatives.

Access to improved forage seed has a significant and positive effect on the uptake of irrigation fodder technologies in the intervention areas. However, the lack of marketing of forage seed is a major impediment to the adoption of these technologies. Thus, the government should strengthen forage seed producers in both the private and government sector and research institutes to improve forage seed development.

Water use associations play a vital role in the management of water supply and distribution. However, their existence can be detrimental to the adoption of irrigation technologies as they usually do not lead to proper organization. This leads to disputes among members and they might resign from the membership. This was the reason that the probit model results showed significantly and negatively affected the adoption of irrigated fodder technologies. Thus, the concerned body should organize the association using a set of rules and regulations that includes the official rules and procedures as well as unofficial values, norms, traditions, and practices.

The probit result revealed that farmers who have a crossbreed milking cow are more positive about the operation than those who have a local milking cow. This indicated that adaptive breed milking cow is necessary. Therefore concerned governmental and non-governmental bodies should concentrate on crossbreed cow and dairy production aspects. Enhancing infrastructural and institutional facilities such as livestock extension service, and organizing training for less experienced farmers were also found to be vital to motivate irrigated fodder and increase fodder productivity.

Based on the information gathered through FGD and key informant’s participants, it was concluded that the role of the irrigated fodder integrated with the dairy value chain is untouched. But this is important to the increased production of irrigation fodder and has significant advantages to the dairy industry. As a result, research institutions, universities, NGOs, governmental organizations, smallholder producers, and any concerned stakeholders should involve in their responsibility regarded in the irrigated fodder-based dairy value chain in the area.

According to the ESR result, the adoption of irrigation fodder technologies has a positive impact on dairy income and total household farm income. Both the ATT and ATU findings indicated that adopting an irrigation fodder system has a significant positive impact on dairy income and total household's farm income as compared to their counterfactual, and those households' who did not adopt irrigated fodder technologies will be better off if they could adopt irrigated fodder technologies. Therefore, the concerned body should concentrate to motivate adopters to continue adopting irrigated fodder technologies and to bring non-adopters to adopt irrigated fodder through technology supply and access. This can be promoted based on extension approaches such as sustained demonstration and pre-scaling up activity by research centers, extension agents, and universities.

5.3. Further research

This study was about the driver to the adoption of irrigated fodder technologies and its impact on smallholder farmers' income. Hence, the researcher advises some further research thematic areas regarding irrigated fodder production such as assessment of the impact of irrigated fodder technologies on household nutrition and food security. In addition, assessment of the existing value chain marketing of dairy products and the development of market-oriented forage seed production systems and recommend visible options to solve the market-related problem would be an important future research area.

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APPENDICES

Appendix table 1. Parameter estimates of the impact of irrigated fodder technologies on household's dairy income at intervention areas.

VARIABLES	Non-Adopter	Adopter
Sex	748.367687***	-201.817727
	(251.283248)	(785.778283)
Age	-2.966613	-31.437257
	(9.133350)	(24.829825)
Education level	-82.605921**	-9.407115
	(39.528271)	(87.785162)
Family size	-112.950590	-359.924744
	(149.429334)	(342.183387)
Total cultivated irrigated land size	-59.247888	-500.305824
	(467.508204)	(892.492982)
TLU	-11.814228	-90.792714
	(54.055080)	(152.071140)
Irrigated fodder training	-231.661184	711.068479
	(244.383073)	(672.856816)
Number of milking cow	-468.142964***	962.194402***
	(115.091880)	(333.823392)
Livestock extension service advice	-246.622654	280.920782
	(232.216055)	(739.097368)
Dairy cooperative	417.962380*	329.641990
	(239.845021)	(576.366496)
Market information	-105.497580	-653.739396
	(283.312876)	(834.579955)
Dairy farm experience	-5.128298	34.446922
	(9.930472)	(23.532004)
Credit utilization	213.589831	-199.771148
	(261.812641)	(566.585720)
Forage seed access	19.920670	-588.736830
	(226.006190)	(840.410271)
Dairy cow type	218.552137	-480.600865
	(242.339448)	(561.049523)
Grazing land size	996.529662	256.500586
	(681.762503)	(1,569.978299)
Member of water use association	-365.427557	1,211.984058
	(268.807269)	(1,327.060092)
Constant	9,122.390780***	13150.883147***
	(618.453258)	(1,864.078518)
Observations =351	Wald chi2(17) = 37.62	
Log likelihood = --3421.7867	Prob > chi2 = 0.0028	

LR test of indep. eqns. : chi2(2) = 8.68**

Note: ***, **, * are significant at 1%, 5% and 10% level respectively; St. err. in parenthesis

Appendix table 2. Parameter estimates of the impact of irrigated fodder adoption on household farm income.

VARIABLES	Adopter	Non-adopter
Sex	1,516.843417	-4019.415958
	(3,248.746938)	(3,354.763679)
Age	-68.533329	-30.286700
	(101.855763)	(122.197368)
Education level	-149.295216	-342.443517*
	(357.476825)	(528.905536)
Dependency ratio	-1035.829398	1,073.083745
	(1,421.566027)	(1,994.370841)
Total cultivated irrigated land size	13515.869264***	-9401.929178
	(3,720.442361)	(6,312.761793)
TLU	731.322851	621.298055
	(625.844011)	(729.794645)
Irrigated fodder training	1,121.963008	1,964.652717
	(2,737.137829)	(3,292.875546)
Number of milking cow	4,321.664575***	5,147.382534***
	(1,346.964975)	(1,490.180727)
Livestock extension service received	4,867.055514	1,295.344861
	(3,001.325602)	(3,101.745404)
Dairy cooperative	8,006.474315***	-1287.927166
	(2,354.754179)	(3,224.231557)
Market information	1,200.775881	-616.111612
	(3,427.208386)	(3,808.322848)
Dairy farm experience	-57.634524	108.427042
	(93.319680)	(132.666758)
Credit utilization	-4594.863061**	4,228.620727
	(2,314.360667)	(3,525.849096)
Forage seed access	-5165.041662	1,389.474297
	(3,541.727735)	(2,996.827797)
Dairy cow breed type	-4532.364693**	5,125.811207
	(2,282.846724)	(3,251.190359)
Grazing land size	-3376.496031	-840.653534*
	(6,489.855308)	(9,096.416208)
Member of water use association	8,925.779710*	2,768.679682
	(5,377.158124)	(3,605.715076)
Constant	71055.489062***	49837.354810***
	(7,483.521367)	(8,967.102374)

Number of observation = 351　　Wald chi2(17) = 26.28

Log likelihood = -4121.045　　Prob > chi2 = 0.0698

LR test of indep. eqns. :	chi2(2) = 7.22 **	
	Prob > chi2 = 0.0271	

Note: ***, **, * are significant at 1%, 5% and 10% level respectively; St. err. In parenthesis

Appendix table 3. Tropical livestock conversion factors

Animals	TLU-equivalent
Calf	0.25
Heifer and Bull	0.75
Cows and Oxen	1.00
Donkey young	0.35
Donkey adult	0.70
Sheep and Goat	0.13
Mule	1.00

Source: Storck *et al*. (1991)

Test of assumption of OLS

Appendix table 4 . Multi collinearity problem test using VIF at intervention areas

Variable	VIF	1/VIF
TLU	1.34	0.745485
Irrigated fodder training	1.30	0.771846
Total cultivated irrigated land size	1.28	0.779896
Age	1.27	0.790124
Dairy farm experience	1.26	0.791971
Number of milking cow	1.24	0.804078
Forage seed access	1.23	0.811989
Grazing land size	1.21	0.828225
Livestock extension service received	1.18	0.845853
Dairy cow breed type	1.17	0.851169
Member of dairy cooperative	1.16	0.860782
Education	1.16	0.863854
Member of water use association	1.12	0.896015
Dependency ratio	1.11	0.896871
Sex	1.10	0.913187
Livestock market information	1.09	0.913973
Distance to FTC	1.08	0.921715
Credit utilization	1.08	0.928676
Mean VIF	1.19	

Test of heteroscedasticity assumption

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of Adoption decision

chi2(1) = 0.89
Prob > chi2 = 0.3459

STRUCTURAL SURVEY QUESTIONNAIRE
ILRI – ILSSI Project
Drivers and impacts of Adoption of Irrigated Fodder Cultivation: Quantitative Evidence from Ethiopia.

Hello, My name is ________________________. We are from ILRI working on **ILSSI project**. The project focuses on irrigated fodder development for improving smallholder livelihoods. In this community, we are conducting a study to assess the socio-economic factors for irrigated fodder adoption and its impacts. For this purpose we are interviewing randomly selected households. Your household is one of these randomly selected households and would like to talk to you. The interview will take about one hour. All the information we obtain will remain strictly confidential and your answers will never be shared with anyone other than our project team.

Module I: Household Information

Section 1: Household location

No.	Variables	Response
1	Region	
3	District/Woreda	
4	Kebele/Village	
5	GPS location of the house	
6	Name of respondent (head)	
7	ILSSI project participation	1. Yes; 0. No
8	Gender of household head	1. Male 0. Female
9	Irrigated fodder cultivation (adoption decision)	1. Adopter 0. Non-adopter

Section 2: Household Demography

Variables	Response			
HH head age (year)				
HH head education (year of schooling)				
HH head marital status	1. Married 0. Not married			
HH head primary occupation	1.Farming, 0. Non-farming			
HH head main source of income	1.Off-farm, 0. Farming			
HH head off-farm activity participation	1.Yes, 0. No			
HH head farming experience (year)				
HH head farming system types	1.Crop system, 2. Mixed system, 3.Livestock system			
HH head and family food secure in last 12 month	1.Yes, 0.No			
Family size (Number of persons in the household)	**Age (year)**	**Male**	**Female**	**Total**
	0 -14			
	15 - 65			
	> 65			

	Total			

Note: A household consists of who live in the same compound and eat from the same pot in the last 12 months

Module 2: Livestock Ownership and Dairy Production

Section 1: Livestock ownership in the last 12 months

Types of animal	Number of Head	Total # sold (TLU)	Average unit price (Birr)	Total estimated value (Ethiopian Birr)
Local cows				
Cross bred cows				
Local heifers				
Cross bred heifers				
Draft Oxen				
Sheep				
Goats				
Donkeys				
Horse/mules				
Local poultry				
Improved poultry				

Section 2: Dairy production experience

Item	Response
Have you currently produce & sale dairy products?	1.Yes, 2. No
If yes, type of dairy cow that a household keeps	1.Cross breed 2. No
Local milking cows currently owned (#)	
Total number of crossbred cows currently owned(#)	
How long have you been engaged in dairying?	
Who are your customers	
How far do you travel to deliver farm produce	

Section 3: Dairy products and dairy income

Product types	Milking cows (#)	Average yield per day(lit)	Lactating days per year	Amount sold (lit/kg)	Average price(birr/lit)	Total income (birr/year)
Milk						
Local						
Crossbred						
Butter						
Local						
Crossbred						
Cheese						
Local						
Crossbred						

Module 4: Land Allocation and Crop Production

Section 1: Household land allocation

Description	Response

Total land owned (ha)	
Total area of cultivated land (ha)	
Total cultivated land under irrigation (ha)	
Area of grazing/farrow land (ha)	
Access to communal grazing land	1.yes 0.no

Section 2: Plots size and crops grown

Plots	Crop/fodder grown		Plot size (ha)	
	Rain fed	Irrigated	Rain fed	Irrigated
Plot A1				
Plot A2				
Plot A3				
Plot A4				
Plot A5				
Plot A6				

Section3: Crop production and marketing

Crops grown	Area (ha)	Total yield (qtl)*	Quantity sold (qt)	Average selling price/qt	Amount consumed (qt)	Stored for sales(qt)	Stored for seeds(qt)
Food crops (list three main food crops)							
Total				[redacted]			
Cash crops (list the top three)							
					[redacted]		
					[redacted]		
					[redacted]		
Total				[redacted]	[redacted]		

*qt = quintal = 100kg

Module 5: Irrigation Information

Section 1: Types of irrigation and sources of water

Description	Response
Did you use irrigation in the last production season?	1.Yes, 0. No
If yes, what type of irrigation have you used?	1. Sprinkler/ overhead, 2. Drip, 3. Surface
Access to water for irrigation	1. Shallow well, 2. River/lake/ dam/ pond,
Did you receive any irrigation related support?	1.yes, 0.no
Is there water users' association in your community?	1. Yes, 0. No
If yes, are you a member?	1. Yes, 0. no
What method have you used for obtaining water?	1. Pulley 2. Motorized 3. Solar pump
Did you have prior irrigation experience?	1. Yes. 0.No

If yes, irrigation experience (year)	
Total estimated irrigation related costs (Birr)	
Which crops do you grow with irrigation? (list them)	

Section 2: Irrigated fodder cultivation

Irrigation constraints	Response
Do you produce irrigated fodder	1.Yes 0.No
If yes, for how many years you have produced irrigated fodder	
Have you increased or decreased the size of irrigated fodder plot	1. Increased 2.decreased 3. No change
If it is your first year, what is your plan	1.Expand more 0. No change
What type of fodder variety have you often used for irrigated fodder production	1.Improved variety 2. Local variety
If 1, why?	1.Increase yield 2.healthy for animals 3. All

Module 6: Access to Services and Rural Institutions

Section1: Access to collective institutions

Description	Response
Are you a member of dairy cooperative?	1.yes 0.no
If yes, for how long are you a member of this cooperative (year)	
What were the reasons to join this cooperative?	**XXXXXXXXXX**
... in order to get a better price for my dairy products	1.yes 0.no
... Because there are no other buyers for my products	1.yes 0.no
... in order to get easy credit service	1.yes 0.no
... in order to obtain training for higher yield & quality	1.yes 0.no
Are you a member of informal collective institution (e.g. Mahiber)?	1.yes 0.no

Section 2: Access to credit service

Had access to credit (1.Yes 0.No)	Received credit (1.Yes 0.No)	Source	Terms of credit (months)	Annual interest rate (%)

Section 3: Access to improved forage variety (IFV) seed

Have access to IFV seeds (1.Yes 0.No)	Have used IFV seeds (1.yes, 0.no)	Sources (Code B)	Level of satisfaction (Code B)
Code A: 1. Local Market, 2.NGOs , 3. Woreda BoA Code B: 1. Very satisfied 2. Satisfied 3. Not Satisfied			

Section 4: Access to markets for farm produces

Description	Response
What is the distance from your residence to the main nearby market?	________km ______hours
What means of transport are you mostly used to bring your products to markets?	1. Cars/truck 2.Carts 3. Donkey
Did you have good access to market information?	1.Yes 0.No
If yes, who provides you the information?	1. Dairy coop 2.Traders 3. Relatives 4. Woreda BoA

What type market information have you received?	1.Price 2. Demand 3. Market intelligence

Section 5: Access to extension services in the last production season

Description	Response
Did you have access to livestock extension service?	1.yes 0.no
How frequent is the DA visit you and your farm in the last 12 months?	1. Twice 2. Monthly 3. Once
What is the distance from your residence to the FTC/DA office?	______Km

Section 6: Types of extension service and level of satisfaction in the last production season

Type of extension services/advice	Availability (1. Yes 2. No)	Received service (1.Yes; 2. No)	Service provider (Code A)	Satisfaction level (Code B)
Irrigated fodder management				
Dairy production & marketing				
Livestock health extension/ advices				
Livestock vet services				
Code A: 1. Woreda BoA 2. NGO/project 3. Private sector **Code B:** 1. Very satisfied 2. Satisfied 3. Not Satisfied				

Module 6: Feed Resources and Marketing

Section 1: Feed resources and utilization practices

Feed resources	Have access and used (1.Yes 2.No)	Sources (1.Own, 2. Market)	Use rank (1 - 7)
Cultivated forage			
Natural pasture/grazing			
Crop residue			
Hay			
Concentrate feed			
Brewery by-product (*Atela*)			
Eneset by-products			

Section 2: Feed marketing practices

Feed types	Average unit price (birr)	Total income (birr/year)	Who sold it? (Code C)	Which market (Code A)	Buyer (Code B)
Improved forage/fodder					
Crop residue					
Hay					
Straw					
Code A: 1. Farm gate, 2. Local market, 3. District market, **Code B:** 1. Urban dairy farmers, 2. Other farmers in the locality 3. Local Traders, **Code C:** 1. Husband 2. Wife 3. Male children 4. Female children					

Module 7: Effects of Adoption of Irrigated Fodder Cultivation

Section 1: Improved forage varieties (IFV) adopted and produced

No.	Types of IFV	IFV adopted (1.Yes 2.No)	IFV plot size (ha)	Year started adopting IFV	Mode of utilization (Code A)
1	Susbania susba				
2	Elephant grass				
3	Desho grass				
4	Rhodes grass				
5	Desmodium				

6	Alfalfa				
Code A: 1. Feed to own animals 2. Sale in local markets 3. Save for seed 4.All					

Section 2: Reasons for adoption of irrigated fodder (only adopter)

Reasons for adopting	Response	Rank (1 - 7)
Feed source during the dry season	1.yes 0.no	
Expecting higher milk yield	1.yes 0.no	
Expecting higher milk quality	1.yes 0.no	
Learning and training participation	1.yes 0.no	
Observation of peers	1.yes 0.no	
Motivation to expand dairy	1.yes 0.no	
Good access to water	1.yes 0.no	
Other		

Section 3: As a result of adoption of irrigated fodder, what happened to the following?

Outcome variables	Unit	Before	After
Milk yield	Liter		
Milk quality	1. Low 2. High		
Butter yield	kg		
Butter quality	1. Low 2. High		
Cheese yield	kg		
Cheese quality	1. Low 2. High		
Improved forage area	Hectare		

Section 4: As a result of the adoption of irrigated fodder, what happened to the following?

Outcome variables	Response	Percent change (use ten seed rule)
Land allocated for crops	1. Increased; 2. Decreased; 3. Not changed	
Water availability for family use	1. Increased; 2. Decreased; 3. Not changed	
Crop yields	1. Increased; 2. Decreased; 3. Not changed	
Labour demand	1. Increased; 2. Decreased; 3. Not changed	
Household nutrition	1. Increased; 2. Decreased; 3. Not changed	
Overall family income	1. Increased; 2. Decreased; 3. Not changed	

Section 5: Forage marketing and income from the sale of forages in the last production year

Types of forage	Sold (1.Yes 0.No)	Average unit price (birr)	Total income (birr/year)	Market place (Code A)	Buyer (Code B)
Green forage					
Hay					
Code A: 1. Farm gate 2. Local market 3. District market **Code B**: 1. Urban dairy farmers 2. Other farmers 3. Both					

Section 6: Reasons for not adopting irrigated fodder cultivation (only non-adopter)

Reasons for never adopting	Response	Rank them (1 - 8)

Lack of access to IFV	1.yes 0.no	
Land shortage/high trade-off with crop	1.yes 0.no	
Water shortage	1.yes 0.no	
Lack of access to training and information	1.yes 0.no	
Shortage of labor	1.yes 0.no	
Not convinced about the benefits	1.yes 0.no	
No crossbred cows	1.yes 0.no	

Thanks the Respondent!!!

Semi-Structured Checklists for KIIs and FGDs (ILRI - ILSSI Project)

<table>
<tr><th rowspan="2">Objectives</th><th colspan="2">Participants</th></tr>
<tr><th>KIIs</th><th>FGDs</th></tr>
<tr><td>• To learn the perception of key actors in feed value chain on the attributes of irrigated fodder cultivation
• To assess how adoption of irrigated fodder production had happened in the community
• To identify the key challenges in the adoption process
• Suggest possible solutions to sustain and expand irrigated fodder production</td><td>• Farmers
• DAs
• Woreda livestock experts
• Livestock researchers
• NGO field experts
• Cooperative leaders
• Feed processors</td><td>• Farmers</td></tr>
</table>

A. Location information	
variables	**Response**
Region	
Woreda	
Kebele	
B. Respondent information	
Name	
Age	
Gender	
Education status	
Years of services /farming experience	
Role in the Feed Value Chain (FVC)	1. Producer 2.Processor 3. Trader 4. Supporter

1. Who are the key actors/stakeholders involved in the irrigated fodder production & marketing in the study site?	
key actors	Functions/roles

2. Compare the positive and negative aspects of the irrigated fodder and rain-fed /traditional fodder production?			
Irrigated fodder production		Rain-fed fodder production	
Positive	Negative	Positive	Negative

3. What small-scale irrigation technologies were adopted in the kebeles? (provide list of practices)	
List of irrigation technology practices	Extent of adoption (1.low, 2.medium 3.high)

4. Describe how the adoption happened. (Explain step-by-step the activities undertaken & sequence of events that led to adoption)		
5. What are the key cost items in the production of fodder under irrigation?		
6. Do you consider the benefit of irrigated fodder production is more than the cost incurred on it? Why? Explain		
7. As a result of the adoption of irrigated fodder, what happened to the following?		
Outcome variable	Response (1.increased 2.decreased 3.Not changed)	Percent change
Milk yield & quality		
Land allotted for improved fodder		
Land allotted for crops		
Total family income		
Household nutrition		
8. What are the key challenges in the adoption of irrigated fodder in the kebeles?		
9. What has to be done to address the above challenges and increase adoption of irrigated fodder in the kebeles?		

BIOGRAPHICAL SKETCH

I was born in Dera woreda of south Gondar zone, Amhara region on Oct 02, 1983, E.C. I had completed my primary education at Wofargif primary school in 1999 E.C. The secondary education was completed in 2001 E.C from TanaHaik and then preparatory school was completed at Bahir Dar preparatory school in 2003 E.C. Then, I joined Mekelle University, Ethiopia in 2004 E.C and received my BSc degree in Natural Resource Economics and Management, in July 2006 E.C. After my BSc graduation I was employed as a hotel receptionist at Blue Nile Resort Hotels_Avanti, Bahirdar in 2007 E.C. After 3 months stayed I employed as a community facilitator internship in Digital Opportunity Trust (DOT) Ethiopia, which is a Canada project working on youths and business in 2007 E.C. Then I was working as a socioeconomics junior and assistance researcher at Adet agricultural research center since 2008 E.C until joined my MSc. study 2012 E.C. in Agricultural Economics. After finished my course work, ILRI announces ILRI research/graduate fellowship employment in 2013 E.C and I competed on this fellowship. Finally, ILRI given a chance to me and did my MSc. thesis entitled with "drivers to adoption of irrigated fodder technologies and its impact on smallholder farmers' income: evidence from innovation lab small-scale irrigation project sites, Ethiopia".