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TITLE: IMPACT OF ADOPTING WATER PUMP TECHNOLOGY ON SMALLHOLDER FARMERS' INCOME INKERSA MALIMA DISTRICT OF SOUTHWEST SHEWA ZONE, ETHIOPIA

WATER POLICY M.Sc. THESIS By BEKAM BEKELE GULTI

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IMPACT OF ADOPTING WATER PUMP TECHNOLOGY ON SMALLHOLDER FARMERS' INCOME IN KERSA MALIMA DISTRICT OF SOUTHWEST SHEWA ZONE, ETHIOPIA

BY

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DECLARATION

I, Bekam Bekele Gulti, declare that this M.Sc Thesis titled “Impact of adopting water pump technology on smallholder farmers’ income in Kersa Malima district of Southwest Shewa zone, Ethiopia” is my original work and has not been presented to acquire a degree in any other University. Where other sources of information have been used for this Thesis, they have been duly acknowledged and properly cited. To the best of my knowledge and belief, I declare that I have not committed or induced an act of plagiarism in the writing of this thesis.

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This is to certify that the thesis entitled "Impact of adopting water pump technology on smallholder farmers' income in Kersa Malima district of southwest shoa zone, Ethiopia" submitted in partial fulfillment of the requirements for the degree of Master of Science in Water Policy, the Graduate Program of the Pan Africa Institute for Water and Energy Sciences (incl. Climate Change), and has been carried out by Bekam Bekele Gulti Id. No PAUWES/2023/MWP02, under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the Thesis to the Water Program for defense.

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ACRONYM

ATT	Average Treatment on Treated
ATU	Average Treatment on Untreated
FGD	Focus Group Discussion
KII	Key Informative Interview
MESR	Multinomial Endogenous Switching Model
MFA	Multiple Factorial Analysis
MNL	Multinomial Logit
MSA	Multivariate Statistical Algorithm
PSM	Prosperity Score Match
OLS	Ordinary Least Square
SDG	Sustainable Development Goal
ATT	Average Treatment on Treated

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ABSTRACT

The application of water-saving irrigation technology has great significance for maintaining farmer's income and the sustainable development of agricultural water resources. However, farmers in Ethiopia face numerous obstacles while attempting to adopt new Water technologies. The purpose of this study was to identify determinants of water pump technology adoption and its impact on smallholders' income, in Kersa Malima district of Southwest Shewa. Primary and secondary data were collected from the study area by considering various water pump adoption factors. Primary data were gathered using scheduled interview, group discussion, and observation. Two-stage sampling techniques were employed to draw representative samples. The multinomial logit model (ML) was used to study adoption and a multinomial endogenous switching regression model (MESR) was employed to evaluate the impacts of adoption on farmer's total income. The result of the multinomial logit indicates that education (99% confidence), livestock holding (not significant), cooperative (99% confidence), and technology information (99% confidence) are the explanatory variables that affect adoption significantly and positively. However, distance from market (90% of confidence) and water source (99% of confidence) is the variables that affect the adoption of water pumping technology negatively. The finding of the MERS shows that, if the household head adopter decided to non-adopt of solar powered, diesel powered, or and both solar and water powered water pump, the household total income intake were decreases by 12.36%, 1.86% and 6.97%, respectively. On other if non adopter decided to adopt solar pump, diesel and mix of both solar and diesel power pump, their income will be raised by 31.9%, 19.6% and 25.4% respectively. The result suggests that to boost more stationmaster pumping technology and increase total household income among rural households, concerned bodies should strengthen promoting the adoption of solar water pumping technology.

Keywords: Adoption, Solar Pump, Diesel Pump, Total income, Ml model, MESR model

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Ethiopia has an estimated population of 130 million people, making it the second largest country in Africa next to Nigeria (CSA, 2021). The country is also blessed with abundant water resources, with twelve river basins providing an average annual water flow volume of 122 million m^3 and an estimated ground water potential of 2.6 to 2.65 million m3 (SWP, 2021). Agriculture plays a vital role in the Ethiopian economy, contributing to the livelihoods of more than 85% of the total population (Oreamuno & Marco, 2020). However, rain fed agriculture has frequently suffered from uneven distribution of rainfall and frequent drought shocks, leading to food insecurity of the poor rural communities (Solomon *et al*., 2021).

This days, there is a keen interest in small-scale irrigation due to its cost-effectiveness *(*Tesfaye et al., 2021) and sustainable management as compared to rainfall agriculture (Mihretie *et al*., 2022). It is believed that Ethiopia has more than 6 million hectares (ha) of land that is appropriate for small-scale irrigation use (Mohammedshum *et al*., 2023) and ample water resources suitable for irrigation (Eshete *et al*., 2020). Nevertheless, irrigated agriculture comprises only 3% of the national food production, using less than 5% of the cultivated land for irrigation (Yimam et al., 2021) due to various constraints. Study depicted that Ethiopia has the potential to add about one million ha of land irrigated by small-scale irrigation systems by 2030 (Xie *et al*., 2021). Several studies also suggested that using sustainable irrigation technology, the country can be increase labor and water productivity and environmental sustainability (Biswas & Iqbal, 2018).

Small scale irrigation, like other activities, is currently attempting to incorporate sustainability, including the reduction in energy consumption, the diminishment of environmental impact, and the preservation of natural resources, such as water and soil (Barrueto et al., 2018).According to cross-sectional data from the World Bank, Ethiopian farmers have the lowest farm income (Asia, 2015). Therefore, Ethiopian farmers must make more efforts to transform the agriculture sector so that it reaches the level of modern agriculture and set long-term targets to achieve higher incomes.

The advancement of irrigation technology can boost this extremely low level of production and income by creating alternative source of water for agricultural production (Wondimagegnhu & Bogale, 2020)

This is expected to improve the income of small-scale farm household. One of the potential solutions in addressing agricultural water management problem in Ethiopia could be the promotion of affordable small-scale water lifting technologies for irrigation such as motorized water pumps, pulley, and rope and washer pumps. Such technologies could increase smallholder farmers' access to agricultural water during dry seasons that allow farmers to practice multiple cropping in a year. By providing supplemental irrigation, access to agricultural water also cushions failure of the main wet season crops from dry-spells in rain-fed agriculture system (Lankford & Agol, 2024).

Recently, the Ethiopian government has started paying attention to the expansion of Water lifting to increase production and productivity. Specifically, it planned to increase the area of land covered by water pumping irrigation from 2.34 million hectares in 2014/2015 to 4.14 million hectares by the end of 2019/2020 and provide access to at least one alternative water point for 1.74 million ha of additional irrigated land (FDRE National Plan Commission, 2016).

Irrigation is one of the coping mechanisms for agriculture under a changing climate aside from the use of different crops or crop varieties, planting trees, soil conservation, and changing planting dates (Sinore & Wang, 2024)). However, the a recent study done by Belay & Mengistu, (2021)reveal that the proportion of households entering small scale irrigation remains still low (i.e. 10%) compared to alternative rain fed cropping strategies such as changing planting dates. Water scarcity during the main rainy season as well as off-season strongly influences the sustainable productivity of these systems (Pemunta *et al.*, 2021). Small scale irrigation, using available surface water and ground water resources, could decrease household vulnerability to climate shocks and improve livelihoods (Assefa *et al*., 2021).

Many scholars have conducted cost-benefit comparison of diesel versus solar-energy-derived water pumping using various approaches. Based on the design, investment, and yearly return, Olum *et al.*, (2020) developed a techno-economic analysis of solar water pumping systems . They found that, discounted payback period was nine years, which is within the system's lifetime according to the reports. Other economic criteria were examined, such as the 1.6 benefit-cost ratios and the 18.15 % internal rate of return (Barrueto *et al.*, 2018).

The study conducted by Agrawal & Jain, (2018) reveal that, cost-effective alternative water pumping was crucial for agricultural irrigation. Though the initial investment is high, some government like of India is supporting the farmers by providing subsidies. This system also has the potential to replace fuel-operated and electrical pumps; thereby providing a sustainable solution for meeting the irrigation requirements of crops (EIC, 2019). Berhanu, (2023) conducted research on replacing diesel with solar power, to increase income of small farmer household and reduce emission due to climate change. An increasing global climate change has brought with it social ills and food insecurity. Due to these social problems, it has become increasingly important for farmers to innovate how they conduct farming activities in a way that allows them to produce more income.

Understanding adoption and impact of water lifting technologies for smallholder farmers remains challenging in Ethiopia (Coalition, 2021). Often studies on water pumping technologies lacks the all demographic, technical and socio-economic factor which leads to the result biased(Kamwamba-mtethiwa *et al*., 2016). Hence, little information is available on impact of adoption of water pumping technologies given a particular geographical location, socio economic conditions. For example, diesel water pump found to have positive impact on crop revenue in Zimbabwe, Kenya, and Ghana however totals household crop profit hampers potential adoption in some African countries like Malawi. Moreover, diesel powered pump studies do report positive result in terms of total income (Mali, Mauritania) whereas negatively evaluated in Nigeria (Kamwamba-mtethiwa *et al*., 2016). In contrast, Bizimana & Richardson, (2019) found lower benefits from the solar pump than the pulley and motor pumps due to higher initial investment costs and low flow rates.

1.2 Statement of the Problem

Kersa Malima district has diverse watercourses that seem appropriate for small-scale irrigation farming. In the district, donors such as the International fund for agricultural development participated in irrigation scheme development and promoting new water pumping technology to improve smallholder farmers 'livelihoods. More than 5071 ha of land in the district have the capacity to be irrigated; of which 2704 ha have been cultivated using various techniques of irrigation. Due to small land available for irrigation, only 5834 households in the district benefited from small-scale irrigation farming. Despite the efforts made thus far to promote and distribute the water pumping technology to smallholder farmers, its adoption rate is still exceptionally low and varies amongst farmers (Nrsoweb, 2022).

Several studies were undertaken to determine adoption of diesel powered water pump adoption in Ethiopia (Schmitter, 2018, Nigussie *et al*., 2017,Schmitter *et al.*, 2018, Durga *et al*., 2024), while the remain focus on only factor determining adoption of solar water pump (Gebregziabher *et al*., 2016, Desta *et al*., 2023,Bizimana *et al*., 2023). Moreover, those studies were implemented binary (either probit or logit model) methods to investigate the factors that influence the adoption of water pumping technology and utilized Prosperity Score Matching (PSM) model and instrumental variable approaches to examine the impact of water pumping technology on various welfare metrics. Further, to the best of the authors' knowledge, no empirical research was undertaken that investigated the adoption of different water pumping technology, and the welfare impact of this technology adoption in the kersa Malima district.

Unlike prior research, this study employing the Multinomial Endogenous Switching Regression (MESR) model has triple advantages. First, bias resulting from the unobservable variable can be addressed. Second, with a fair adjustment for the result equation, the model allows getting consistent and efficient estimates of the adoption process. Thirdly, it facilitates the simultaneous computation of the effects of distinct and combined adoption of multiple technologies. This study, therefore, attempted to determine the variables that affect the adoption of water pumping technology as well as their effect on total household income in the study area.

1.3 Research Question

1. What are the key determinants of technology adoption decision?
2. How solar water pump adoptions affect total farmer income?
3. How diesel water pump adoptions affect total farmer income?
4. What is the combine effect solar and diesel water pump on total income of farmer?

1.3. Objectives of the Study

1.3.1 General Objective

The general objective of this study will be to evaluate the determinants of water pumping technology adoption and its impact on the small holder farmers' income in Kersa Malima district of Ethiopia.

1.3.2 Specific Objectives

The specific objective of this study will be.

1. To identify the key factors that determine simultaneous adoption of solar, diesel and combination water pumping technology
2. To assess the impact of solar water pumping technology on small household income.
3. To assess the impact of diesel water pumping technology on small household income.
4. To assess the impact of combine effect of both solar and diesel water pumping technology on small household income.

CHAPTER TWO: LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Agriculture

As in most Sub-Saharan African countries, the agricultural sector in Ethiopia constitutes a major source of livelihoods, dominated by smallholder farmers primarily relying on agricultural production for food consumption. Reflecting the sensitivity of Ethiopian agriculture to agricultural shocks, including droughts and locust invasion, the history of Ethiopia has been marked by a succession of massive famine events. In the past decades, the government of Ethiopia established successive Growth and Transformation Plans I and II to modernize the agricultural sector, transform the agri-food system and finally reduce the number of food-insecure households (Merrey, Schmitter, & Namara, 2020)

Consistently, a vast literature has documented that the growth in agricultural productivity generated by the agricultural modernization in Ethiopia has contributed to economic growth and poverty reduction (Mohammedshum, 2023) . However, rigorous and generalized evidence on the effects of those widespread agricultural interventions on yields and food security is still limited. The lack of specific assessments on food security impacts, in particular, is a major knowledge gap given its persistence in Ethiopia. Declining farm size (due to rising population pressure), soil degradation and repeated agricultural shocks have placed Ethiopian farmers in a situation of high vulnerability. These factors also raise concerns about Ethiopian smallholders' capacity to gain from large investments directed at agricultural exports, including those related to agro-industry.

Income-improving agricultural interventions have the potential to improve food security, in particular, when the household livelihood strategy is considered. By expanding output, they provide farm households with more food produced for their own-consumption, or greater liquidity to purchase food, through commercialization of agricultural products. While an increase in the total income of local small household it can contribute to rural development and the generation of employment opportunities (Oreamuno & Marco, 2020) , thus leading to farmer income stability.

2.1.2 Water

Water is a precious natural resource, vital for life, development and the environment. It can be a matter of life and death, depending on how it occurs and how it is managed. Irrespective of how it occurs, if properly managed, it can be an instrument for economic survival and growth. It can be an instrument for poverty alleviation, lifting people out of the degradation of having to live without access to safe water and sanitation, while at the same time bringing prosperity to all on the continent (Bizimana, 2023) .

Ethiopia is one of East African countries with enormous water resources potential. This water resource potential accounts for 122 billion cubic meters of annual surface runoff and 2.9 billion cubic meters of groundwater, despite uneven geographical and temporal patterns (Tesfaye, et al, 2021) . The researcher also mentioned that, only employing a small portion of its tremendous water resource potential for irrigated agriculture. Ethiopia has a tremendous irrigation potential, despite the fact that there is no consistent information from various sources. Ethiopia is renowned as Africa's water tower because of its rich water resources, which include more than ten river basins and 22 natural and artificial lakes (Workieh, et al, 2021) .

There are more than ten river basins in the country, with a total annual runoff volume of 122 billion m3 of surface water and an estimated 2.6 billion m3 of ground water potential, providing an average of 1557.5 m3 water per person per year. This is a significant amount of water. The country's largest four river basins, Abay, Baro-Akobo, Tekeze, and Omo-Ghibe, account for 80 percent to 90 percent of the country's water resource.

2.1.3 Irrigation

Irrigation is provided to supply water to crops and other cultivated plants to increase productivity during dry periods and erratic rainfall conditions as a supplementary irrigation. Irrigation has been implemented to increase agricultural productivity and reduce food insecurity in the nation (Lankford, *et al.*, 2024) . Irrigation projects have been classified as small scale, medium scale and large scale based on the extent of the irrigated command area. According to the Ministry of water, irrigation and electricity small scale irrigation projects cover an area less than 200 hectares, medium scale covers an area between 200 to 3000 hectares and medium scale covers an area greater than 3000 hectares (Nrsoweb, *et al*, 2021) .

In Ethiopia such irrigation system classification is common. Hence about 46% of irrigation development is categorized under small scale irrigation project category (Nigussie, *et al,* 2017) . Small scale irrigation projects are community based and traditional methods of irrigation.

Most of the time medium scale irrigation projects are community based or publicly sponsored, while large scale irrigation projects are commercially or publicly sponsored. On the other hand, Irrigation development in Ethiopia is in its infancy stage (Nrsoweb, et al, 2021) . The Ethiopian government is therefore pursuing plans and programs to develop irrigation in an effort to substantially reduce poverty and create an atmosphere for social change. As a result, the Ethiopian average rate of irrigation development for the last 12 years was about 1,090 - 1,150 ha/year (Solomon, *et al*, 2021) . In Ethiopia, only 10% of the estimated potential irrigable land is actually irrigated and 2% of cultivated lands are irrigated (FDRE, *et al*, 2016)

Similarly, irrigated agriculture comprises only 3% of the total national food production (Nigussie, *et al,* 2017). That is why; irrigated agriculture is far from satisfactory despite considerable investment, public interest, and strategic support of the government. Gebregziabher, (2018) explained that irrigation water is critical to poverty alleviation through increased production in rural areas so as to improve food security and rural livelihoods.

2.1.4 Concept and Definition of Water Pumping Technology

When people or groups adopt a new idea, it becomes a part of the social structure. Just (1985) defined adoption as incorporating innovation into farmers' regular farming operations over an extended period. Adoption, however, is not a persistent tendency, as discovered by (Theron *et al*. 2004). Different writers have described technological adoption in different ways. Adoption in the context of technical advancements is defined as the process by which an agricultural producer replaces a previously unknown procedure with another (Ramirez, 1992). Feder *et al*. (1985) had also given another definition for adoption, which is the integration of an innovation into farmers' normal farming activities over an extended period. In all these definitions, the actual practice and time factor are mentioned.

Although adoption is taken as a behavioral change, it might not be permanent. Discontinuation of adoption might also take place due to many reasons. Some of them are personal, institutional, and social. Another remarkable reason is that, a person might discontinue the adoption of a specific technology due to the availability of a superior technology that will be able to satisfy the consumer expectations at an elevated level (Barber *et al.*, 1989). This demands the creation of new information and the modification of its production function (Ramirez, 1992).

Water pumping technology refers to the methods and tools used to elevate water from one level to a higher one for applications such as irrigation, domestic consumption, and industrial purposes. These technologies are vital in regions with uneven terrain or limited access to surface water sources. Traditional techniques include the Shaduf and Archimedean screw, which rely on manual or animal labor, while modern advancements feature motorized pumps powered by electricity, diesel, or renewable energy sources such as solar and wind (Maryane., et al 2007). Solar-powered water pumps, for instance, have gained traction in remote areas due to their efficiency and sustainability. The choice of water lifting technology often depends on factors like the water source, required discharge head, energy availability, and cost-effectiveness. Efficient implementation of these technologies can significantly improve water accessibility and agricultural productivity, especially in developing countries (FAO, 2011)

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2.2 Empirical Review

2.2.1 Factor Affecting Adoption of Water Pump.

Despite the recognition of the sustainable benefits of solar water pump, the adoption rate of technology remains below the level designated by the Sustainable Development Goals (SDGs) identified by the United Nations for 2030, as many farmers are reluctant to adopt innovations (D'Amato *et al*., 2021). To understand where the obstacle to the innovative adoption may lie, several studies and reviews have been proposed to deepen the analysis of the innovation adoption process among farmers and the multiple factors that may influence their behavior (Guerin, 2001). It turned out that psychological factors play a strategic role in influencing the process of innovation adoption and diffusion among farmers (Caffaro & Cavallo, 2019), as well as socio-economic factors, including farmer's age, income, and education (Akimowicz *et al*., 2021), and some contextual factors, such as the size of the farm, and the environmental and political context in which it operates (Piñeiro *et al.,* 2020). Nevertheless, psychological, socio-demographic, and contextual determinants that influence the farmer's innovation adoption process are often analyzed separately, producing in some cases conflicting results.

Similarly, Piñeiro et al., (2020) mentioned that, by a selection of 20 studies, the acquisition of good information and education level as the socio-demographic factors most influencing the adoption of innovations. On the contrary, in accordance with previous studies by Gupta et al., (2020), it was found that the complexity of innovation, a high degree of innovation aversion, and the low perceived control over innovation are strong barriers to innovation adoption as they make the adopter insecure. At the same time, low education, poor advice support (Lindblom et al., 2017), and unfavorable working conditions (Caffaro & Cavallo, 2019) turn out to be rather common hindering factors. Finally, the change of work routine and the increase in the market cost of the product also negatively influence the innovation process (Ghadge et al., 2021) as it reduces the farmer's certainty in implementing innovation. In fact, resistance to change in work routines and the personality of the entrepreneur are related (Creissen *et al*., 2021). Farmers who are not predisposed to change in general may be particularly against change in general (Bonke & Musshoff, 2020), as changing routines triggers a high perception of risk in them (Trujillo-Barrera *et al.*, 2016). However, high-risk perception can be mitigated by a good risk tolerance (Trujillo-Barrera et al., 2016). Despite this, a lot of farmers reject the change (Barreiro-Hurle *et al*., 2018)

Indeed, this review showed that the possibility of having a comparison with other peers and technical and/or financial support significantly increases the likelihood that the innovation will be adopted (De Steur *et al.,* 2020). One of the reasons for this is that policies can enhance the farmers' confidence and incentivize the adoption of sustainable practices. By offering tangible guidelines and support, policies can help farmers mitigate income volatility and foster a greater sense of security in embracing sustainable approaches.

2.2.2 Impact of Water Pumping Technology on Small Farmer Holder of Sub-Sahara Africa

Understanding adoption and impact of irrigation technologies for smallholder farmers remains challenging in Sub-Saharan Africa (SSA) (Namara *et al.*, 2014). Often studies on waterlifting technologies are conducted in controlled environments, at different scales, focus on specific location/regions, fail to specify whether technologies were given to farmers/owned by farmers or taken up on credit whilst using different evaluating factors, complicating the technical and socio-economic comparison between technologies (Kamwamba-mtethiwa *et al*., 2016). Hence, little information is available on suitable technologies given a particular geographical location, socio economic conditions (market access, input availability and access, etc.). For example, manual water lifting devices (i.e., rope and washer, treadle pumps) were found to have a positive performance on farmer income in Zimbabwe, Kenya and Ghana however their labour intensiveness hampers potential adoption in some African countries like Malawi (Kamwamba-mtethiwa *et al*., 2016).

When using farmer income indicators, motorized pump studies do report a positive impact on household consumption amongst other socio-economic factors (e.g., Nigeria, Mali, Mauritania, Niger, Ethiopia) whereas when factors such as labour, energy and water consumption are used motorized pumps a rather negatively evaluated (e.g., Mauretania, Nigeria, Kenya, South Africa, Ethiopia, Mali) (Kamwamba-mtethiwa *et al*., 2016). Solar pumps are in growing demand in Asia (e.g., Bangladesh and India) but a relative new technology for SSA and available literature on success rates is limited (Burney, 2012). The studies evaluated a positive effect of solar powered drip on household nutrition and food security for households (mainly women) below the poverty line (i.e., 1.25 USD day-1 in the study).

Number of available studies investigating the full technical as well as the socio-economic benefits are rare and their potential in improving livelihood of poor households need some further investigation. International Integrate water resource management indicates water lifting and scheduling technologies suitable for irrigated crop production as function of the available water source(Merrey *et al*., 2020).. In many of the site's farmers are involved in multiple protocols increasing the stress on available water resources. Kersa Malima district is one of the implementation sites where potential irrigable land is underutilized due to a scarcity of surface water despite a potential of shallow groundwater. Rapid expansion and promotion of irrigation within SSA calls for associated water management recommendations and guidelines to accompany the promotion of small-scale irrigation and avoid sub-optimal agricultural performance and negative environmental effects.

2.2.3 Impact of Water Pumping Technology on Small Farmer Holder of Ethiopia

Deferent study was conducting to assess impact of adopting water pumping on smallholder farmer. One of the study done by Schmitter et al., (2018) reveal that, cabbage the average profit obtained using solar based irrigation (16,703 USD) exceeded those made in the control (8,689 USD), rope and washer (7,758 USD) or service provision group (9,239 USD). For carrot the highest profit was obtained for the service provision of water (14,343 USD) followed by the control group (9,969 USD), rope and washer (9,890 USD) and solar pump (8,977 USD). From this finding, solar power needs less labour but less efficient in terms of water efficiency with other water pumping technology. in other word, the carrot yield obtained in the drip system was 1.7 times the yield obtained in the solar group whereas for cabbage it was only 1.2 times higher. Hence, the higher net income for cabbage when using solar pumps is mainly related to the absence of fuel costs and the reduction of labour. Which means, the higher carrot yield obtained in the drip compensated the fuel cost and the increased of irrigation labour.

Regarding improving warfare of small household, (Workineh et al., 2020) conducted his study on Impact of water pumping adoption. The result show that, adoption of water pumping technology should be more intensified to improve smallholder farmers' welfare. This mean that, average household income (4778.5 USD) for adopters of water pumping technology while (4268.73 USD) for adopters in the counterfactual case. Then the adoption effect on adopters can be found by subtracting(509.77 USD).This suggests that the farm household's average income adult equivalent for those who adopted IWV is significantly higher than if they did not adopt.

Similarly, the study conducted on Impact of improved agricultural technologies adoption on farm household income in east Shewa zone, Ethiopia (Hawas & Degaga, 2023), revealed that, a statistically significant gain in household farm income as a result of using improved agricultural technologies in the study area. More specifically, the researcher found that households using improved agricultural technologies obtained, on average 102USD higher annual farm income compared to those households not using such technologies. This is a significant result implying that adoption of improved agricultural technologies and practices resulted improved welfare of the farmers in the study area.

Furthermore, the recent study carried out by Kalle Hirvonen, Elia Machado, (2024) confirm that, positive impact of agricultural technology adoption on farm income is accepted at 5% significance level. Validating the hypothesis, Solar power adopters were much better to get birr190 USD than their non-adopter counterparts. Furthermore, still validating the null hypotheses, this technology adopters were found to be earners of birr 35 USD much better than their counter parts. Hence, the result is as expected with our hull hypotheses in such a way that, water pump technology adopters can really produce high valued and marketablecrops that accelerate additional income and further motivate farm households to adopt technologies again and again.

2.3 Analytical Framework

2.3.1 Techniques for Measuring the Determinants of Technology Adoption

Following the seminal work of Kassie et al., (2015) the PSM model was adopted to explore the factors that determine the adoption of technology packages in this study. In binary choice models, information about farmer's adoption of a single technology package does not alter the likelihood of the decision to adopt another technology (Kassie et al., 2015). Thus, probit and logit models have been widely used to model discrete decisions (SHELEMO, 2023).

In addition, a bivariate model has limited applicability for estimating interdependent decisions. Subsequently, (Dorfman, 1996) adopted a Multinomial Logit (MNL) model to estimate multiple adoption decisions. However, the MNL model has its own drawbacks, even if it estimates the influence of the explanatory variables on dependent variables that include multiple choices with unordered response categories (Webel, 2011). The MNL model classifies households into different categories based on the technology packages adopted. As a result, the factors that cause households to choose a particular set of technology packages cannot be considered at the same time. It assumes that the household assigned to a particular adoption category will not participate in another adoption category. Thus, a MNL is appropriate only when the adoption categories are independent and mutually exclusive.

In contrast, PSM is appropriate when different technology packages are interdependent, and this approach fills the gap in the methods (Marenya & Barrett, 2007). The PSM is a method of interrelated binary response regression model that estimates the effect of a set of independent variables on the adoption of different packages at the same time and allows free correlation of noise terms and correlations between adoptions of different maize technology packages (Belderbos et al., 2004). This study assumed that the selected maize technology packages are correlated and not mutually exclusive; therefore, the use of PSM is the best fit.

2.3.2 Techniques for Assessing Impacts of Technology Adoption

In impact evaluation, if the treatment and control samples are randomly drawn from a well-defined set population, selection bias becomes zero and, therefore, the Ordinary Least Square (OLS) regression method can be used to estimate the average treatment effect of the program on treated (Khandker et al., 2010). However, due to possible selection bias and the existence of an unobservable correlation between the outcome variable and the program intervention (omitted variable bias), the use of the OLS procedure leads to biased estimates (Becerril & Abdulai, 2010). However, when it is not possible to draw the treatment and control groups randomly from the population, several non-experimental impact evaluation methods can be used to assess the impact of technology adoption on farmers' welfare measures. These methods include regression discontinuity design, propensity score matching, different, instrumental variable estimation, endogenous switching regression as well and multinomial endogenous switching regression models.

Multinomial endogenous switching regression model: Bourguignon *et al.*, (2007) has recently been used in empirical investigation (Ng'ombe *et al.*, 2017). The MESR model has been widely utilized to assess the relative impact of adopting two or more upgraded technologies, as well as the impact of taking part in two or more initiatives or interventions that are mutually incompatible (Steve Hatfield-Dodds, 2007).

Multinomial endogenous switching, according to Maddala and Nelson (1975), is a two-stage regression-based technique that models two outcome equations, one for the treatment and one for the comparison, allowing for endogenous treatment selection. While the second stage of the Multinomial endogenous switching model utilizes OLS to analyze the determinants of food security in each of the categories of adopters and non adopters in the sample, the first stage of the model uses a multinomial logit model to study the determinants of adoption. Employing the Multinomial endogenous switching model has triple advantages. First, bias resulting from the unobservable variable can be addressed. Second, with a fair adjustment for the result equation, the model allows getting consistent and efficient estimates of the adoption process. Thirdly, it facilitates the simultaneous computation of the effects of distinct and combined adoption of multiple technologies (Steve Hatfield-Dodds, 2007).

So, for this paper, Multinomial endogenous switching is employed because it captures biased selection as well as can account for endogenous stratification, which occurs when the choice set is impacted by the decision maker's traits or the circumstances in which the choice is made rather.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Descriptions of the Study Area

Kersa Malima district was located between latitudes of $8^0$35’0”N to $8^0$42’0”N and with longitudes of $4^0$2’0”E to $4^0$9’30”E (Fifure1). The district is located at 60 Km southwest of Addis Ababa with the total area of 58613 hectare (586 km^2). Elevation varies from 1839 to 3568 meters above sea level. It is bounded with Buta jira southwest, East Shewa zone to the east, Sodo Dachi, Alemgena, and Tole district to the south, northeast and northwest, respectively. The district has an estimated total population of 101,796 males and 97,805 females (CSA, 2021).

The agro-ecology is classified as midland (74%), highland (20%), and some lowland (6%).The study area is characterized by tropical and warm too cold humid temperate climates. These areas are characterized by an average temperature that ranges from 10-19^0C and the rainfall that ranges from 974-1319 mm. The highland part of the district is characterized by; moderate an average temperature 10-15 ^{0}C and 1170-1319 mm rainfall. The vegetation type in the district is Juniperus forest, Podocarpus, sub afro alpine region with discontinuous canopy and larger trees limited in spatial cover.

The farming system in the district is mixed crop-livestock type, whereby crops contribute larger share to farmers’ income. As of potentialities, the district has high potential for crop production. The five major crops grown in the area are sorghum, maize, wheat, barley, and pulses. Khat and vegetables are the known cash crops. In 2023/2024cropping season, about 31.25% of crop land was covered by wheat, 19.79% by maize, 18.47% by barley, 10.19% by sorghum and 6.30% by chickpea of the cultivated area (Dawid et al., 2023). Kersa Malima is a potential Faba bean producing district where, faba bean production is about 22.77 quintal per hais greater than the national average, which is the highest next to Arsi zone in Oromia region. Khat and vegetables are the known cash crops. Cattle, goats, and sheep are among the livestock species reared by the community in the district. The main economic activities were food crops, cash crops (khat), and livestock production. The most important crops sold were khat, potatoes, and onions. Land ownership, livestock production, and other resources determine the wealth status of the district (Nrsow, 2022).

Kersa Malima district has enough water resources potential and flat land escape which is available for irrigation activities. In the area modern and traditional irrigation systems have long been practiced in the catchment area of Awash River basin by using furrow and pressurized irrigation system. Few land holders are engaged in irrigated agriculture using water from the Awash River, ground water while the others rent out their holdings for private farmers who use their own solar to pump out the water from the water sources and most of the farmers in the district are rain dependent (Shiferaw et al., 2023).

Based on the information obtained from district office, about 55,000 hectares of land is under agricultural production is dependent on rained. From the total agricultural area, the irrigation potential for the Awash River catchment is estimated to be 13,300 ha in 10 in rural area of the Kebels. Out of these, 82% (10,880 ha) have been developed under traditional and modern small-scale irrigation. The water sources for small-scale irrigation schemes are river and groundwater which allow up to three cropping per year, mainly high value crops. Livestock production is another economic activity in ATJK, and the number of animals still is a symbol of wealth among farmers. The estimated livestock population in Kersa Malima district is 139,486 cattle, 39465 goats, 6424 sheep, 11573 equines, and 45378 chickens (Nrsow, 2022).

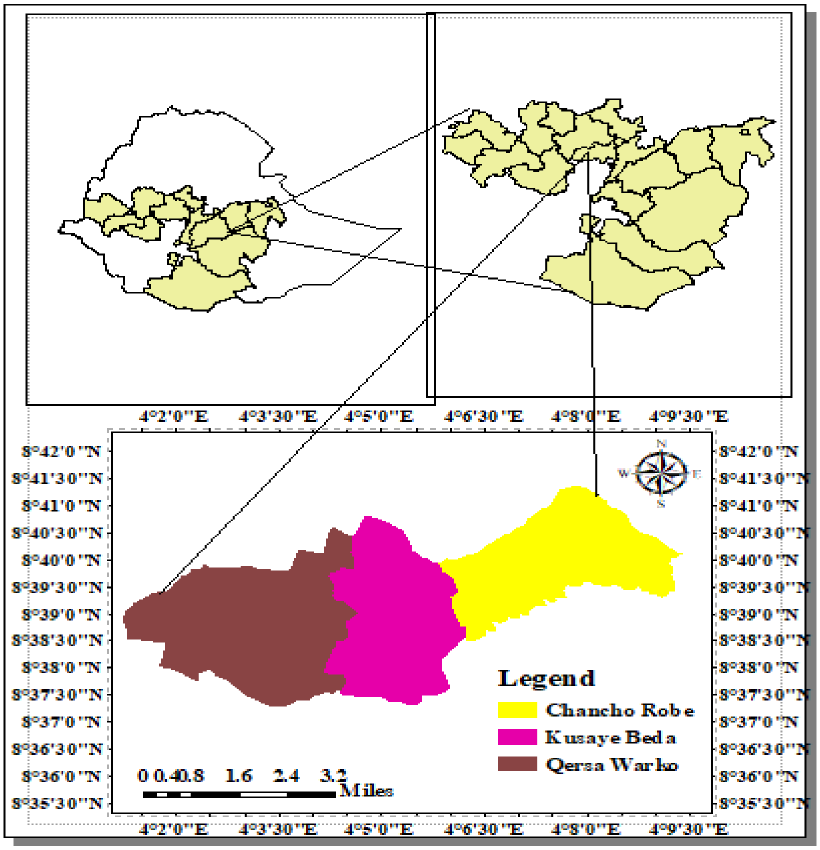

Figure 1 Map of the study area

3.2 Research Design

A cross- sectional primary data was collected through semi-structured questionnaire to capture quantitative or qualitative data (Sterling et al., 2017). This sub section clearly shows, the different factors that affect the adoption probabilities and use intensity of water pumping technology, and the household income as outcomes.

The adoption and use intensity of water pump technology determined by demographic characteristics (age, gender, education level and family size), socio-economic factors (cultivated size of land, livestock holding and non-farm income) and institutional factors (access to credit and technology information, membership of cooperative, farming experience of household, frequency of extension, distance from market and distance from water source).Similarly, the household's income is the outcome of several interactions of farmer internal and external factors. Diagrammatic relationships of the different factors that determine adoption of water pump technology are presented following Figure 2.

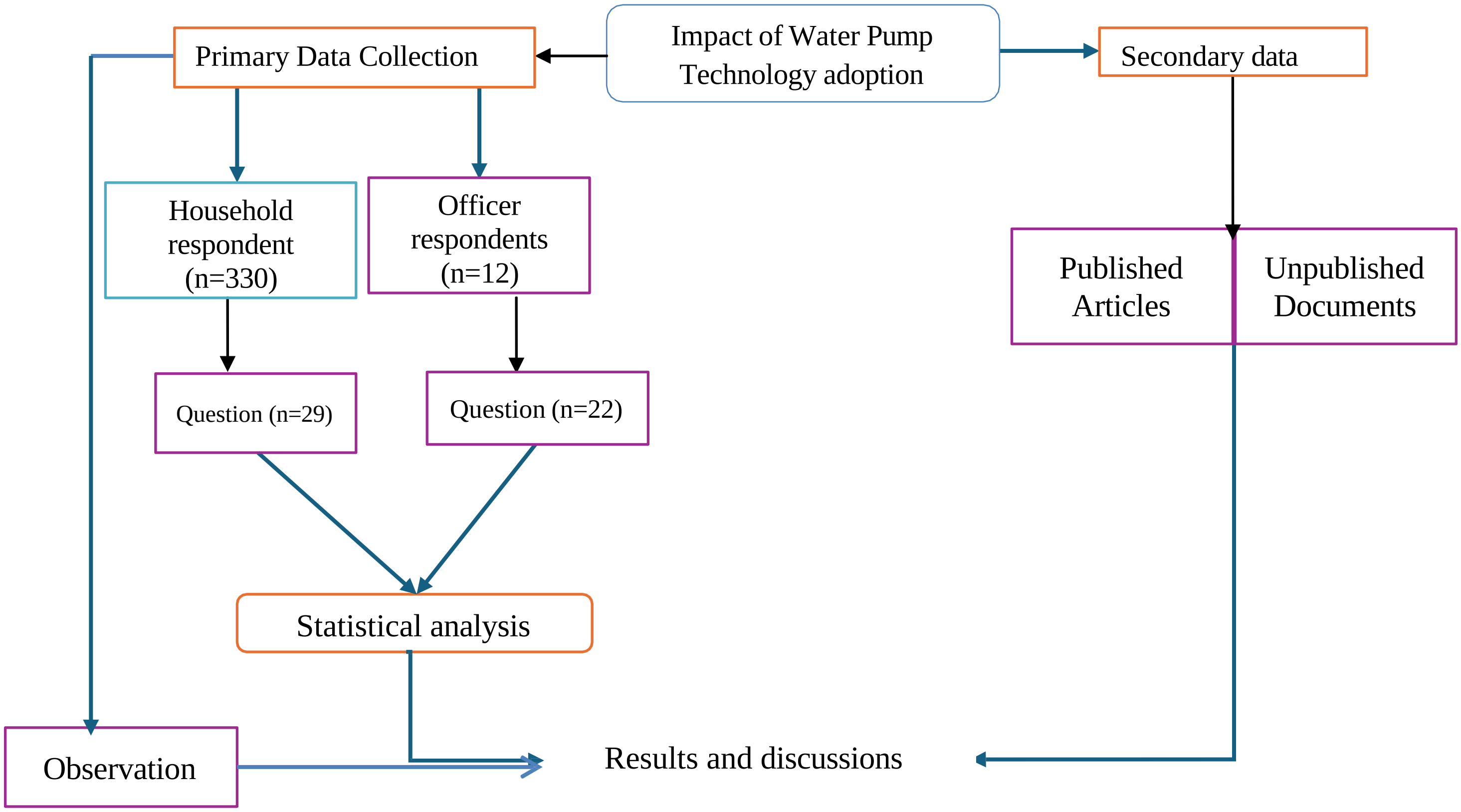

Figure 2 Research Design

3.3 Data Collection Method

Primary and secondary data were gathered for this investigation. The study's data were both quantitative and qualitative. The quantitative data were collected from sample households by using the semi-structured questionnaire.

Cross-sectional data were collected from 330 sample household heads using a semi-structured questionnaire consisting of open (29) and closed-ended (22) formats. Initially, the questionnaire was designed in English and then translated into Afaan Oromo language to ease communication with respondents. Before delivering the actual questionnaire to sample respondents, a pilot test was carried out with 30 randomly selected farm household heads (5 from each village in the watershed) that were not the members of sample respondents but had comparable backgrounds. The purpose of the pilot test was to check the consistency and validity of the questionnaire.

The questionnaire was modified and corrected based on the responses obtained from pilot test. Then, six enumerators (agricultural experts working in the watershed) were purposefully selected and trained on data collection and interviewing techniques for two days at the end of November 2024. Subsequently, data were collected from sample household heads through individual interview methods on the beginning of December 2024. The questionnaire consisted of the socio-economic and the demographic variables of rural households, plot characteristics, the major crops growing, sources and income status of the households, water technology adoptions and their benefits.

The intentions of FGDs were to obtain supplementary information and triangulate the quantitative data. According to Eeuwijk & Angehrn, (2017), noted that the participants in FGDs have 6 to 12 members. They advised that in a FGD, more than 12 participants can be difficult to facilitate and less than 6 may not represent the community. Totally 18 participants, consisting of kebele administrative leaders, development agents, elders, model farmers and youths were involved in the discussions. The participants were purposefully identified considering: detailed knowledge about the irrigation; well-water pumping technologies on his or her farmlands; knowledge on the pros of technology adoptions to improve households' income. The type of water adopting technologies adopted in the study area, households' income and sources of household income were addressed in the discussion. Discussions were held in December 2024, concomitantly with households' survey.

Key informant interviews were captured with 6 purposively identified water resource management experts, pump management and use experts, crop production and income experts, and local elders. The KII checklists were prepared to obtain detailed information on the performance of water pumping technology adoptions on yield production, and households' income. Besides, participatory field observation (village walk) was held with the aid of development agents, water resource experts, religious fathers, and elders to seize ground evidence on water pumping technologies adopted in the study area, the status of straw (fodder) in the village, vegetable production and khat production. Both KII and village walks were held concurrently with the household survey to triangulate the actual ground information. The research was utilized photographs to support field observations.

3.4 Sampling Procedures and Sample Size Determination

To choose the sample of respondents, multi-stage sampling procedures were used. In the first stage, the Kersa Malima district is selected purposively based on user of irrigation and water pumping. In the second stage, from three potential irrigation user of rural kebeles of the district, three kebeles were selected randomly. In the third stage, households that adopt water pumping in the three kebeles were stratified into two groups: adopters, who used water pumping (sola power, diesel power and mixing of both), and non-adopters, who did not utilize water pumps. Then, a total sample of 330 (163 that adopted and 167 that did not adopt) respondents was randomly selected proportional to the number of households in each kebele (Table 2). The sample frame was obtained from the sampled kebele office of agriculture.

There are several approaches for determining sample size. Most techniques rely on the mean, meaning that because each feature is likely to have a distinct variation, the sample size might vary significantly across them. These characteristics often lead to the preference for a proportionately defined sample size.

As a result, Crochian,(1967)was used to establish the sample size (Eq. 1). In sample size determination, confidence interval, level of precision, and degree of variability are the main useful statistics.

$$n = \frac{Z^2 * p * q}{e^2} \tag{1}$$

$$\frac{1.96^2 * 0.5(1 - 0.5)}{0.05^2} = 384$$

Where n = desired sample size, Z - Values of standard variant at 95% confidence interval (Z = 1.96), P - The estimated proportion of farmers who adopted small-scale irrigation and is unknown and P= 0.5 was used to obtain a maximum number of sample household heads.

Crochian,(1967)pointed out that if the population is finite, then the sample size can be reduced slightly. He proposed a correction formula to calculate the final sample size which is given below in Eq.2

$$n = 1 + \frac{no}{\frac{no-1}{N}} \quad (2)$$

$$n = 1 + \frac{384}{\frac{384-1}{2350}} = 330$$

In the last stage, before conducting the selection of sample households in the selected kebeles, sampling frame will be established by taking the complete list of households from the record available in the kebeles' administration and agriculture office and disaggregated them into adopters and non-adopters.

Table 3.1Sample district, kebeles, and numbers of household

Kebeles	Total Household	Sampled			
		Adopter (number)	Non- Adopter (number	Total (number)	Proportion (%)
Chancho Robe	897	55	58	113	34.25
Kusaye Beda	697	52	52	104	31.50
QersaWarko	756	56	57	113	34.25
Total	**2350**	**163**	**167**	**330**	**100**

3.5 Data Analysis

To analyze the data and provide answers to the study's objectives, both descriptive and inferential statistics were used.

Descriptive statistics such as means, percentages and standard deviation, minimum and maximum values were used to describe the demographic, socio-economic, and institutional characteristics of sample households. The chi-square (discrete variables) and t-test (continuous variables) were applied to check the statistical significance association and differences among adopters and non-adopters. Besides, inferential statistics such as independent t-test were used to compute the mean difference of continuous demographic, socioeconomic and farm characteristics of water technology adopters and non-adopters while non-parametric indicators were computed using the chi-square test through SPSS version 22 and STATA version 14.2 software. MESR was deployed to quantify the impact of water pumping technology adoptions on the income of rural livelihood, measured in terms of total farm income.

3.6 Multinomial Endogenous Switching Model

3.6.1 Multinomial Logit Selection Model

This study uses MNL to study the determinants of farmers' decisions on adoption of water pumping technology. According to Upton, (2016) in conditions where the IIA assumption is full field MNL model is chosen over MNP (, since MNL is much more stable model than MNP. Beside MNL model is relatively simple, and computers can maximize the resulting likelihood function almost instantly, even for many choices.

Assuming that the aim of a farmer is to maximize thier income, $U*_{ij}$ (Eq 3), the requirement for a farmer "i" to choose package "j" (1…,n), over "m" the amount of utility obtained from alternative packages ($U_{im},$). If the farmers obtain higher income from technology "j" than "m" then he/she will adopt, "j", ($U_{ij} > U_{im} if m \neq$ j.); or equivalently $\Delta U_{im} = U_{ij} - U_{im} > 0$ $m \neq j$. The expected profit $U*_{ij}$, that the farmer derives from the adoption of a package "j" is a latent variable determined by observed household, plot and location characteristics (X_i) and unobserved characteristics (ε_{ij}):

$$U*_{ij} = ¥ + a_j Z_i + \varepsilon_i \qquad (3)$$

$U*ij$: Expected profit obtained from technology j

Zi: observed characteristics such as (age, gender, education level, marital status, household size, distance from market, distance from water source, land size of farmer, membership of corporative, access non/off farm income, frequency of extension service, access to credit, farming experience household and number of livestock).

ε_i: Captures all the variables that are relevant to the farm household's decision maker are unknown to the researcher such as skills or motivation.

The utility that gained from adopting new technology is not observed, but the technology adoption decision is observed. A farmer will choose water pumping technology (solar power and diesel power) combination “j” with respect to adopting any other “m” technologies if:

$$\begin{cases} 1 & U^*_{i1} > \max_{m'j} U^*_{im} \text{ or } ή_{i1} < 0 \\ j & U^*_{ij} > \max_{m'j} U^*_{im} \text{ or } ή_{ij} < 0 \end{cases} \quad (4)$$

Where $ή_{ij}$ is the expected income difference between alternative package “j” and any other alternative package “m”. Therefore $ή_{ij} = \max(U^*_{mi} - U^*_{ji}) < 0$ equation (4) indicates that i[th] farmer adopt “j” package if it make him/her get more income than any other alternative “m” package were “m”≠ “j”.

Assuming that $\varepsilon_i$is independently and identically gumbel distributed (Eq. 3), so the probability that, the farmer “i[th]” with characteristics “X_i” will choose package “j” can be specified by a multinomial logit model (di Falco & Veronesi, 2012).

$$P_{ij} = pr(ή_{ij} < 0/x) \frac{ex(Z_{ji}a_j)}{\Sigma_{m=1}^{n} \exp(Z_{ji}a_M)} \quad (5)$$

In the **second stage** the MESR model evaluates the relationship between the outcome variable (Y_j) and explanatory variables (X_i) for each of the alternative packages. “Y_j” is observed when alternative “j” is adopted. This study used 4 combination alternatives technology choices (Eq 6-9), hence analyzing these choices is not detectible. In the model specification farmers are considered as non adopters if they didn’t adopt any technology (S_0P_0) whereas they are considered as adopter if they adopt at list one water pumping technology (j = 2, 3 and 4). The outcome equation for each possible regime “j” is given as:

$$regime\ 1\ Y_{i1} = X_i\beta_1 + U_{i1}\ if\ A = 1$$
$$regime\ j\ Y_{iJ} = X_i\beta_1 + U_{iJ}\ if\ A = j \quad (6)$$

Where: $Y_{ij} are the outcome variable of the i_{th} farmer in regime$ "j”,

$U's are distrbuted with$ $(U^*_{i1}/X, Z) = 0$ $(U_{iJ}/X, Z) = \sigma_J)$

X_I is exogenous variables that affect the outcome variable,

Yij is observed if, and only if, package j is used, which occurs when: $U^*_{i1} > \max_{m'j} U^*_{im}\ where\ m \neq j$,

$(U_{ij}/\varepsilon_{i1} \ldots\ldots\ldots\ldots\ldots \varepsilon_{ij}) = \sigma j \sum_{m\neq j}^{j} \varepsilon_{im} - E(\varepsilon_{im})\rho j$ (7)

Where $\sum_{m\neq j}^{j} p = 0$; (by construction, the correlation between u's and ε's sums to zero). Using this assumption, the equation of the multinomial ESR in Eq. (3) is specified as:

$$Y_{i1} = X_i \alpha j + \sigma \hat{\lambda}_{i1} + \omega_{i1} \text{ if Ai} = 1$$

.

$$Y_{ij} = X_i \beta j + \sigma \hat{\lambda}_{ij} + \omega_{ij} \text{ if Ai} = 1 \qquad (8)$$

Where: $\lambda \sum_{j}^{m} p_j \left(\frac{\hat{P}_{im} \ln (\hat{P}_{im}}{1-\hat{P}_{im}} + ln \hat{P}_{ij} \right)) is$ the inverse mile ratio.

P_{ij} represents the probability that i[th] farm household chooses technology "j"; ρjrepresents the correlation between $\varepsilon_{ij}$and U_{ij}; and $\omega_{ij}$is a residual term which is orthogonal to all ε_{ij}& $E(\omega_{ij}) = 0$. Practically, the model in Eq. (5) has heteroskedasticity problem that arise from the computation of inverse mills ratio$\lambda^{\wedge}$. In addition, standard errors are bootstrapped to account for the heteroskedasticity arising from the two-stage estimation procedure.

For the model to be identified, it is important to use exclusion restriction not only those selected by non-linear model (in equation1), but also other variables that directly affect the selection variable but not the outcome variable. The reason for this exclusion restriction is that the inverse Mill's ratio is a non-linear function of the explanatory variables in the multinomial logit equation; thus, the second stage equation (i.e., Income equation) is identified because of this nonlinearity.

However, the non-linearity of the inverse Mill's ratio is not normally tested or justified. Therefore, to make the source of identification clear, it is advisable to have an explanatory variable in the multinomial logit equation, which is not included in the second stage outcome equation (Greene, 2003).

The explanatory variables that are only included in the multinomial logit specification to meet this exclusion restriction in case of this study we use agriculture extension visit, asset value, community meeting, co-operative membership, walking distance from home to plot, and parcel ownership used as selection instruments. This study establishes admissibility of these instruments by performing simple falsification test. If the variables are valid selection instruments, they will affect the decision of choosing an adoption strategy; but it will not affect the net productivity among farm households that did not adapt (di Falco & Veronesi, 2012). Table 4 A in the appendix show valid selection instruments. They are jointly statistically significant drivers of the decision to adapt strategy "*j"* but not of the productivity by the farm households that did not adapt at the 10 percent statistical significance level**.**

3.6.2 Building up a Counterfactual Analysis

Multinomial endogenous switching model is important framework to evaluate the impact of multiple treatments on the outcome variable when there is self-selection problem. This method builds counterfactual as follow:

One can follow Di Falco & Veronesi, (2012) and derive the expected net output of farm households who adopted, that in our study means j=2, 3 and 4) 'non-adopting' "j=1"

Income of Adopters with adoption of "j" combination (actual)

$$E\,(Y_j/A=j,X_{ji},\,\lambda_{ji}) = B_jX_{ji} + \sigma_{je}\lambda_{ji} \tag{9a}$$

Income of Adopters without adoption (counterfactual).

$$E\,(Y_{1j}/A=1,X_{ji},\,\lambda_{ji}) = B_1X_{ji} + \sigma_{1e}\lambda_{ji} \tag{9b}$$

Non adopters' income without technology adoption (actual)

$$E\,(Y_{1i}/A=j,X_{1i},\,\lambda_{1i}) = B_1X_{1i} + \sigma_{1e}\lambda_{1i} \tag{9c}$$

Non-adopters' income if they adopt "j" combination of technology (counterfactual)

$$E\,(Y_{ji}/A_i=1,X_{1i},\,\lambda_{1i}) = B_{ji}X_{1i} + \sigma_{je}\lambda_{1i} \tag{9d}$$

This allows us to calculate the treatment effects (ATT), for example, as the difference between equations (10a) and (10d).

$$ATT = E\,(Y_{ji}/A=j,X_{ji},\,\lambda_{ji}) - E\,(Y_{1i}/A=j,\,X_{ji},\,\lambda_{ji}) = X_{ji}\,(B_{ji}-B_{1i}) + \lambda_{ji}\,(\sigma_{je} - \sigma_{1e}) \tag{9e}$$

The first term on right hand side of Eq. (9) represents the expected change of outcome in adopters of agricultural technology (j =2, 3 and 4); if adopters had the same characteristics as non-adopters. The second term (λ_j) is the selection term that captures all potential difference between adopters and non-adopters which arise due to unobserved variable. Similarly, the average treatment effect on untreated (ATU) is calculated as the deference between (9b) and (9c):

$$ATU= E(Y_{ji}/A=1, X_{1i},\lambda_{1i})- (Y_{1i}/A=1,X1i,\lambda 1i) = X_{1i}(B_j-B_1) +\lambda_{1i} (\sigma_{je} - \sigma_{1e}) \quad (10)$$

The right-hand side of Eq. (10) shows expected change of non-adopter output if they decide to adopt agricultural technology given that adopters had the same characteristics as non-adopters.

3.7. Variable Specifications and Their Expected Signs

3.7.1. Treatment Variable

Adoption of Water Pump technology: This variable is categorical, with possible values of (1) solar power, (2) diesel power, (3) both solar and diesel power, farmers who adopted water pump technology, and (0) non-adapted. Following a few years of consistently higher yield from the water pump technology, the consequences of using water pump types become apparent. For adopters in this study the households who used the water pump technology for two and more years.

3.7.2. Outcome Variables

Increasing total annual income of the smallholder farmers is the final planned outcome of water pump adoption program. Total annual income for each household was computed for production year of 2025 using information on the price and quantity of the income generated by water pump technology as reported by the household. An average small family farm in Ethiopia generates a gross annual income of about $ 1246 USD (FAO, 2018).

3.7.3. Independent Variables (Explanatory Variables)

A comprehensive list of variables that may influence farmers' acceptance of water pump was determined by focusing on estimating mechanics and then reviewing theoretical literature and empirical studies on water technology adoption. Indeed, it is hypothesized that a combination of various factors, including household characteristics, social economic conditions, and institutional features that affect farmers' operations, affect their choice to use water pumping technology over a specific period. The explanatory variables listed below were chosen and the following hypotheses were made.

Gender (GEN): categorized as dummy variables taking 1 if the household is male and 0, otherwise. According to Chia et al., (2020), the female household head has less access to land; FTC (Farmer Training Center)-based training, and improved technologies and lacks in adopting new technologies as compared to their male counterpart (Diro *et al.*, 2017). Gender is found to be one of the factors influencing the adoption of new technologies. Thus, it can be hypothesized that male farmers are more likely to adopt new technologies.

Age (AGE): It is a continuous variable, much as the number of years. Older farmers could be better able to explore new technology because they have greater resources, authority, or expertise (Alemu & Embiale, 2023). However, it's also possible that younger farmers are more willing to embrace new technology since they may have had more education than more experienced ones, which has exposed them to novel concepts and made them more willing to take risks (Abdurehman & Abdi, 2021).

Marital Status (MRS): Is discreet variable taking I if household is single, 2 if married 3 if divorced/ widowed/ separated. The marital status of the household is one of the considered explanatory variables of adoption decisions. The reason is that unmarried farmers have few responsibilities and channel their financial resources to agricultural technology adoption contrary to their counterfactuals. The marital status of the household is negatively associated with the decision of agricultural technology adoption, indicating that married households are less likely to adopt than their counterparts(Neway & Zegeye, 2022).

Education level (EDN): This variable represents the years of the household head attending formal schooling. As a greater number of years are enrolled, there is a greater tendency to access new information and easily understand the importance of newly innovated technologies (Ayele *et al.*, 2023). Educated farmers may also be more aware of the benefits of modern technologies and may have a greater ability to learn new information. Hence, it can be hypothesized that it has a positive influence on the status and speed of technology adoption (Birhanu & Jensen, 2023)

Frequency of extension service (FES): It is a continuous variable that is determined by how frequently farmers and extension personnel interact. It facilitates farmers' decision to embrace new crop technology by hastening the distribution of tailored agricultural information to them (Yitayew *et al*., 2021).

Land size (LAS): it is a continuous variable measured in hectares. It is an indicator of wealth social status and influence within the community. This emphasizes that farmers with more farmlands are more likely to adopt new technologies. The land size returned a positive and significant relationship with the adoption of new technology (Workineh *et al*., 2020). Therefore, it can be hypothesized that more land size will increase a farmer's likelihood of adoption and intensity of adoption of improved maize varieties.

Access to credit (ACR): It is a dummy variable; if a family has access to credit, its value is 1, and if not, it is 0. The availability of credit has a favorable impact on the uptake of new technology (Lemecha, 2023). Thus, it is anticipated that having access to loans would raise both the likelihood and the rate at which improved varieties of maize will be adopted.

Number of Livestock (NOL): It's a continuous variable with a TLU (Tropical Livestock Unit) measurement. The farm household makes more money when there are more cattle, which enables the farmer to buy more input for the operation. According to Guye *et al*., (2024), owning more animals raises the degree of adoption of advanced agricultural technologies. Therefore, it is predicted that the adoption of improved water pump is strongly correlated with animal ownership.

Household size (HHS): It is a continuous variable that is expressed as the adult equivalent of all the household members. The adoption of water pump needs a sufficient worker pool to execute the farming process. The availability of labor is positively correlated with the uptake of new, improved technology (Baker & Nuno, 2021). Therefore, it is likely that the adoption of the adoption of water pump is positively impacted by the availability of labor.

Distance from market (DFM): It is a continuous variable with a kilometer-based measurement. It is among the deterministic elements of the adoption of technology. It is anticipated that farmers close to the market will have easy access to the market for their goods, which will lead to their quick adoption and heavy use of modern technologies (Keba, 2019). Therefore, it is hypothesized that the acceptance of water pumping is inversely correlated with market distance.

Distance from water source (DSW). Farm distance from water sources had significant negative effect on the adoption of motorized water pump. Therefore, the farmland located far from the source of water has less chance to adopt the irrigation technology and vice versa. The reason behind this is, in the study area the major water sources for irrigation are lakes, ponds and rivers. When the farm far from these sources, it needs high financial costs to purchase the hose of motorized water pump and minimize the chances to adopt the pump(Abebe, 2017).

Non-farm income (NFI): It is a continuous variable that is earned from non-farm activities in dollar per year. When there is income from sources outside of the farm, the farmer may afford better inputs, which raises the possibility of adoption (Jena & Tanti, 2023). Therefore, as off-farm income sources become more available to households, it is expected that the likelihood of superior water pump adoption will increase.

Membership in farmers' cooperatives (MFP): It is a dummy variable that represents a household member's level of active participation in farmers' cooperatives. It is expected to positively influence the adoption of water pumping technology. It is expected that farmers' cooperatives will provide members with the necessary input and help them reach more lucrative markets, so this positive link will occur (Fasika *et al*., 2019).

Farming Experience (FEXP) continuous variable measured in number of years staying on production of coffee. Experienced people might acquire skill of production and marketing, might have accumulated capital if experienced farmers are older aged that might have many active family members which could tends to produce and participate more in the chain.Experienced farmers are more likely to adopt such innovations due to their familiarity with water management challenges, understanding of efficiency benefits, and willingness to invest in proven solutions. Their practical knowledge helps them assess the technology's potential for improving irrigation and crop yields (Rukundo *et al.*, 2023).

Access to technology information (ATI) It is a dummy variable; if a family has access to information, its value is 1, and if not, it is 0. Access to information about technology greatly affects the adoption of water pumping technology. Farmers with better access to information through training, extension services, or digital platforms are more likely to understand its benefits, functionality, and cost-effectiveness, increasing their confidence to adopt and use the technology efficiently (Chen & Kamal, 2016).

Table 3.2 Measurement and definition of variables

Variable	Description	Influence
Response variable	Adoption of water pumping technology (1) solar water pump (2) diesel water pump, (3) both sola and diesel, (0) non-adopter	
Outcome	Annual income of household (continuous)	
Explanatory Variables		
Age	Age of participants in year	+/-
Gender	Dummy 1 male 0 female	+
Education level	Education enrolled by study participants	+
Marital status	Status of household marriage	
Household size	Man- adult equivalent	+
Distance from market	Distance in kilometer	-
Distance from water source	Distance in kilometer	-
Land size of farmer	Landholding by household in hectare	+
Membership of corporative	Dummy 1 member 0 otherwise	+
Access to technology information	Dummy, 1 Get 0 otherwise	+
Access to credit	Dummy, 1 Get 0 otherwise	+
No farm income	Continuous measured in dollar ($)	+
Extension contacts	Frequency of extension	+
Farming experience household	Year of farming	+
Number of Livestock	Livestock owned measure by TLU	+

Source: empirical studies reviewed in the literature and own observation, 2025

CHAPTER FOUR: RESULT AND DISCUSION

4.1 Descriptive Statistics for Explanatory Variables

An independent t-test and Chi-square test were used to ascertain if there were mean and proportional differences in the respondents' demographic and socioeconomic profiles among 330 respondents. Before analysis, assumptions were checked, and no significant violations were observed.

At the 1% significance level, the mean difference between the four groups in terms of household Age is statistically significant. All sample household heads were 46.8 years old on average at 1% level of significance level. The average age of non-adopter, solar power adopter, diesel power adopter and both solar and diesel power adopter was 50.8, 43.1, 49.1, and 44.2 years, respectively. This indicates that the head of the household who adopted the improved solar power technology was younger than the head of the household who did not accept them which is also confirmed by (Abdurehman & Abdi, 2021).

Regarding household size, the mean family size of respondent solar power adopter was 6.5 greater than compared to the rest of non-adopter with 4.1, diesel power adopter 5.1 and both technology adopter 5.8. The survey results revealed that there is a significant mean variation in family members among the four groups at 1% level of significance. The result show that, the highest the family size the more they able to adopt solar water pump which is absolutely agree with the finding obtained by (Baker & Nuno, 2021).

Based on sample respondents were asked about distance between their homes to the farthest water source taken in walking distance in kilometers (km). Based on their responses, the mean walking distance from their residence to the farthest farmlands was taken average distance of 0.59 km, with a minimum of 0.26 km and a maximum of 1.41km distance. Within the groups, diesel water adopter walked an average of 0.35 km from their home to water source, while both solar and diesel adopter walked an average of 0.32 km from water source. This suggests that a significant and positive mean variation in farmland distance among the four groups. From the result, the closer the farmer to the source of water, the more they encouraged to adopt solar water pump technology (Abebe, 2017).

In terms of land size, the respondents mean land landholding size was 0.44 hectares (ha), with landholding size of solar powered adopters 0.51 ha, diesel powered adopter 0.43 ha, both technology adopter 0.45 ha (Table 4.1). Which means solar powered adopter was high land holding size among four groups at 1% significance level which agree with (Workineh *et al.*, 2020).

Table 4.1 Descriptive statistics of continuous explanatory variables

Variable	Non-adopter (n=168)	Water pump adopter			All Sample (n=330)	F-value
		Solar (n=62)	Diesel (n=52)	Both (n=48)		
Age (year)	50.8	43.1	49.1	44.2	46.8	7.56***
Distance from market (km)	2.05	0.59	0.91	0.74	1.07	3.75
Distance from source (km)	1.41	0.26	0.35	0.32	0.59	2.32***
Land size (ha)	0.37	0.51	0.43	0.45	0.44	16.28
Household size (number)	4.1	6.5	5.1	5.8	5.38	12.84***
Frequency of extension (number)	2.8	4.5	3.02	4.01	3.58	15.69***
Farming experience (year)	7.5	11.5	8.69	9.4	11.02	12.1*
Livestock (number)	20.54	22.47	20.62	21.58	21.3	0.96

A shown in the table (4.2) the result depicted that of a total 330 respondents, 251 (76.1%) were males and 79 (23.9%) were females. From this, 123 (73.2%) males, 45(26.8%) females were non-adopter (n=168), 45 (72.6%) males and 17(27.4%) females were solar power-adopters (n=62), 40 (66.7%) males and 12 (19.3%) females were diesel power-adopters (n=52), while 43 (89.6%) males and 5(10.4%) females were both solar and diesel powered-adopters (n=48), which make total water pump adopter of the district (162). In terms of gender, there is appreciable difference between the two groups which agree with the result obtained by (Diro *et al.*, 2017, Chia et al., (2020))

As can be seen Table 4.2, nearly 80 (24.2%) of respondents were found to be illiterate, primary education level 72 (21.8%), secondary education level 75 (22.7%) and College and University level 103 (31.3%). The result indicated that solar powered technology adopters have better accessed both informal and formal education, with significant percentage variation among the four groups at a 1% significance level. The mean farming experience of the solar powered adopterwas13.5, for diesel powered was 10.7, for both technology 12.4 and non-adopter 11.0

years. The result of survey reveals that, solar powered adopter was high farming experience among four group at 10% significance level (Ayele *et al.*, 2023,Birhanu & Jensen, 2023). As determined by an independent t-test, the mean dependent households of non-adopters are predominantly higher than adopter groups.

The survey results display that nearly 50 (29.8%) of non-adopter has access to water pumping technology information while 118 (72.2%) non adopter has no information. The larger proportions of 55 (88.7%) of solar power adopter received information related to water pumping technology from development agents, model farmers and natural resource management experts whereas nearly 7 (11.3%) of solar waterpower adopter were not accessed. The percentage variation among the four intra-groups was significant at 1% significance level (Table 5).

Table 4.2 Descriptive statistics of categorical variables

Variable	Alternatives	Non-adopter (n=168)		Water pump adopter: Solar (n=62)		Diesel (n=52)		Both (n=48)		All Sample (n=330)		χ^2
		Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	
Gender	Male	123	73.2	45	72.6	40	66.7	43	89.6	251	76.1	31.5^{***}
	Female	45	26.8	17	27.4	12	19.3	5	10.4	79	23.9	
Education level	Illiterate	60	35.7	7	11.3	6	11.5	7	14.6	80	24.2	25^{***}
	Primary	39	23.2	15	24.2	10	19.2	8	16.7	72	21.8	
	Secondary	31	18.5	17	27.4	15	28.8	12	25.0	75	22.7	
	College/University	38	22.6	23	37.1	21	40.4	21	40.4	103	31.3	
Membership Cooperative	Yes	39	23.2	49	79.0	37	71.2	40	83.3	165	50.0	9.4^{***}
	No	129	76.8	13	21.0	15	28.8	8	16.7	165	50.0	
Access to technology Info	Yes	50	29.8	55	88.7	42	80.8	35	72.9	152	46.1	21^{***}
	No	118	72.2	7	11.3	10	19.2	13	27.1	148	53.9	
Off farm income	Yes	36	21.4	47	75.8	39	75.0	41	85.4	163	49.4	18.9^{***}
	No	132	78.6	15	24.2	13	25.0	7	14.6	167	50.6	
Access to credit	Yes	30	17.9	47	69.1	38	73.1	30	62.5	145	43.9	11.4^{***}
	No	138	82.1	15	30.9	14	26.9	18	37.5	185	56.1	
Marital Status	Single	18	10.7	4	6.5	9	17.3	5	10.4	36	10.9	3.17
	Married	118	70.2	50	80.4	37	71.2	41	85.4	246	74.5	
	Divorce/	32	19.1	8	13.1	6	11.5	2	4.2	48	14.6	

4.2. Factors Determining the Adoption of Water Pumping Technology

Regarding factor determining water technology adoption, educational level, land size of farmer, membership of cooperative, access to technology information, frequency educational service, access to credit, farming experience household significantly affect technology adoption (Table 6). The outputs of MESR demonstrated that age of household, distance from market and water source significantly affect adoption of water pump technology but negatively affected households' decision toadopt the three of technologies 5%, 10% and 1% respectively. This indicate that, their high tendency of farmer to adopt technology as they close to water source and younger age. The result is consistent with another recent studies (Bassa, 2019). At the same time, the study conducted by Chuang *et al*., (2020) reveal that younger farmer was more exposed for adopting water pumping technology. Moreover, farmer with far distance from source of irrigation was less likely to adopt water pump technology (Table 6).

Concerning educational level and household size, both have positive consequence in terms helping farmer to make decision and efficient use of information received. The result from survey shows that, there is strong significance level between education level and household size and tendency of adopting solar water powered, diesel powered and both solar and diesel-powered water pump at 99% confidence level. In line with these result, recent empirical research by Ewunetu *et al*., (2023) found that less educated households are lesslikely to adopt a water technology the same is true for household size. In addition to educational status and household size, farming experience and off farm income have potential effect on farmers technology adoption(Seid *et al*., 2022). The model output indicated that off-farm activity ($p < 0.01$) and farm experience ($p < 0.01$) increase households' adoption of water pumping technology (Table 6).

This implies that households that regularly attend off-farm activities and earn a higher income from such activities are high likely to adopt water pump technologies in the study area consistence with another study (Gemi & Semane, 2020).Particularly, farm household who participated in village membership, higher household size, access to water pumping technology information, access to credit and frequent extension service were more likely adopt solar powered than the rest of water pumping technology at 1% significant level. This suggests that households that receive information related to the advantages of water pumping technology technologies from DAs and agricultural experts are more likely to adopt the technologies.

Similar finding were observed by Nigussie *et al.*, (2017), who confirmed farmers with more social group membership higher tendency to adopt solar powered technology. Moreover, Yigezu *et al*., (2018), Girma, (2022) and Waje *et al*., (2024) we are also found that households with more household size, access to credit and farming experience have a higher probability of adopting solar powered water pump than the rest of technology respectively. *Waje et al.*, (2024) noted that, farmers who regularly employ development agents (extension services) are more likely to embrace solar powered than the rest of technology technologies due to the benefits of technical information shared by extension specialists.

Qualitative data obtained from FGDs and KII also proved that farmers' frequent contact with DAs, village model farmers, and natural resource management experts can effectively encourage farmers' enthusiasm for adopting water pumping technologies. The majority of KII participants reported that as farms were found farther away from farmers' residences, the probability of being treated with solar power water pumping technology decreased.

Table 4.3 Multinomial endogenous switching regression results (average treatment effect)

Variables	Solar powered		Diesel		Solar and diesel powered	
	Coef	Std.Err	Coef	Std.Err	Coef	Std.Err
Age	-0.045**	0.034	-0.093**	0.030	-0.070**	0.028
Gender	0.093***	0.063	0.081***	0.062	0.0086***	0.07
Education level	1.06***	0.0283	1.02***	0.0281	1.01***	0.032
Marital status	0.057	0.319	0.635	0.313	0.498	0.351
Household size	0.538***	0.130	0.447***	0.146	0.500***	0.128
Distance from market	-0.31*	0.079	-0.124*	0.088	-0.120**	0.094
Distance from water source	-1.203***	0.0795	-1.038***	0.091	-1.042***	0.0920
Land size of farmer	0.747***	0.175	0.849***	0.180	0.876***	0.176
Membership of Corporative	0.376***	0.144	0.3230***	0.197	0.032***	0.116
Technology information	0.068***	0.417	0.056***	0.437	0.0528***	0.457
Access non/off farm income	0.669***	0.385	0.735***	0.413	0.667***	0.428
Frequency of extension service	0.407***	0.046	0.384***	0.052	0.414***	0.086
Access to credit	0.409***	0.086	0.252***	0.117	0.28**	0.107
Farming experience	0.401*	0.090	0.351*	0.097	0.388*	0.090
Number of Livestock	0.04	0.016	0.027	0.015	0.033	0.016

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

4.3. Impact of Water Pumping Technology Adoption on Farmers Income

The mean total farm incomes of water pumping technology adopters, along with the related counterfactual results, are shown in Table 7 as projected by MESR. The calculation of the mean treatment (ATT) and the associated t-test value demonstrated that the difference between the various type of water pumping technology adopters and non-adopters in terms of average farm revenue was statistically significant and deviated from zero. The ATT answer, "What would have happened to water pump technology adopters' farm incomes if they hadn't adopted the technology?" Likewise, the model created an average treatment effect on untreated (ATU) or control groups in response to the query, "how would the adoption of the technology have affected the mean farm incomes for control groups (non-adopters)?".

The expected impact of adopting solar powered, diesel powered and both solar and diesel-powered water technology on total income of farm households was found to be $573.91 USD, $486.04 USD and $524.84 USD respectively. If adopter groups chose not to use the technology, the expected impact on their total farm income under counterfactual scenarios would be 495.90 USD, 4434.48 USD and $462.10 USD respectively. While the predicted total incomes for non-adopters were 390.68 USD, if they decided to adopt the technology, it would be about 434.48 USD,$$ 426.36 USD and 4$29.84 USD of total farm income.

As illustrated in Table 7, ATU = 182.384 USD (c and d) reveal that, the total income of household who used solar water technologies would increase by $31.92% (573.91 USD – $390.69 USD)/$573.91*100if they decided to adopt solar power water pump technologies. In the same scenario, ATT = $95.18 USD (c and d) from table 7 shows that, the expected total farm incomes for households using Diesel technology would likewise increase by 19.58% (486.04 USD – $390.69 USD) /$486.04 USD*100 if they decided not to adopt the technologies. Moreover, ATT = $133.381 USD value indicate that, household with mix of both solar and diesel power, their predicted log of total farm incomes will also raise by 25.4% ($524.66 USD – $390.69 USD)/$524.66 USD *100 if they decide not to adopt technology

Regarding model outputs of ATT = $61.30 USD (a and b), indicate that the total income would decrease by 12.36% ($434.48 USD-$495.90 USD)/495.90 USD *100 for families that really adopt solar power water pumping technology if they did not decide to adopt the technologies. Furthermore, under counterfactual sicario, ATU = $8.10 USD (a and b) For households that adopt, the total farm incomes would experience decrease by 1.86 % (426.36 – 434.48 $USD)/$434.48 USD *100 if they did not decide to adopt the Diesel water pump technologies (Table 8). In addition to that, the model outputs of ATU = #32.19 USD, it indicated that for households that adopt mix of both solar and diesel water pump technologies, the total income will reduce by $ 6.97% ($429.84 USD – $462.10 USD) /$ 462.10 USD * 100 if they refuse choose to the technologies. To sum up, the implementation of solar power water technologies has had a substantial and beneficial effect on rural livelihoods, as reflected in improved total farm incomes ($p < 0.01$) in the Kersa Malima district.

Table 4.4Multinomial endogenous switching regression results (average treatment effect

Treatment		Household type and Treatment effect	Decision stage		Average treatment effect	t = value
			To adopt Mean	Not adopter Mean		
Farmer Income	PVC adopter	Adopter	**495.90 USD[a]**	**434.48 USD[b]**	**ATT = 61.30 USD**	2.88***
		Non-adopter	**573.91 USD[c]**	**390.69 USD[d]**	**ATU = 182.384 USD**	3.91***
	Diesel Adopter	Adopter	**434.48 USD[a]**	**426.36 USD[b]**	**ATT = 8.10 USD**	2.50***
		Non-Adopter	**486.04 USD[c]**	**390.69 USD[d]**	**ATU = 95.18 USD**	3.37***
	Both Adopter	Adopter	**462.10 USD [a]**	**429.84 USD [b]**	**ATT = 32.19 USD**	2.70 ***
		Non-Adopter	**524.66 USD[c]**	**390.69 USD[d]**	**ATU = 133.381 USD**	3.65***

*** Significant at 1% significance level, respectively.

Table 4.5 discussion on result of previous study

The above table (8) shows, how smaller household farmer affected by using varies type of water pumping technology. All study was done in different part of the world by using not identical model, sample and adoption method. X represent the type of technology not used in the study

Country	Sample size	Model	Adopter			Adopter			Non-Adopter	Reference
			Solar ATT	Diesel ATT (%)	Both ATT	Solar ATU	Diesel ATU	Both ATU	Non-Adopter	
Ethiopia	140	Logit model	6.3	×	×	22	×	×	√	(Mohammed, 2020)
Ethiopia	92	Probity model	×	11	×	×	13	×	√	(Workneh *et al.*, 2020)
India	10253	ESR model	6.5	1.5	×	19	9.3	×	√	(Jena & Tanti, 2023)
Ethiopia	301	Logit regression	×	24	×	×	31	×	√	(Getacher *et al.*, 2013)
Pakistan	950	Multivariate probity model	20	×	×	33	×	×	√	(Ali et al., 2016)
Bangladesh	130	Probity model	15	×	×	13	×	×	×	(Rana *et al.*, 2021)
Ethiopia	161	BCR	15	×	×	5.2	×	×	√	(Negera *et al.*, 2025)
China	847	ESR model	24.5	16	×	6.20	5	×	√	(Wu, 2022)

while, √ represent non adopter. as we can see from illustration, all the adoption method was binary type which means, the researcher only compare two type of technology (Adopter and non adopter). However, in this paper i consider three type of technology which is definitely make this paper unique. Concerning the result of the study, researcher's focused to see the difference between if farmer adopted the technology decided to not adopt (ATT) and if non adopter of technology was decided to adopt the technology (ATU).

According to Mohammed & Shallo, (2020) if non adopter of solar water pump technology was willing to operate on the next round his income will be increased by 6.3 % (ATT). But if adopter of solar water pumping technology not chose to adopt on next round their income will reduced by 22 % (ATU). On the other hand, Rana *et al*., (2021) conduct a study by effect of solar water pump on adopter and counterfactual non adopter by using different model, sample size and country which might make their result different. In this case ATT value was 15% while ATU value is 13%. In my cause ATT value for solar water pump was 31.92 % while for ATU were 12.36 %. This is due to the model used to see the impact of technology in my study (MESR), model used to do how factor affect adoption of technology (Multinomial Logit model) as well as a number of sample (330).

Regarding impact of diesel technology adoption, Getacher *et al*., (2013) conduct his study in Ethiopia and he report the value of ATT and ATU for those who decided to adopt and not adopt. Those farmers who adopt technology and decided not to adopt latter on, their income was reduced by 24 % (ATT) but those who first not adopt and then decided to adopt latter, their income will increased by 31 % (ATU). In the same way, the finding of Workneh *et al.*, (2020) reveal that ATT as 11% and ATU value 13% which is not actually the same due to the fact that they are applying different model and sample number. In my cause ATT value for will increase by 19.58% while ATU will be reduced by 1.86%. the reason behind in consistence among the find was due to the different model (MESR and MLM), sample size and country applied for each of study. non-off the above able to see the mix use of both solar and siesel water pumping technology which make my study unique.

The response from FGD shows that, solar water pump will make their life so easy since I don't have to worry about fuel costs. For those who use diesel water pump they feel like better than while they are fully depend on rainfall. Similarly, adopter of mix technology was flexible which means they will use solar during a day and diesel at night which makes their life easy. Regarding, incensement on crop yield and income of farmer, who use solar water pump got 40% increment than before they are applying. Concerning those use diesel water pump, their production will increased by 20 % despite they their net product will become low due to diesel cost.

Most of participant of FGD reply that, they will decided their crop type based technology they are adopting. For example, those who adopt solar as prefer to produce, vegetables like tomatoes, onions, and cabbage, while diesel adopter will go for cash crops like maize and wheat. Concerning time of technology adoption, participant of solar was free to use the technology without any extra cost, while diesel users will careful. Regarding the change in total income generated from water technology user, each of them gets different total income based on their cost. Farmer those adopt solar water pump respond that, they will make crops outside the rainy season and sell at higher prices which will boost their income. However, Diesel user will also produce good income affected cost of diesel. According to diesel user response, their total income is not ad they expected, since diesel expenses eat into their profits. Their response confirms the finding from data analyzed and above reviewed study.

Regarding response from official, most of farmer in Kersa Malima is not adopting solar water pump technology due to high initial investment costs**,** limited access to credit**,** and lack of awareness about the long-term benefits. Many smallholder farmers cannot afford water pumps or do not understand their economic advantages. Additionally, inadequate technical support and maintenance services discourage adoption. From their view point, the government should subsidized water pumps, training programs, and construction of facilities; provide policy support and collaboration with NGOs. Indeed, the result of this discussion was similar with (Mohammed & Shallo, 2020) in Ethiopia , (Workneh et al., 2020) in Ethiopia and (Jena & Tanti, 2023) in India

CHAPTER FIVE: CONCLUSION AND RECOMANDETION

5.1 Conclusion

The result of the Multinomial logit model shows that, the adoption of water pumping technology is significantly influenced by age, distance from water source, household size, frequency of extension, farming experience, educational level and off farm income of study area. Distance from market and distance from water source negatively affect adoption of water pump technology. Regarding impact solar, diesel, and mix of solar and diesel water pump adoption, total income of farmer decrease by 12.3% 1.86% and 6.97% income respectively if they are decided to not adopt water technology. On the other hand, total incomes will increased by 31.92, 19.58 and 25.4 if the non-adopter is decided to adopt solar, diesel ad mix of both solar and diesel water pump technology respectively. The finding of this paper confirm that, proper adoption of solar power technologies has the potential to increase total income of farmers than the rest of two option, thereby improving the economic benefits of rural households in the Kersa Malima district. Moreover, adopting and not adopting solar water pump technology have their significant impact on household total income, this means if the adopter decides to not adopt the solar pumping technology will decrease a much more than the rest of water pumping technology the reverse is also true. Generally, farmers who adopted solar water pumping technology got much more income than the rest of water pumping technology.

5.2 Recommendations

Based on the findings of this study the following recommendations were forwarded

- ✓ Kersa Malima education office facilitates for the farmers how they can learn as well as work on their farms and work on the adult education system in the farmer's area.
- ✓ Distance from the district market and water source is the main factor that negatively affects the adoption of water pumping technology. So, the government should build road and water diversion structure rural areas.
- ✓ Research centers, NGOs, Universities, and Agricultural offices give high attention and provide training for farmers on the application and use of improved varieties as well as on new technology.
- ✓ Governments should subsidize the institution that provides credit service for farmers and demonstrates credit service organizations with discounted interest rates.
- ✓ Agricultural offices and should focus on other source of income and support farmer to make them member of cooperative increase the frequency of demonstration
- ✓ The agricultural office, farmers union, researcher centers, and NGO have to focus on disseminating solar water pumping which can boost total income than the rest of technology

CHAPTER SIX REFERENCE

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CHAPTER SEVEN: APPENDICES

APPENDIX I: Questionnaire for the General Public.

The purpose of this questionnaire is to collect data that are imperative to "Impact of adopting water pump technology on smallholder farmers' income in Kersa Malima District, Southwest Shoa, Oromia". The data will be applied for direct academic research fulfillment of the Master of Science degree (M.Sc) in Pan African University Institute for Water and Energy Science (incl. Climate Change). The information you provide in these questions will be utilized only for study purposes. Your genuine response is highly valuable for the achievement of the objectives of the research. Confidentiality is guaranteed. Hope, you will consider this questionnaire important for collecting relevant information and participate in answering openly and honestly.

I thank you in advance for your cooperation!

Bekam Bekele Gulti

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General information

Date of Interview ------------------ Respondent code ----------------Kebele------------

I. Questions about household demographics

1. Sex of household head ☐ male ☐ female
2. Age of household head ___________(Years)
3. Marital status of household head☐ single ☐married ☐ divorce ☐widow.
4. Total number of family size in the household ____________
5. Educational level of household head: ☐ illiterate ☐ primary education □ Secondary education (9-12) e) college graduated f) university graduate.
6. How many years you live in Kersa Malima ____________?

II. Institutional related question

1. How many irrigations lands size you have ______________(ha)?
2. What is the size of the land you use for irrigation ____________(ha)?
3. How far is your irrigation farm from the nearest market____________(Km)?
4. How far is your irrigation farm from the nearest water source ________(Km)?
5. Did you have any contact with extension agents during the last irrigation season?

   ☐yes ☐no

6. If yes, on average how many days did the development agent contact (visit) you________________?
7. Have you ever attended in any practical water pump technology field demonstration or practical workshop arranged by anybody?

   ☐yes ☐no

8. If yes for Q8,
   - ✓ where? ____
   - ✓ duration ____
   - ✓ title of the training _________________________________
   - ✓ which organization gives the training ____________________________
9. Have you ever used water pump? ☐yes ☐no
10. If the answer of Q 9 is no, what is the reason.

    ☐ no availability of water pump material ☐not heard about introduction of the water pump in the area ☐land shortage ☐not accustomed in the area ☐ the water pump is expensive.

11. If yes for Q 9 what type of water pump you have?

    ☐solar water pump ☐diesel water pump ☐both solar and diesel ☐no water pump

12. Where did you get the water pump technology you use?

    ☐ market ☐agriculture office ☐ NGOs ☐neighbor ☐other fellow farmers

13. Why did you decide to use the water pump technology (select all that apply)

☐ to save human labor ☐to cultivate large area of land ☐to ensure food security

☐to increase income ☐ Other (specify) ----------------------------------

14. Do you get adequate water pump technology on time?

☐yes ☐no

15. If Q14 is no, what is the reason not getting inadequate water pump for the cultivation of different crops?

☐not available in the market ☐to expensive ☐not available on time ☐cash shortage

☐other (specify) ---

16. Is there access of maintenance service for water pump technology?

☐yes ☐no

17. What factors influenced your decision to adopt climate-smart agriculture practices? (Check all that apply)
18. Do you use water pump technology through buying in cash?

☐yes ☐no

19. If the answer for Q18 is "no" what is the reason?

☐ do not have cash ☐no access of credit ☐use the cash for other business activity.

☐if other specify --

20. Have you ever received credit service for irrigation? ☐yes ☐no

21. If yes for the above question, whom you received the credit?

☐from government ☐ from NGO ☐ if other specify ____________________

22. For what purpose do you used the credit?

☐ to purchase water pump ☐to purchase improved seed ☐to purchase fertilizer

☐if other (specify) ___________

23. What factors hinder to access of credit?

☐shortages of collateral ☐high interest rate ☐bureaucracy ☐no credit service for water pump ☐ if other specify ----------------------------------

24. Do you get inputs at the right time?

☐yes ☐ no

25. Are you a member of co-operatives? ☐ yes ☐ no

III. Socio-Economic Questioners

25. Please indicate the amount of Income you got from irrigation agriculture for the year 2024 in the following table

Type of crop	Area(ha)	Crop production and utilization (in Kg)				Price per unit	Total income in USD
		Total output	Amount consumed at home	Total (Qt) given to others	Total (Qt)sold		
Onion							
Tomato							
Potato							
Cabbage							
Peppers							
Carrot							
Khat							

26. During the last 12 months (2024), did you or any household member work off the household's farm for wage payment?

☐yes ☐no

27. If your answer is yes for the above question, would you please give us the details of the off-farm (wage) payment activities and income?

1= farm worker for pay, 2 = professionals: teacher, health worker, 3= skilled laborer: builder, carpenter, 4 = Unskilled non-farm
5 = others Specify

28. During the last 12 months (2024), did you or any household member work in off-farm business activities?

☐yes☐no

29. If your answer is yes for the above question, would you please give us the details of the off-farm business activities, the expenditures and income?

Appendix II: Questionnaire for the Officials

Checklist for Focus Group Discussion.

1. How has the use of water pumps changed your farming activities?
2. Have you observed an increase in income since adopting water pumps? If yes, by how much?
3. What types of crops do you mainly grow using irrigation?
4. Have you seen an increase in your household income since adopting water pumps? How?
5. Has water pump adoption helped you increase profits?
6. What are the biggest financial benefits you have experienced from using water pumps?
7. Have you been able to access better markets for your income due to increased total income?

Appendix III: A Checklist for Key Informants' Interview

Checklist for key informants' interview

1. How has the trend of water pumping activities changed over the past five years in the district, and what factors have influenced these changes?
2. What are the existing policies in relation to agriculture in general and water pumping in particular and how do you view them?
3. How do you view the role played by government in water pumping technology development in the district?
4. What are the key factors influencing household participation in adopting water pumping technologies in the area?
5. What strategies do you think could be implemented to improve the adoption and effectiveness of water pumping technologies in the district?
6. What do you think are the major environmental problems associated with water pumping activities in the area, and how do they affect the community and local ecosystems?

Appendix IV: A Checklist for the Officials

Questionnaire for the officials

1. Why do most farmers in your community not adopt water pumping technology?
2. What are the major factors affects small-scale irrigation participation in your community?
3. How the governments give attention on adopting water pumping technology in the area?
4. What help do you need from the government or non-governmental organization to adopt water pumping technology in your local community?
5. Which types of water pumping technology is mostly found in the community area?
6. What type of water pumping technology do you think is more advantageous for the community in the area?
7. What are the major social organizations in the area and what are their roles in adopting water pumping technology?
8. What are non-farm activities available in the community? What is the effect of those non-farm activities on water pumping technology?
9. What are your recommendations for improving the adoption and utilization of water pumping technology in your community?

Appendix V: A Checklist for Model Validation

vif

Variable	VIF	1/VIF
LAS	1.16	0.858671
LYF	1.12	0.889932
HHS	1.10	0.911127
AGE	1.09	0.914516
NOL	1.06	0.939454
MDI	1.06	0.941506
FES	1.05	0.950136
DSW	1.04	0.958502
Mean VIF	1.09	

Figure 1. Multicollinearity test for continuous variables

. linktest

Source	SS	df	MS
Model	127.859363	2	63.9296816
Residual	282.928516	327	.865224818
Total	410.787879	329	1.24859538

Number of obs =	330
F(2, 327) =	73.89
Prob > F =	0.0000
R-squared =	0.3113
Adj R-squared =	0.3070
Root MSE =	.93017

Adopt	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
_hat	.8860951	.2025923	4.37	0.000	.4875463	1.284644
_hatsq	.0611948	.09944	0.62	0.539	-.134428	.2568176
_cons	.0293503	.1043241	0.28	0.779	-.1758808	.2345813

Figure2. Link test for model specification

```
. estat endog

  Tests of endogeneity
  Ho: variables are exogenous

  Durbin (score) chi2(1)          =  .608493  (p = 0.4354)
  Wu-Hausman F(1,346)             =  .602586  (p = 0.4381)

. estat firststage

  First-stage regression summary statistics
```

Variable	R-sq.	Adjusted R-sq.	Partial R-sq.	F(2,346)	Prob > F
FES	0.0613	0.0532	0.0047	.808901	0.4462

```
  Minimum eigenvalue statistic = .808901

  Critical Values                      # of endogenous regressors:    1
  Ho: Instruments are weak             # of excluded instruments:     2
```

	5%	10%	20%	30%
2SLS relative bias	(not available)			

	10%	15%	20%	25%
2SLS Size of nominal 5% Wald test	19.93	11.59	8.75	7.25
LIML Size of nominal 5% Wald test	8.68	5.33	4.42	3.92

Figure 3. Test of validity of instruments used to identify the MESR model.

```
. hausman fe re
```

	Coefficients (b) fe	Coefficients (B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
HHS	.104503	.0934313	.0110717	.
MSG	.2526362	.3322033	-.0795671	.
ACI	.5001439	.7430664	-.2429225	.0595124
ANOFI	.4113918	.5002124	-.0888206	.0218817
FES	.1347326	.1063897	.0283429	.0061256
ACR	-.1376945	.0242063	-.1619008	.030513

```
                 b = consistent under Ho and Ha; obtained from xtreg
      B = inconsistent under Ha, efficient under Ho; obtained from xtreg

  Test:  Ho:  difference in coefficients not systematic

                chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                        =       22.23
              Prob>chi2 =      0.0011
              (V_b-V_B is not positive definite)
```

Figure 4. Hausman test of IIA assumption in MNL

Appendix VI: List of Images During Data Collection

Image 1. Interview with solar water pump reservoir operator

Image 2: FGDs discussion with community members at Chancho robe village in Kersa Malima District

Image 3. Interview with Kersa Malima Agriculture administration officer

Image 4: Discussion with Kusaye Beda key Informants.