

Evaluation of Adoption and Effectiveness of Diesel Engine Operated Water  
Pump for Irrigation: A Case of Kewet and Tarmaber District, North Shewa  
Zone



Endalamaw Fikad Amare

A Thesis Submitted to the Department of Mechanical Engineering  
School of Mechanical, Chemical, and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of  
Masters of Science in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

February 2024  
Adama, Ethiopia

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## **DECLARATION**

I, hereby declare that this Master thesis entitled “Evaluation of Adoption and Effectiveness of Diesel Engine Operated Water Pump for Irrigation: A Case of Kewet and Tarmaber District, North Shewa Zone” is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other University. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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## **RECOMMENDATION OF ADVISOR**

I, the major advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Evaluation of Adoption and Effectiveness of Diesel Engine Operated Water Pump for Irrigation: A Case of Kewet and Tarmaber District, North Shewa Zone” Prepared under my guidance by Endalamaw Fikad Amare and submitted in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Machinery Engineering. Therefore, I recommend the submission of a revised version of the thesis to the department following the applicable procedures.

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## APPROVAL PAGE OF M.SC. THESIS

I, the advisor of this thesis entitled “Evaluation of Adoption and Effectiveness of Diesel Engine Operated Water Pump for Irrigation: A Case of Kewet and Tarmaber District, North Shewa Zone” and developed by Endalamaw Fikad Amare, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Endalamaw Fikad Amare have read and evaluated the thesis entitled “Evaluation and Adoption of Diesel Engine Operated Water Pump for Irrigation: A Case of Kewet and Tarmaber District, North Shewa Zone” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the degree of Master of Science in Agriculture Machinery Engineering.

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## ACRONYMS

ANOVA	Analysis of Variance
AGP	Agricultural Growth Program
AOR	Adjusted Odd Ratio
BHP	Brake Horse Power
COR	Crude Odd Ratio
DAs	Development Agents
EC	Energy Cost
GIZ	Gesellschaft für Internationale Zusammenarbeit
GPM	Gallons Per Minute
LCC	Life Cycle Cost
MC	Maintenance Cost
MoIL	Ministry of Irrigation and Lowlands
NGO	Non–Government Organization
NPSH	Net Positive Suction Head
PdM	Predictive Maintenance
PVWP	Photovoltaic Water Pump
PV	Photovoltaic
RC	Repair Cost
SPV	Solar Photo Voltaic
SC	Salvage Cost
SNV	Sustainable Development
SPSS	Statistical Package for Social Science
SSA	Sab-saharan Africa
TDH	Total Dynamic Head
WHP	Water Horse Power
WLTs	Water Lifting Technology

## ABSTRACT

*Irrigation has played a crucial role in Ethiopia's agriculture and food security. Water pumps are an essential component of the irrigation system as they ensure efficient distribution of water to crops, especially during dry seasons. These pumps are responsible for lifting water from rivers or wells and delivering it to farmlands. There are different types of water pumps used in Ethiopia, but the performance and adoption status of most pumps remain unknown. The objective of this study was to evaluate of the adoption and effectiveness of diesel engine-operated water pumps for irrigation in the Kewet and Tarmaber districts, North Shewa Zone. A total of 420 respondents were selected from 20 kebeles in the two targeted districts using a cross-sectional survey methodology and a standardized questionnaire. The acceptance and effectiveness of diesel engine-operated water pumps were assessed using regression, one-way ANOVA, and descriptive statistics. The results of this study suggest that a number of factors, including training, lack of operating experience, and the availability of spare parts and maintenance services, impacted the uptake and efficiency of water pumps powered by diesel engines. The assessment of the water pump's adoption was influenced by a number of criteria, including the land size, rental service availability, education level, and water pump cost. Whereas pump flow rate, pressure capability, fuel consumption, and maintenance requirements of water pumps were factors that affected the effectiveness of diesel engine-operated water pumps. Participants with primary education or higher were more than 42 times likely to adopt water pumps compared to illiterates. Similarly, participants with adult education were more than twice as likely to adopt water pumps. Those with a land size of greater than one hectare were 6 or more times more likely to adopt water pump than those who had less than 0.5 hectare of land. Respondents who received training on water pumps were 17 or more times more likely to adopt diesel engine-operated water pumps than those who did not received training. Participants who used diesel engine-operated water pump through rental service were 3 or more times more likely to adopt water pump compared to non-users. The study also found that as the head level increased from 2.2245m to 23.4m, both pump efficiency and total system efficiency decreased linearly, with a highly significant effect ( $P = 0.000$  and  $R^2 = 0.9$ ). Evaluating the effectiveness of diesel engine-operated water pumps involved assessing their performance and efficiency. The effectiveness of water pump testing was determined based on head levels and pump power of 4.476 kw, and this result showed a comparison of the actual performance with manufacturer specifications in terms of efficiency of 78.48% and 80%, respectively, due to maintenance requirements and fuel consumption. Diesel water pumping systems and solar PV systems were compared economically using life cycle cost analysis and investment analysis for both systems. The result showed that using solar PV water pumping systems is more economical for small-scale farmers compared to diesel pumping systems. Diesel engine-operated water pumps are an ideal technology that facilitates modern irrigation systems. Therefore, further studies will be conducted to improve the performance, efficiency, and adoption of water pumps in the region and at the national level.*

**Keywords:** Adoption, Diesel engine-operated, Effectiveness, Irrigation, Life cycle cost analysis, Water pumps.

## CHAPTER ONE

### 1. INTRODUCTION

Agriculture plays a pivotal role in the Ethiopian economy (Makombe *et al.*, 2011). Ethiopian agricultural practice has been traditionally dominated for centuries by small-scale farmers and its performance has long been adversely affected by the shortage of rain and water that left many to sustain their lives on famine relief support (Ejigu *et al.*, 2011). Irrigation has been the main driver of increasing food production worldwide. Just 20% of the world's arable land is used for irrigation, but 80% of that area is used for rain-fed agriculture, which generates roughly 60% of the world's grain output (Gebul, 2021).

Irrigation essentially boosts agricultural output in three ways, according to Mukherji and Facon (2009). Initially, it evens out harvest variations, which leads to increases in average yields since a consistent water supply is maintained throughout the growing season. Secondly, enhanced command over available water resources might, in certain cases, allow for a second or even a third cropping. Last but not least, the availability of consistent water supplies permits the introduction of new farming methods, the use of chemical fertilizers more frequently, and the use of improved seeds.

The estimated total irrigable land potential in Ethiopia is 5.3 million hectares assuming the use of existing technologies, including 1.6 million hectares through rain water harvesting and ground water (Awulachew *et al.*, 2010). Despite this potential, only between 160, 000 and 190, 000 hectares (5–10%) of land have been irrigated. Traditional irrigation systems are expected to cover around 65,000 hectares of this total. According to Gebremedhin and Peden (2003), approximately 352,000 hectares of land can be irrigated using small-scale irrigation projects.

Most diesel engine-operated water pumps were not effectively utilized, and the adoption of water pumps was not proficient. when they collected the field data to calculate the water pump efficiency curves on the theoretical and the actual can be compared. The main goal of this study was the evaluation of the adoption and effectiveness of diesel engine operated water pump for irrigation in Kewet and Tarmaber districts, North Shewa zone, Amhara regional state. In particular, evaluate the current status of diesel engine-operated water pumps used by the two districts, assess the factors hindering the adoption of the agricultural water pumps, determine the performance of water pumps in the field, to evaluate the effectiveness of the diesel engine-

operated water pumps, to evaluate diesel engine-operated water pump handling and economic analysis. The study's main contribution was the creation and implementation of effective water pumps for irrigation management systems to ensure that the water pump was in top working condition, repairable, and secure for use in producing high-quality commodities. The main outcome that can be anticipated from these studies was the identification of suitable diesel engine operated for irrigation management systems and the enhancement of the already existing ones.

### **1.1. Background and Justification**

Pumps used for irrigation include centrifugal, deep-well turbine, submersible, and propeller pumps. Centrifugal pumps are the most commonly used engine-powered pumps for small-scale irrigation (Awulachew *et al.*, 2009). Ethiopia has a lengthy history of introducing small engine machinery. Agricultural mechanization has been greatly aided by state farms, both irrigated and rainfed. This was especially true in the latter part of the former communist administration, when massive, mechanized state farms were established across 200,000 hectares, of which 47,000 hectares were under irrigation (Yohanna *et al.*, 2011). Laajine *et al.* (2022) suggest that improving energy efficiency can reduce pump demand by 25%, but limited studies investigate real-world pumping system behavior and component aging effects.

Dessalegn & Merrey (2015), stated that pump irrigation is beginning to revolutionize irrigated agriculture and rural development in sub-Saharan Africa in much the same ways as it has in Asia. As in Asia, it is enabling millions of smallholder farmers to create wealth and move out of poverty while also contributing to nonfarm rural development as well as national economic growth. It has also created a new generation of problems related to the management of scarce water resources and equitable access. This is still an emerging issue in SSA, though it is already taking shape in some localized areas, including Fogera in Ethiopia. They have argued that the root of the problem is that while traditional community-managed irrigation is perceived by both farmers and governments as having both technical and social dimensions, pump irrigation is viewed largely as a technological innovation. This narrow focus on technology repeats an earlier error committed by governments and donors wishing to promote small-scale irrigation. Researchers and governments have focused on one institutional dimension, the need for effective supply chains for pumps, spare parts, and maintenance services; and markets for agricultural products.

The results on the determinants of farmers' adoption of alternative energy-based water pumping suggest that several socioeconomic and demographic features of farmers have been either hindering or promoting the use of these water-pumping technologies based on alternative sources of energy; for instance, these are more likely to be used by more educated, younger, and wealthier farmers. Access to credit facilities is another key determinant of farmers' adoption of alternative energy technologies for irrigation by water pumping. Hence the following policy implications can be drawn: firstly, the government of Pakistan should provide access to credit to farmers who are willing to buy these technologies; secondly, there is a need to spread awareness about the merits and availability of these renewable technologies through various extension services, particularly among less-educated, smallholder farming communities residing in remote areas of Pakistan (Ali *et al.*, 2016).

Since most facilities throughout the world rely on traditional energy production for power, pumping water is an energy-intensive activity. When fossil fuel prices rise, so does the cost of using them because of the extra expenses associated with pollution and greenhouse gas emissions. Transporting fuel to isolated, rural locations can be challenging, even if it is available within the nation. Many rural places lack roads and other necessary infrastructure. As a result, it makes more sense to combine the production of renewable energy with water pumping. The International Renewable Energy Agency reported in 2016 (Shouman *et al.*) that in the following two years, renewable energy costs will decrease by over 40%, and by 2017, 80 percent of the solar energy sector is expected to attain grid parity. The promotion of reasonably priced small-scale water lifting technology (WLTs) for irrigation, such as motorized water pumps, pulleys, and rope and washer pumps, could be one of the potential answers to Ethiopia's agricultural water management issues. By enabling multiple cropping throughout the year, such technology could improve smallholder farmers' access to agricultural water during dry seasons. Access to agricultural water also prevents rain-fed agriculture systems' major wet-season crops from failing due to dry spells by providing supplemental irrigation (Tesfaye *et al.*, 2021). Pumps are widely used for extracting groundwater and lifting water from surface systems for irrigation (Sikka *et al.*, 2006).

Numerous sources (Chandel *et al.*, 2015; Foster & Cota, 2014; Rajini & Paramasivam, 2013) examined the viability of utilizing PV and diesel generators to power water pumping systems in remote and rural areas across the globe. With an emphasis on increasing industry productivity,

the Ethiopian government has made agricultural-led industrialization the cornerstone of its economic agenda. Numerous studies have shown that more agricultural power and energy can lead to increased productivity and production (Faleye *et al.*, 2012).

### **1.2.Statement of the Problems**

The primary industry in Ethiopia that has a significant impact on poverty reduction, food security, and economic development is agriculture. Nonetheless, the performance of agriculture is characterized by low levels of technological adoption and both high and low levels of rainfall unpredictability. Furthermore, smallholder farmers dominate the industry. The availability and consistency of information regarding smallholder irrigation practices and private smallholder irrigation technologies are lacking. According to recent studies, Ethiopia has between 1.4 and 2.8 million hectares of potential for small private motor pump irrigation, which might help between 9 and 18 million smallholder farmers (Gebregziabher *et al.*, 2014). Ethiopia's irrigated agriculture, which accounts for 10–12% of the country's potential, faces challenges like limited technology availability, insufficient funding, and insufficient extension services (Abebe, 2017).

It is well known that agriculture is the biggest economic pillar of our country (Zerssa *et al.*, 2021). Irrigation is one of the activities that make agriculture effective. Understanding this, the Ethiopian government has paid great attention to irrigation and has gone as far as establishing its own ministerial office. As a part of the initiative, diesel engine-operated water pumps are widely distributed to farmers in different parts of the country. Some of the areas, where the diesel engine is distributed, are in the North Shewa zone of the Amhara region, especially the Tarmaber and Kewet districts.

The majority of the farmers did not, however, make good use of the water pumps powered by diesel engines. In order to acquire, transport, and distribute the water pumps to the designated farming areas, the Federal Democratic Republic of Ethiopia, working with the Ministry of Irrigation and Lowland and various organizations such as the Haomax 3" diesel water pump for Ambasel, allotted a budget. Some farmers even bought water pumps themselves. This practice of developing water pumps powered by diesel engines should be limited.

### **1.3.Objectives**

#### **1.3.1. General objective**

The general objective of this research was the evaluation and adoption of diesel engine-operated water pumps for irrigation.

#### **1.3.2. Specific objectives**

The specific objectives of this thesis are:

- To evaluate the current status of the diesel engine-operated water pumps.
- To evaluate the effectiveness of the diesel engine-operated water pumps.
- To assess the factors hindering the adoption of diesel engine operated water pumps.
- To evaluate diesel engine-operated water pump handling and economic analysis.

### **1.4.Significance of the Study**

The study's primary contribution was to evaluate the adoption and effectiveness of water pumping systems to make sure that the equipment is in excellent working order, repairable, and safe to use in creating high-quality goods. Through the use of this study, agricultural output has been raised and irrigation efficiency has been improved by giving each field the appropriate amount of water at the right time to facilitate faster irrigation. The first beneficiary has been the office of irrigation and lowland area development, which was able to identify the main effectiveness evaluation and obstacles to adopting a water pumping system and then come up with solutions. Local farmers and other institutions that may apply the knowledge produced in this study was also benefit. Second, the study will serve as a starting point for future scholars and researchers who wish to do more research in the subject area. Thirdly, this study has been crucial for related governmental organizations in that the decision-makers utilized the conclusions to develop comparable new initiatives involving the adoption of water pumping systems. This study aimed to evaluate the impact of smallholder farmers' adoption and distribution of diesel engine operated water pumps on farm income and factors related to these adoptions. It is anticipated that this study will serve as a basis for more in-depth research projects for other researchers.

### **1.5.Scope of the Study**

This study's focus was on assessing the effectiveness of diesel-powered water pumps for small-holder farmers in the Tarmaber and Kewet districts of the North Shewa Zone, as well as the current trend in their adoption. Through structured surveys, interviews, field observations, and focus group discussions, the evaluation has taken into account several characteristics about aspects that contribute to the effectiveness and adoption of water pumps powered by diesel engines.

### **1.6.Limitation of the Study**

The following are the obstacles encountered while doing this research paper: When they went to collect information, they didn't like a person with a paper. There are problems due to the political instability of the country. This led to a delay in the data collection process.

The current situation of the country, especially Kewet district, was a challenge for my research. Diesel engines can contribute to air pollution through the emission of pollutants like carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and particulate matter, but cannot calculate the percentage needed to pollute the environment.

Furthermore, even though different efforts have been made, the researcher faced some other challenges while doing this study, such as the respondents showing some negligence in filling out the survey questionnaires, rejection of appointments from scheme representatives, some not giving values to the questionnaires, and others being unwilling to provide accurate data.

## CHAPTER TWO

### 2. LITERATURE REVIEW

#### 2.1. History and Status of Irrigation Development in Ethiopia

According to sporadic accounts, small-scale irrigation development in Ethiopia has a lengthy history that likely began more than 2,000 years before the Axum dynasty. Traditional irrigation has been used for many years in many parts of the country. It entails small-scale river diversions, recession framing, and rainfall gathering. However, when the nation endured repeated droughts and famines in the 1970s and 1980s, more focus was placed on small-scale, peasant-based irrigation development as a means of increasing agricultural output and achieving food self-sufficiency (Gebul, 2021). Medium- and large-scale commercial irrigated farms have begun in the Upper and Middle Awash River Basins, which are among the most extensively developed in the country. However, it might have been less important because rain-fed agriculture, terraces, and small-scale irrigation were found sufficient to maintain ancient inhabitants (Harrower et al., 2020).

Ethiopian irrigation development has, for the most part, concentrated on building infrastructure. This implies that irrigation management's significant function is mostly disregarded. As a result, numerous studies show that irrigation schemes perform poorly when evaluated using a variety of relevant measures (Abera *et al.*, 2019). While the causes of poor performance vary, they are primarily due to bad scheme administration. Not only are schemes' productivity and efficiency low, but the irrigated areas are significantly smaller than the potential irrigable areas generated by project implementation. According to reports, around 50% of irrigation systems currently provide functional services, while the remaining 34% of implemented schemes are not being used to their full potential and 16% are non-functional.

#### 2.2. Water Pump

A pump is a device that converts fuel energy into usable water energy and requires either an electric motor or a gasoline or diesel engine to operate. Additionally, using solar or wind energy may be feasible in certain situations. The pump raises water from an aquifer or groundwater into a channel or pipe system for surface irrigation. In addition to providing the energy required to raise water from the source, the pump also supplies the pressure and discharge required to distribute water in the pipes to the sprinklers and emitters for sprinkler and trickle irrigation (Abebe, 2014).

### **2.3.Type of Water Pump**

Zone (2014) states that while there are numerous additional kinds of pumps and water lifts, the most commonly used types are the radial flow (also known as centrifugal), mixed flow, and axial flow (also known as propeller) pumps. Farmers employ a variety of water pumps, including piston, submersible, shallow well jet, deep well jet, and centrifugal models. Each type transfers clean water in a particular way based on the requirements and available resources of the area.

#### **A. Axial flow pump**

A propeller, which is housed inside a tube submerged in water, is the component of an axial flow pump, hence its other name. Lifting water from a lake or river to deliver surface irrigation water to a farm with open channel distribution is an ideal use for the tube, which also functions as the discharge pipe. The power unit drives the propeller via a long shaft that travels down the middle of the water at low pressure. The reason these pumps are more expensive than typical is that they require expensive materials, particularly the driving shaft and the bearings supporting the shafted propeller. Due to this, no small axial flow pumps that are suitable for a 1–2 ha farm have been produced. They are often exclusively utilized on larger farms and in communal irrigation systems, which employ one pump to irrigate multiple small farms. Due to the substantial amounts of water that this crop often requires, it is especially well suited to paddy rice projects.

#### **B. Radial flow pump**

Due to their lower initial cost and ongoing maintenance costs than axial pumps, centrifugal pumps are the most popular type of pump utilized on modest projects. In most underdeveloped nations, compact pump sets are frequently easily accessible. They work well with sprinklers and trickle watering, which require more pressure than surface irrigation.

#### **C. Mixed flow**

This pump combines the best qualities of both the axial flow and centrifugal pump types, which is advantageous. Axial flow pumps are less effective at pumping to greater pressures and less effective at pumping bigger volumes of water than mixed flow pumps. To function as submersible pumps, they must be submerged beneath the source water's surface.

## **2.4. Water Pump Classification**

Girma *et al.*, (2015) found that mechanical and electrical systems both fall under the category of wind pumps. Roto-dynamic pumps and systems with positive displacement are additional categories for mechanical wind turbines. The mechanical wind pumping option uses a variety of pumps, including screw pumps, piston pumps, centrifugal pumps, regenerative pumps, and compressor pumps.

According to (Prasad *et al.*, 2016), the researcher said that there are two classifications of pumps;

- Volumetric (Positive displacement pump)
- Centrifugal (Roto-dynamic pump) out of which we have used a positive displacement pump.

Hence for better displacement and sufficient water discharge, we have used Piston Pump (single-acting reciprocating pump). Piston pumps are generally connected to a surface-mounted motor and used to pump water from shallow wells, surface water sources, pressurized storage tanks, or through long pipes.

## **2.5. Water Pump Distribution**

Motor pump irrigation is more advanced in sub-Saharan Africa than it is in Asia, but it is expanding quickly in many nations. Research and policy in Africa have, up to this point, concentrated on streamlining supply chains to increase the affordability of pumps. Irrigation in Africa mostly relies on two sources: tiny streams and rivers and shallow groundwater aquifers. Both typically have inconsistent and restricted yields. We give a case study from Ethiopia, where the use of pump irrigation based on tiny rivers and streams is growing quickly, and we draw comparisons to situations in Asia and other African nations. While farmers are aware of the social aspects of community-managed irrigation, our research demonstrates both they and policymakers have limited knowledge of pump irrigation, viewing it as largely "technical" (Dessalegn & Merrey, 2015).

Smallholder agriculture plays a significant role in Ethiopia's economy and has a direct impact on the nation's efforts to reduce poverty, secure its food supply, and build its economy. An important policy concern on the nation's development agenda is the use of smallholder irrigation technologies to address these problems. Unpublished studies at the regional bureaus of water resources state that motorized small pumps are among the newest private irrigation technologies

in rural Ethiopia. Small pumps are commonly distributed through local water resource organizations, mostly through direct purchases made using farmer resources and on credit. According to government statistics (Ethiopian Revenue and Customs Authority), about 800,000 motor pumps were imported into Ethiopia between August 2004 and December 2010. Meanwhile, unpublished reports from the regions indicate that, as of the end of 2009, the regional bureaus of water resources had distributed 19,338 pumps in Oromia, 20,916 in Amhara, and 18,348 in Tigray (Gebregziabher et al., 2014).

As a result, the only trustworthy option for extracting water from the earth will be a motorized water pumping system. Water is typically pumped using windmills, diesel, gasoline, and kerosene pumps. However, trustworthy solar photovoltaic (PV) and wind turbine pumps are now available on the market and are quickly overtaking conventional power sources in terms of attractiveness. Additionally, there is a resurgence of interest in wind pump technology today due to ongoing fuel shortages and rising prices. Diesel water pumping devices have been used for many years in Ethiopia. Currently, however, practically all of the systems are non-functional due to the global rise in gasoline prices, including in Ethiopia. As a result, the government planned to switch over to solar/wind water pumping systems in 2006, replacing all diesel water pumping systems. The nation has a potential for 1350 GW ( $> 7$  m/s) of wind energy, according to a recent report by HYDROCHINA Corporation. There is low to medium wind energy potential ( $> 2.8$  m/s) in the majority of the country, which can be used for water pumping (Girma et al., 2015).

## **2.6. Water Pump Selection**

According to Pulido-Calvo and Gutiérrez-Estrada (2011), a thorough inventory of the operating circumstances of the irrigation pump must be done before choosing one. Included in the inventory must be:

- The water supply (well, river, pond, etc.).
- The entire number of suction heads; the necessary pumping flow rate;
- The overall dynamic head

When it comes to the water's source, there's usually no choice; the availability of either surface water or well water depends on the hydrologic and geological features of the area. The size of the piping system, the distance from the water source, and the kind of irrigation system will all

affect the flow rate and total dynamic head. The primary responsibility of extension officers when it comes to pumping technology is to assist farmers in choosing a technology that best suits their requirements and available resources. The best possible adequacy between engine power and required discharge and head; low purchase cost; long working life; high efficiency of human or fuel energy; low operating costs; easy access to spare parts at reasonable prices and low repair cost; portability in case of multiple users in different places or to reduce the risk of theft are the suggested selection criteria (Awulachew et al., 2009).

## **2.7. Water Pump Operation**

Any attempt to enhance the pump operations of an existing pump station typically encounters three distinct problem areas: inefficient pumps, inefficient pump combinations, and inefficient pump scheduling. The ratio of the water horsepower generated by a single pump to the input horsepower, which is often electrical, is known as the pump's efficiency. It is important to measure its efficiency at various flow rates. Measuring flow rates after pumps are installed in existing installations is not usually physically feasible. Even if this data can be found and the pump is found to meet its initial performance requirements, there is still no guarantee that it will function effectively within the system. When a pump is used in conjunction with other pumps, its efficiency might vary significantly from that of the pump used alone. The actual flow generated when a pump is operated many times depends on the head variations between the discharge and suction headers. The system head curve, which shows the relationship between these heads and the flow rate, depends on a number of factors, including the position of water consumers in relation to the pump, the pipe carrying capacity near the pump, the tank water level on each size of the pump, and which other pumps are in use. A pump can function at a variety of efficiencies depending on the system head it encounters (Guyer, 2012).

### **2.7.1. Basic pump operating characteristics**

Pump heads are frequently referred to as "heads." The term "head" describes the height of a vertical water column. In irrigation, pressure and head are synonymous terms because a column of water 2.31 feet high corresponds to 1 pound per square inch (PSI) of pressure. The many forms of head that make up a pump's total head contribute to defining the pump's operational characteristics.

### 2.7.2. Pump power requirements

The power added to water as it moves through a pump can be calculated with the following formula (Roy *et al.*, 2018):

$$WHP = \frac{Q \times TDH}{3960} \dots \dots \dots (2.1)$$

Where: WHP=water horsepower

Q=Flow rate in gallons per minute (GPM)

TDH=Total Dynamic Head (feet)

However, the actual power required to run a pump will be higher than this because pumps and drives are not 100 percent efficient. The horsepower required at the pump shaft to pump a specified flow rate against a specified TDH is the Brake Horse Power (BHP) which is calculated with the following formula:

$$BHP = \frac{WHP}{Pump\ Eff. \times Drive\ Eff.} \dots \dots \dots (2.2)$$

BHP = Brake Horse Power (continuous horsepower rating of the power unit).

Pump Eff.= the efficiency of the pump is usually read from a pump curve and has a value between 0 and 1.

Drive Eff = The efficiency of the drive unit between the power source and the pump

For direct connections, this value is 1. For right-angle drives, the value is 0.95, and for belt drives, it can vary from 0.7 to 0.85.

### 2.8. Energy Performance Assessment of Water Pumps

Energy Efficiency Bureau (2006) The process of adding kinetic and potential energy to a liquid in order to transport it from one place to another is known as pumping. This energy will cause the liquid to do work such as flow through a pipe or rise to a higher level. A centrifugal pump transforms mechanical energy from a rotating impeller into kinetic and potential energy required by the system. The most critical aspect of energy efficiency in a pumping system is the matching of pumps to loads. As a result, even if an efficient pump is chosen, if there is a mismatch between the pump and the system, the pump will operate at very low efficiency. In addition, an efficiency drop can also be expected over time due to deposits in the impellers.

### 2.8.1. Performance terms and definitions

Pump Capacity: Q is the volume of liquid the pump can deliver in milliliters per hour or millisecond.

Q is a function of N, where N-is the pump's rotational speed.

Total developed head, or H, is the pressure differential between the suction and discharge.

The net work performed on unit weights of a liquid as it travels from the pump's inlet to its discharge is represented by the pump head. Pumps typically have three heads in use: the static head, the velocity head, and the friction head.

In a network of pipes, valves, and fittings, the frictional head varies in proportion to the capacity flows through the system, approximately as the square.

Resistance of the system: The entire static head plus the frictional head in resistance

**Pump efficiency** is calculated by dividing the pump's useful work and fluid power by the power supplied into the pump shaft (Uche *et al.*, 2023).

$$\text{Pump efficiency} = \frac{\text{Hydraulic power, } P_h}{\text{Power input to the pump shaft}} \times 100 \dots \dots \dots (2.3)$$

Where: Q = Volume flow rate ( $m^3/s$ )

$\rho$  = Density of fluid ( $kg/m^3$ )

$P_h$  = Hydraulic power  $P_h(kw) = \frac{Q}{100} (h_d - h_s) \times \rho \times g$

$g$  = acceleration due to gravity ( $m/s^2$ )

$(h_d - h_s)$  = Total head in meters

### 2.8.2. Field testing for determination of pump efficiency

To determine the pump efficiency, three key parameters are required: flow, head, and power. Of these, flow measurement is the most crucial parameter, as normally online flow meters are the majority of pumping systems that lack this feature. The following methods outlined below can be adopted to measure the flow depending on the availability and site conditions (Slycke *et al.*, 2018).

#### Flow Measurement, Q

The following are the methods for flow measurements:

- Tracer method BS5857
- Ultrasonic flow measurement
- Tank filling method

- Installation of an inline flow-meter

**Tracer Method**

The Tracer method is particularly suitable for cooling water flow measurement because of its sensitivity and accuracy. This method is based on injecting a tracer into the cooling water for a few minutes at an accurately measured constant rate. A series of samples are extracted from the system at a point where the tracer has become completely mixed with the cooling water. The mass flow rate is calculated from the:

$$q_{cw} = q_1 \times C_1 / C_2 \dots \dots \dots (2.4)$$

Where:  $q_{cw}$  = cooling water mass flow rate, kg/s

$q_1$  = mass flow rate of injected tracer, kg/s

$C_1$  = concentration of the injected tracer, kg/kg

$C_2$  = concentration of tracer at the downstream position during the 'plateau' period of constant concentration, kg/kg.

**Ultrasonic Flow meter**

Operating under the Doppler Effect principle these meters are non-invasive, meaning measurements can be taken without disturbing the system. Scales and rust in the pipes are likely to impact the accuracy.

- Ensure measurements are taken in a sufficiently long length of pipe free from flow disturbance due to bends, tees, and other fittings.
- The pipe section where measurement is to be taken should be hammered gently to enable scales and rust to fall out.
- For better accuracy, a section of the pipe can be replaced with a new pipe for flow measurements.

**Tank filing method**

In open flow systems such as water getting pumped to an overhead tank or a sump, the flow can be measured by noting the difference in tank levels for a specified period during which the outlet flow from the tank is stopped. The internal tank dimensions should be preferably taken from the design drawings, in the absence of which direct measurements may be resorted.

### **Installation of an inline flow-meter**

If the application to be measured is going to be critical and periodic then the best option would be to install an online flow meter which can get rid of the major problems encountered with other types. The efficiency of pumping units plays an important role in the adoption of pumps and their utilization for groundwater development. A wide variety of pumps are available in the market. However, cheaper pumps are mostly low priced but are of low efficiency. Low efficiency of pumping units is also responsible for excessive energy consumption, reduced irrigation efficiency, and low productivity but, due to lack of knowledge and considering the subsidy the electricity, most of the farmers prefer to go for cheaper pumps. These pumps give poor discharge even with higher horse power (hp) capacity pumps. It is, therefore, important that awareness is created about the use of efficient pumps. This requires knowledge about the parameters to be considered for the selection of pumps and, how the efficiency of the pumps can be enhanced. The energy consumption depends mainly on pump discharge, the height of the water lift, time of operation, and efficiency of the pump set (pumps, drive, and motor/ engine, and their installation (Sikka *et al.*, 2006).

#### **2.8.3. Factor affecting water pump performance**

Odeh *et al.*, (2006) studied that the factors that have far inhibited the widespread implementation of photo voltaic pumping systems include;

- high initial capital cost,
- lack of awareness,
- lack of technical installation expertise,
- history of failures and
- lack of sufficient knowledge to predict accurately the system's daily output

The main parameters affecting system performance are well head-flow rate characteristics, pump head-flow rate characteristics, a frequency distribution of insolation, and input power.

### **2.9. Water Pump Maintenance**

Olesen & Shaker (2020) studied that the maintenance process is comparable to the medical treatments given to people. If carried out well, the system will operate with fewer constraints and demonstrate superior performance. This translates to lower costs, better resource management, longer lifespans, and less downtime. On the other side, ineffective maintenance

management can lower safety, reputation, and product quality. Thus, the issue of when maintenance should be carried out arises. In the past, maintenance was carried out either reactively or preventively. The reactive maintenance strategy permits parts and equipment to function until failure. The result is prolonged downtime, which results in the loss of a market opportunity. By using a time or cycle metric, the preventive maintenance approach applies maintenance. The Oxford Learner's Dictionaries describe maintenance as "the process of keeping something in excellent condition by monitoring or fixing it regularly" and the adjective predictive as "connected with the ability to show what will happen in the future". The definition of PdM that results from fusing the two is as follows: "the act and ability to keep something in good shape by comprehending what happens in the future. Predictive maintenance, to put it simply, is an attitude or way of thinking that makes use of the equipment and systems of a plant as they actually are in order to maximize plant performance. The real operational state of essential plant systems is obtained using the most cost-effective tools (such as vibration monitoring, thermography, and tribology), and all maintenance actions are then scheduled by this actual data. To deploy enough countermeasures, PdM aims to spot trends, anomalies, and degradation early on.

Hallaji *et al.* (2021) investigated predictive maintenance (PdM), which is a technique that uses data-driven analysis to identify unusual working conditions and forecast the likelihood that assets will fail in the future. PdM is rarely used in infrastructure facilities like wastewater treatment plants while having numerous uses in the manufacturing and oil and gas sectors.

An excellent opportunity to improve infrastructure maintenance practice by incorporating PdM methodologies has recently arisen with the introduction of information and communication technologies and artificial intelligence. Irrigation pumps and engines should be maintained following the instructions provided in the manufacturer's manual. Inform farmers about these instructions through leaflets and training sessions. Try to involve local pump dealers, spare parts retailers, and mechanics in these sessions. Farmers should be trained to carry out routine maintenance tasks such as changing filters and bleeding fuel lines to remove air. Farmers should know reliable mechanics in case of major problems and where to find spare parts at reasonable prices (Awulachew *et al.*, 2009).

## **2.10. Why Adoption Studies are Important?**

Zone (2014), Researchers can develop and innovate any technology, which they may subsequently make available to users. A large portion of technological invention and development was motivated by user demand. Therefore, adoption studies are important for the following reasons.

- To identify the innovators, early adopters, early majority, late majority, laggards
- To identify the traditional or backward technologies that the farmers used and compare them with the modern technologies and then to update the old technology or create and innovate new technology
- Identify the number of technology users and non-users to provide the proper technology at the appropriate time and location.
- To raise the standard of living for those in need and ensure their access to food
- To plan the release of information
- To create ineffective agricultural development policies. These studies would aid in the creation of strong technology adoption policies.

It is common knowledge that the creation and development of technologies is an iterative process and that user demand must determine how many technologies are produced.

Adoption studies are therefore essential for the following reasons:

- To estimate the number of technology users over time to evaluate effects or establish the need for an extension. A study on adoption would be beneficial for monitoring and providing feedback on technology generation.
- In a typical continuum model for technology production, development, and transfer, researchers would convey the technology to extension agents who would then take it to farmers, where it would work and be adopted by farmers. Years of development work have shown that this strategy is ineffective. A particularly common paradigm for technology development and transfer that encourages participation is the participatory approach. Adoption studies would offer more information about the efficiency of technology transfer.
- To supply data for policy reform. It is well known that efforts to advance agriculture are hampered by the absence of inadequacy of policies to assist both general development and, more specifically, agricultural research and development. Studies on adoption must

emphasize and comprehend the barriers to technology adoption caused by the policy. Such research would aid in the creation of efficient technology adoption policies.

- To offer a foundation for impacts. The significant rate of return on investments in farming systems has been estimated by many economists.

### **2.11. Adoption of Technology and Practices in Agriculture**

The acceptance or initial use of a newly developed technology or product is known as technology adoption. The goal of studies on technology adoption was to comprehend, forecast, and explain the factors that affect how individuals and organizations will adopt and make use of technological advancements. To comprehend how these characteristics, relate to adoption behavior, conceptual models and frameworks have been developed as a result of these investigations. Information and communication technology's explosive growth has had a profound effect on every aspect of human life (Lee & Coughlin, 2015).

The development of novel or enhanced technology and practices is the subject of much research in the field of agricultural innovation studies. In this essay, we emphasize the process of wider dissemination and adoption of new or improved technologies and methods, sometimes known as "scaling out." Technologies include devices like machines, inputs like fertilizer and pesticides, and practices like how farmers sell their produce and buy inputs (for example, from local stores or through contracts with agri-business). The adoption of new or improved technologies and practices is frequently approached from a technology-push perspective and evaluated on a scale from "innovators" to "early adopters" to "late adopters" to "laggards," but this is typically done from a normative perspective on what constitutes "good agriculture" and "appropriate innovation," while different resource endowments and farming styles go with different ways and justifications for adoption (Aguilar-Gallegos *et al.*, 2015).

### **2.12. Factors Influencing the Adoption of Water Pumping Technology**

Assessing the perception and factors influencing the adoption of agricultural technology in Ethiopia's Amhara regional state, namely in the North Shoa zone, is the study's main goal. Information was gathered from 796 agricultural households spread throughout four districts: Moretna Jiru, Menz Gera, Minijar Shenkora, and Angolela Tera. The binomial logistic model and the t-test were used for analysis. According to the findings, households with higher ages, more years of education, larger farms, more animals, and numerous extension contacts are more

likely to adopt enhanced seed, chemical fertilizer, and irrigation. Furthermore, households that get money from sources other than farming, are members of multiple social groups, and have access to financing are more likely to embrace these agricultural technology (Massresha *et al.*, 2021). All empirical review of the literature on agricultural small engine technology in developing countries reveals that the various factors that influence the availability and utilization technology can be grouped in to the following categories.

- Factors related to the characteristics of producers (i.e., the farmers)
- Factors related to characteristics and relative performance of the technology
- Politics and institutional factors

Education level, work history, age, gender, wealth level, farm size, plot features, labour availability, resource endowment, risk aversion, and other factors are all related to the characteristics of producers (Amare & Endalew, 2016). Enabling policies and programs, market linkages, and access to institutional support and credit were found to play a positive role in stimulating farmer investment in and adoption of sustainable technologies. A mismatch between the economy of scale of the technology and farm size is one of the most frequent obstacles to expanding small scale access to the proper small engine machinery (Zegeye *et al.*, 2022). Its availability and that of complementary inputs, the relative profitability of its distribution compared to substitute technologies, the period of investment recovery, local adoption patterns of the technology, the susceptibility of the innovation of failure, the perception by people of characteristics, complexity, and performance of the innovation are some of the factors related to the characteristics and performance of the technology and practices (Dinku & Beyene, 2019).

The institutional element includes the accessibility of markets for goods and inputs, the land tenure system, the availability of credit, the availability and quality of knowledge on technologies, the availability of markets for goods and inputs, the availability of suitable infrastructure, extensions support, etc. and the poetics affect directly or indirectly all activities when it's as a source of conflict and ideal complaint (Rosen *et al.*, 2015).

More than 50% of the food produced on a global scale comes from tiny family farms, many of which have distinct, dispersed fields and are therefore unsuitable for larger machines (Negrete, 2019). Farmers in Ethiopian nations cannot afford to buy equipment, and there is little financial assistance available in the form of subsidy or financing plans. Due to lack of acceptable

collateral and the assumption that agriculture carries a high level of risk, the service sector is reluctant to extend credit to small scale (Bayissa, 2015).

### **A. Demographic factors**

The gender differences between family heads are a crucial explanatory variable when analyzing adoption related factors. The social structures that prevailed in rural households assigned different responsibilities to the male and female household members (Deribe & Jaleta, 2019). Women are generally marginalized in rural Ethiopia and have limited access to technological information. As a result, multiple adoption studies have revealed that having a female head influences technology adoption decision negatively. Because of the prevalent sociocultural attitude and conventions, men are free to move about, attend various gatherings, and receive training. As a result, households led by men are more likely to use innovation than homes headed by women, which are more susceptible to being influenced by cultural norms and traditions. Those that are wealthier can easily afford the cost of modern farming technologies. Another factor in understanding farmers technology utilization behaviors is the age of the household head. This factor is significant because it affects farmers access to information and their capacity to put that information to use. Older farmers might have resources and experience's that would provide them with greater opportunities to experiment with new technologies. As opposed to the elder generation, younger farmers are more willing to utilize available new technologies because they have received more formal education (Melesse, 2018).

### **B. Socio- economic factors**

The household heads educational status is the most pervasive and important factor found to influence farmers utilization of agricultural new technology. Farmers that have greater education are more likely to use new, improved technologies. This result is consistent with prior findings. This is because education can alter farmers knowledge, skill, and attitude. Additionally, it improves farmers analytical and problem-solving abilities (Melesse, 2018).

### **C. Institutional factors**

Institutional consideration is concerned with how much influence institutions have on small-scale technological adoption. Entail all services that support agricultural development, including financing, insurance, and information sharing (Deribe & Jaleta, 2019). They also consist of structures and devices that facilitate farmers access to market opportunities and useful inputs.

Better roads and well-connected rural road networks are among the essential factors in the expansion and development of smallholder mechanization. One very important institutional element that distinguishes farmers utilization status is the extensions service.(Davis & Franzel, 2018). Currently, the extensions system handles a large portion of delivering agricultural technologies. As a result, having access to training demonstrations and other extensions activities creates the frame work for gathering pertinent knowledge that encourage technology adoption. In several studies, several variables have been used to assess farmers access to extension services (Davis *et al.*, 2019).

#### **D. Access to different service provider**

Access to extension services is critical for developing current agricultural production technology. Farmers can learn about new technologies through extension. Access to Agricultural extension services has made automation available to small-scale farmers throughout the country (Sims *et al.*, 2016). The amount of information available about the new technology determines its acceptance. It informs farmers about its existence as well as the appropriate use of technology, facilitating its adoption. Farmers will only use technology that they are aware of or have heard about. When farmers have access to extensions service, they are more likely to accept new technology. Farmers must be confident that new agricultural technology will work on their farms if they are to adopt it. Demonstration farms are diffusion tools that should be used to instruct young farmers who need to be familiar with new and advanced technologies (Oduma *et al.*, 2019).

#### **E. Land fragmentation**

When a family's farmland, which was already modest in size, was divided among the children, it was further divided in to very small pieces of land. This prevents yield from rising and instead causes poverty and food insecurity (Oduma *et al.*, 2019). Because a large number of family members will lose their jobs because there is not enough land to support them as full-time farmers. The national survey of Ethiopia has revealed a positive correlation between yield and land fragmentation, which is an inverse link between farm size, yield, and land fragmentation (Paul & wa Gĩthĩnji, 2018). As a result of the smaller farm sizes poorer yields, mechanizing farms is also challenging and ineffective for securing family's needs.

### **2.13. Research Gap**

The research gap in Ethiopia's agricultural transformation and the adoption of motorized water pumps is primarily due to the lack of adoption of improved agricultural technologies. This lack of adoption is attributed to factors such as inadequate access to irrigation technologies, inadequate extension services and information systems, and limited institutional support and planning. The study aims to identify these barriers and develop targeted strategies to promote the adoption of these technologies. It also highlights the importance of market access and information in enhancing farmers' livelihoods and productivity. The research gap aims to address these challenges and promote sustainable agricultural development in Ethiopia.

The study explores factors influencing farmers' choice of water pumps and their impact on crop productivity, household income, and poverty. It finds educated, younger, and wealthier farmers are more likely to adopt alternative energy-based pumps. Access to credit facilities and frequent loadshedding are key factors. Alternative energy sources significantly reduce poverty by 11–20% (Ali et al., 2016). Zone (2014) recommended that the study find that farmers' opinions of motorized water pumps were more favorable than those of alternative irrigation technologies. This has a big impact on whether motorized water technology gets adopted. However, the adoption of this water pump technology has not been as rapid as anticipated, according to surface water potential (rivers).

## CHAPTER THREE

### 3. MATERIALS AND METHODS

#### 3.1. Description of the Study Area

The study was conducted in two districts of the Amhara regional state of Ethiopia. Particularly, Tarmaber wereda and Kewet wereda from November 2022 to November 2023. Tarmaber were located North Shewa Zone Amhara region in Ethiopia at latitude  $9^{\circ} 52' 59''$  north and longitude  $39^{\circ} 43' 58''$  east with an elevation of 2630 to 2830 meters above sea level. Tarmaber were located in the north Shewa Zone in the Amhara region approximately 190 km from Addis Ababa. Kewet was located in the North Shewa Zone of the Amhara Region, this town has a longitude and latitude of  $10^{\circ}00'N$   $39^{\circ}54'E$  with an elevation of 1280 meters above sea level. It covers an area of about  $146.32 \text{ km}^2$ . Kewet was located in the North Shewa Zone in the Amhara region approximately 225 Km from Addis Ababa.

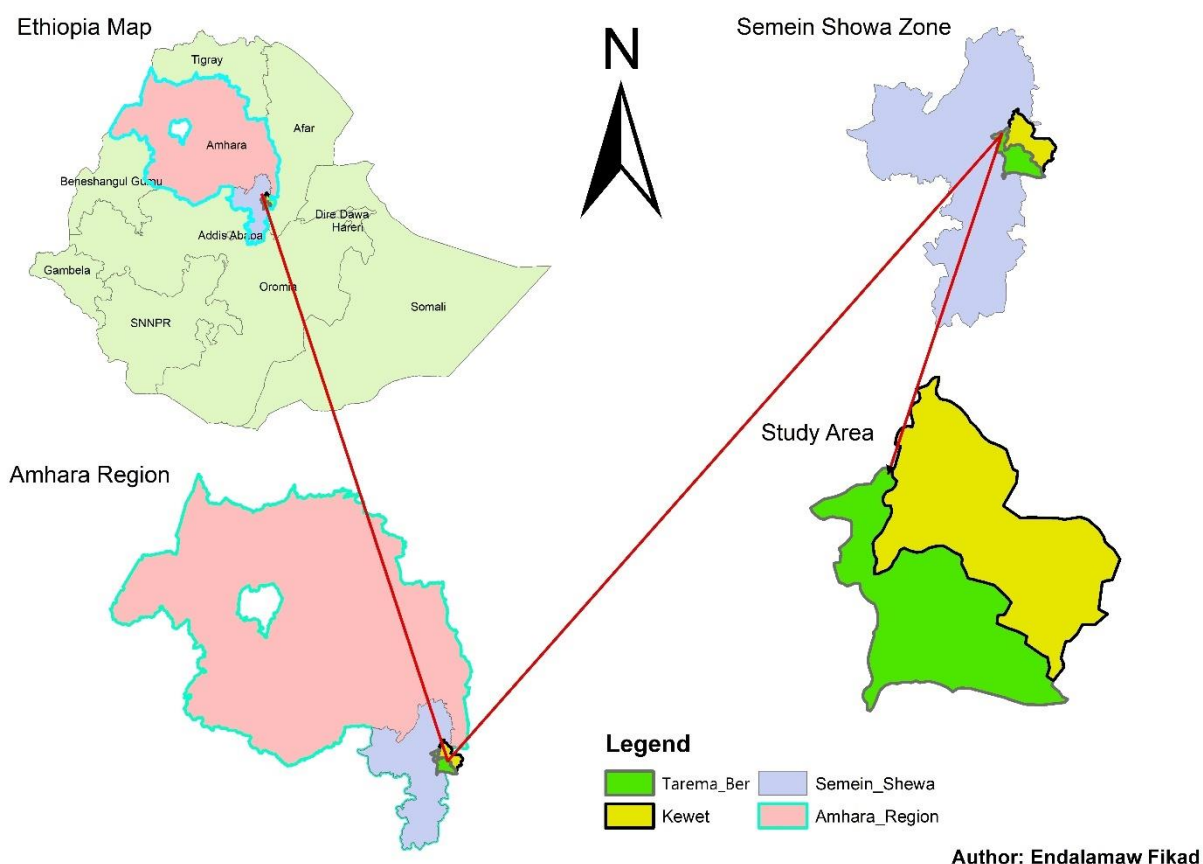


Figure 3.1. Map of the study area

### **3.2. Materials**

The agricultural diesel engine-operated water pumps within the field were recorded during the study. Materials required for the effectiveness evaluation of diesel water pumping systems for irrigation purposes are listed below.

- A graduated flask was used to determine the volume of the liquid.
- A tape meter was for measuring different head levels with an accuracy of 0.1 mm.
- Stopwatch was used for the time taken in hours.
- Pressure gauges used instruments to measure and display pressure mechanically.
- A tachometer was an instrument used to measure the rotation speed of a shaft or disk.
- Flow meters are devices used to measure the rate of fluid flow in a system.

Manufacturer specification of diesel engine-operated water pump in both districts:

- Type of pump or model by 3" (HM80KB13-4(3"))
- Pressure capability or head=25
- Power output=6hp
- Flow rate or discharge=12-16l/s
- Number of motor Pump=HM2208008468
- Motor efficiency=80

### **3.3.Types of Data Collection**

Both primary and secondary data were gathered in order to successfully complete the inquiry and provide the necessary data. By reading documents and taking notes, secondary data were gathered from the internet, agencies, offices, and literature. Key informants, focus group discussants, and structured questionnaires were used to gather primary data from the chosen sample respondents. A structured questionnaire, interviews, focus groups, field observations, and direct communication with agricultural officers from the Tarmaber and Kewet districts, the SNV directorate, the AGP directorate, the irrigation and lowland office directorate, and GIZ directorate were used to gather information about the adoption and efficacy of diesel engine-operated water pumps in the research area. The fuel consumption, water flow rate, pressure head power consumption, and net positive suction head (NPSH) are among the field data.

### 3.4. Research Design

A cross-sectional study methodology was used to analyze the current management system, identify barriers to the adoption of water pumps, and determine how effective the water pump was in reaching the targeted locations. Both primary and secondary sources of data were employed in the investigation. The original, raw, and unprocessed data can be found in the pertinent primary sources. Documents contained the pertinent secondary data that was gathered. From February 2023 to November 2024, a survey on the general performance and condition of water pumps was carried out in two districts within the North Shewa Zones. Primary data were gathered using a structured questionnaire on a subset of farmers who responded. The questions focused on various aspects related to the uptake and efficacy of water pumps, including topography, awareness, skill levels, maintenance expenses, and the availability of spare parts. Additionally, a physical inspection was conducted of the water pump's current operations and the irrigation and lowland area development office's records for the targeted district.

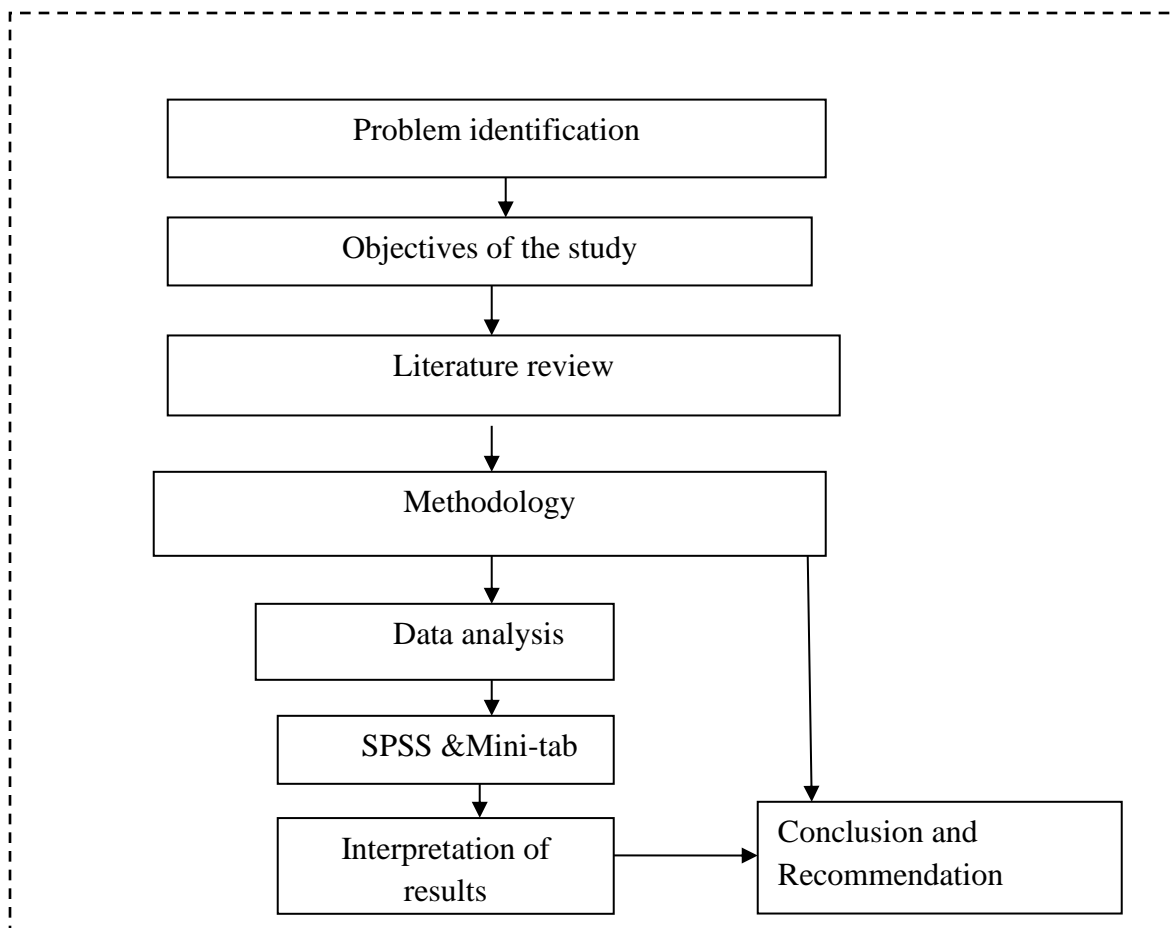


Figure 3. 2. Work flow

### 3.5. Calculating the Sample Size

A single population proportion calculation was used in this study to determine the sample size (Cochran, 1977).

$$n = Z(\alpha/2)^2 P (1-P)/d^2 \dots \dots \dots (3.1)$$

Where: n = the amount of the sample that needs to be calculated

$Z(\alpha/2) = 1.96$  is the standard normal deviation, which matches the 95% confidence interval.

$p = 50\%$  (0.5) is the estimated percentage in a population.

$d$  = the sampling error percentage between the population and the sample is 5% (0.05).

So, to calculate sample size;  $n = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.05)^2}$

$$n = 384$$

When we increase the non-response rate by 10%, we obtain  $n = 384 (1+0.1) = 422$ .

Based on the number of kebeles with operational water pumps, a proportionate sampling technique was used at the district level to determine the sample size. Every kebele received an equal share of the necessary sample sizes at the kebele level. Three hundred out of the overall sample size had a water pump. The sample size detail distribution is expressed in Table 3.1, which is shown below.

$$\text{Amount of responses at the kebele} = \frac{\text{Total Number of respondents}}{\text{Total number of kebeles}} \dots \dots \dots (3.2)$$

$$\text{No of respondents at kebele} = \frac{420}{20} = 21$$

Equation 1. Calculating the sample size at the kebele level

$$\text{No of respondents at district} = \text{No of kebeles} \times \text{No of respondents at kebele} \dots \dots \dots (3.3)$$

Table 3.1. Distribution of sample sizes in selected districts

Districts	No of kebele in the districts	No of respondent in each kebele	The total No of respondent
Tarmaber	10	21	210
Kewet	10	21	210
Total	20	42	420

### 3.6. Sampling Technique

The multi-phase sampling technique was used. The Amhara region's zones served as the main sampling units. of the 11 zones, one, North Shewa, was chosen using a purposive sampling strategy in accordance with the availability of water pumps powered by diesel engines. Second, using the purposive sampling technique, a total of two districts Kewet and Tarmaber wereda in the North Shewa Zone were chosen based on the district's availability of a water pump. Ten kebeles each from the Tarmaber and Kewet districts were chosen for the third sample unit using a purposive sampling technique, taking into account the presence of a working water pump in each kebele. As shown in figure 3.3 below, the necessary sample sizes were then distributed evenly among the chosen kebeles that have a working water pump.

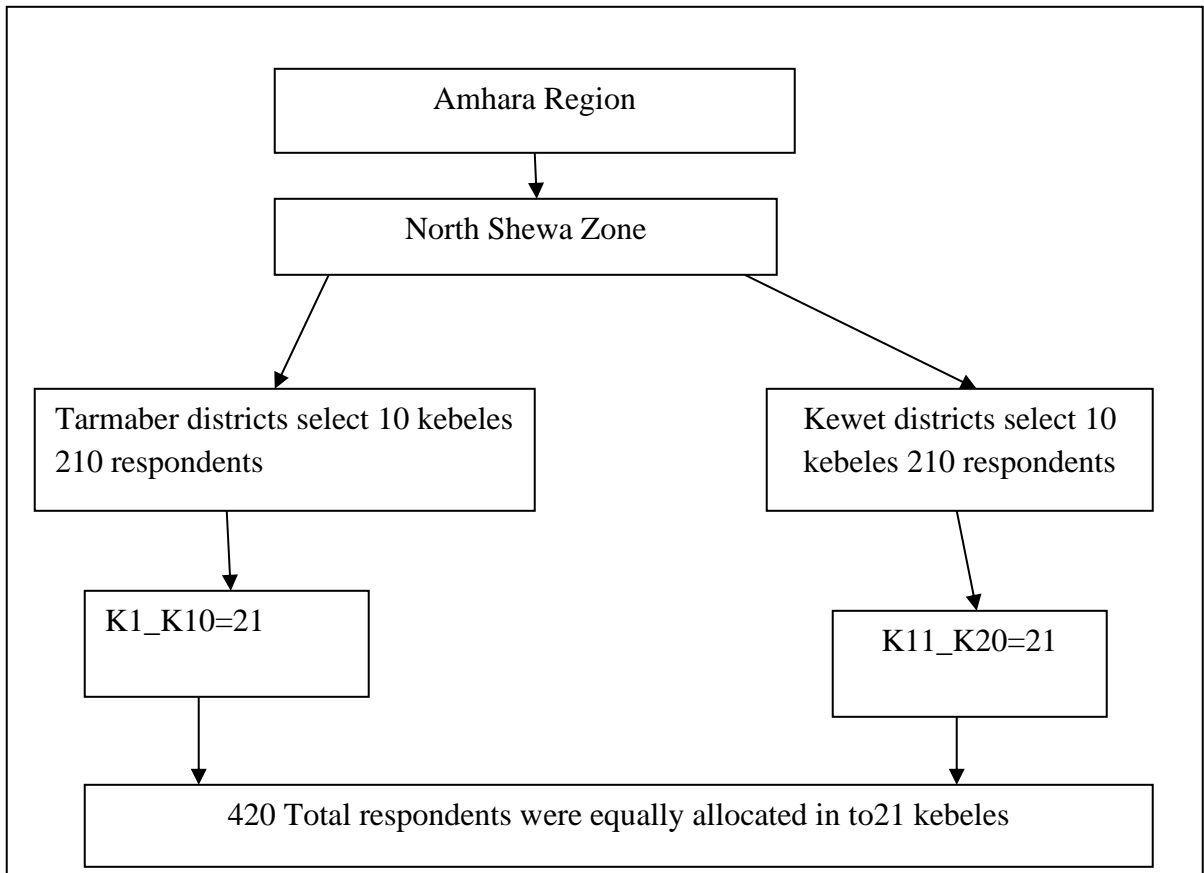


Figure 3.3. The proportionate and equal distribution of sample sizes.

### 3.7. Performance Investigation of Diesel Water Pumping System

A test and experimental performance evaluation of the diesel pumping systems has been conducted at the farmer's site of targeted districts. The analysis was carried out using the Minitab software packages. A split-plot design test was run to evaluate the difference between the

variable treatments at a 5% level of significance if the treatment effects were determined to be significant. The experiment was conducted through nine head levels: H1 = 23.4 m, H2 = 22.905m, H3 = 22.4195 m, H4 = 20.9445 m, H5=19.4795, H6=17.5215, H7=14.5785, H8=10.647 and H9=2.2245. The experimental design was a split-mode design (sub divided into main-factors and sub-factors). The interest is to see the main parameter effects on the performance of diesel water pumping systems.

#### A. Test procedure

There are two steps involved in evaluating your pump's performance. Determining the amount of fuel required to pump one megaliter of water is the first step. The volume of water pumped and the amount of fuel utilized are the necessary pieces of information. It is then easy to compute the cost of pumping if you are aware of your fuel charges. The calculation of the pump's efficiency is the second step. The total dynamic head and fuel usage are the necessary data for this. The efficiency can then be tentatively computed and contrasted with the specs provided by the manufacturer (Smith, 2004).

##### Step 1: Measure the fuel used

A particularly precise estimate of fuel consumption can only be obtained by measuring the amount of fuel used during irrigation. If you have fuel flow meters, you may calculate this using the readings from the meters. If not, it can be accomplished by obtaining dipstick readings both before and after irrigating, or by starting with a full gasoline tank and calculating how much is needed to refill the tank after irrigating.

##### Dipstick reading

- Start time (T1)
- First dipstick reading (F1)
- Finish time (T2)
- Second dipstick reading (F2)

From this data you can calculate the fuel used per hour.

$$\text{Fuel Consumption} = \frac{(F1-F2)}{(T2-T1)}$$

##### Step 2: Measure the flow rate (Q)

The flow rate of your irrigation system (Q) is the volume or quantity of water pumped in a certain time – for example, litres per second (L/s), litres per hour (L/h).

Step 3: Calculate the fuel per megalitre pumped

Step 4: Calculate the pumping cost

To calculate the variable cost of pumping, you need to know the cost per litre of diesel.

Step 5: Determining Total Head

i. Measure the Discharge (or Delivery) Head

When the system is working at full pressure, this is the pressure that is read from the gauge installed at the pump. It is necessary to convert this reading to comparable meters of head.

TIP: A pressure gauge is typically fitted on new pumps, but physical damage to them frequently occurs quickly. Installing an access point on the pump's supply side allows you to temporarily install a pressure gauge whenever you need to take a reading, and this is a better approach. It is simple to remove the gauge when it is not in use.

ii. Suction Head

The distance, plus losses in the suction pipe if the pump is positioned above the water level, between the pump's center line and the source water level is known as the suction head.

B. Performance data sheet

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Shaft speed RPM	Shaft torque Kg-m	Pump power KW	input head M	Total head M	Discharge L/s	Watt power KW	Pump efficiency %
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### 3.8. Variables and Data Field Observations of Pump Installations

A. Independent variables

- Head, it was the main factor considered during the performance evaluation of diesel operated water pumping system. Based on the manufacturer's design, the maximum vertical head of the HAOMAX pump was limited to 25m.
- Time, all the variables such as flow rate, ambient temperature, efficiencies, and irrigation demand were dynamically varied with time (Hartung & Pluschke, 2018).

B. Dependent variables

Data collection of dependent variables was applied through selected samples of four level heads and time from each experimental unit. Variables observed were:

- Pump-input power,
- Flow rate,
- Pump efficiency and
- System efficiency.

### 3.9. Adoption of Water Pumps

#### A. Dependent variable

- Adoption of Motor pump

#### B. Independent variables

- Household head's gender
- Household head age (years)
- Adult household member (number)
- Educated household member (number)
- Training
- Access to extension, Access to credit
- The Household has a market network
- Farm size (ha)
- Land tenure
- Availability of surface water
- Availability of groundwater

### 3.10. Economic Analysis of Solar and Diesel Pumping Systems

For this cost analysis, it needs to achieve an economic evaluation and compare solar PV with the existing diesel pumping system technology for a feasibility study. The comparison is accompanied in terms of initial cost, life cycle cost, energy cost, and corresponding profitability per-determined volume of water. During an economic evaluation, the following approximate values have been taken from the real field-testing results and the purchased importers. The costs of a pumping system having a certain life in years is the sum of all capital, operating, maintenance, and replacement costs. This method was used to access the total cost facility of ownership. It will need to consider all the costs of acquiring, possessing, and placing a system. In this research, we will need to implement LCC for the diesel engine pump and for the best alternative PV pump system, which gives the total cost of both, including all expenses over the life period of the systems.

The life-cycle cost can be calculated using the equation According to(Oehlert, 2010).

**The Capital Cost (CC)** of a project includes the initial capital expense for equipment, system design, engineering, and installation.

**The Maintenance Cost (MC)** is the sum of all yearly operation and maintenance (O&M) costs discounted to the present. Maintenance cost through the life cycle is calculated using the following equation:

$$MC = A \left[ \frac{(i + 1)^N - 1}{i * (i + 1)^N} \right] \dots \dots \dots (3.4)$$

**The Energy Cost (EC)** of a system is the sum of the yearly fuel cost. Therefore, differential fuel inflation rates may be used. Fuel cost through the lifetime of the system is calculated using this equation:

$$EC = A * \left[ \left( \frac{1 + FE}{i + FE} \right) * \left( 1 - \left( \frac{1 - FE}{1 + i} \right)^N \right) \right] \dots \dots \dots (3.5)$$

Where FE is the fuel escalation rate

This equation belongs only to the diesel engine life cycle cost of fuel. Because there is no energy cost considered in the case of the PV system.

**The Replacement Cost (RC)** is the sum of all equipment that will need to be replaced throughout the life of the system. The pump for the PV water pumping system is assumed to be replaced after 10 years and all components of the diesel pumping system also have to be replaced after 10 years. The total replacement cost through the lifetime is calculated using this equation:

$$RC = F * \left[ \frac{1}{(i + 1)^N} \right] \dots \dots \dots (3.6)$$

Where F is the future worth of money

**The Salvage Value (SC)** of a system is its net worth in the final year of the life-cycle period. The salvage value through the lifetime is calculated using the following equation:

$$SC = F * \left[ \frac{1}{(i - 1)^N} \right] \dots \dots \dots (3.7)$$

### **3.11. Data Analysis**

IBM SPSS Statistic 22 stores the dependent and independent variables to help calculate the factors influencing the adoption of diesel-engine-operated water pumps. Minitab was a data analysis software packages that is used data analysis. Minitab provides users with tools to perform statistical analysis, including hypothesis testing, regression analysis, and ANOVA. Some of the procedures used to test the validity of the data collection tool included closely monitoring data in crew and quality assurance, employing additional data collectors to reduce bias, screening the collected data for any unfilled questionnaires, appropriately putting the collected data on data probing software, such as MS Excel, and verifying the validity and consistency testing of the data collection tool.

The descriptive statistical design method was used for the number of water pumps in each district, the interests of farmers in small engine machinery, the purpose of crop production, the distribution of water pumps in targeted districts, the status of water pumps, the cost of water pumps, and ways of affordability of water pumps by using tables, charts, and graphs. In order to assess the efficiency of water pumps, a one-way ANOVA was utilized to examine the dependent variables flow rate, pump efficiency, speed, and output power with independent parameters like head. A 95% confidence interval was employed as an extra mechanism in one-way ANOVA to indicate the presence of a statistically significant difference, while a p value less than 0.05 was utilized in all other analyses as the threshold for statistical significance.

## 4. RESULT AND DISCUSSION

### 4.1. Diesel Engine-Operated Water Pump Status in Kewet and Tarmaber

#### 4.1.1. Farmers' motivations for using a water pump

Diesel-powered water pumps piqued the interest of farmers in both targeted districts, some of whom had been sharing water pumps. Farmers were eager to use water pumps if they could obtain rental service, but the Tarmaber district has a surface water source, so there wasn't an adequate supply of water pumps available for rental. A tiny portion of farmers had little interest in buying water pumps for various reasons. Some were unaware of the expense and the lack of awareness, while others were untrained. According to the data collected in the targeted districts, 4% (N = 15) were not interested in water pumps, 35% (N = 133) were interested, and 61% (N = 232) were highly interested, (Figure 4.1). Increasing farmer interest in water pumps and assisting with their upkeep and operation should be the shared duty of all stake-holders. The government, as the main stakeholder, was accountable for supporting companies, providing financing alternatives, and increasing awareness regarding water pumps that run on diesel engines. On the other hand, the business is in charge of making it possible for replacement parts and repair facilities to be delivered to farmers' homes.

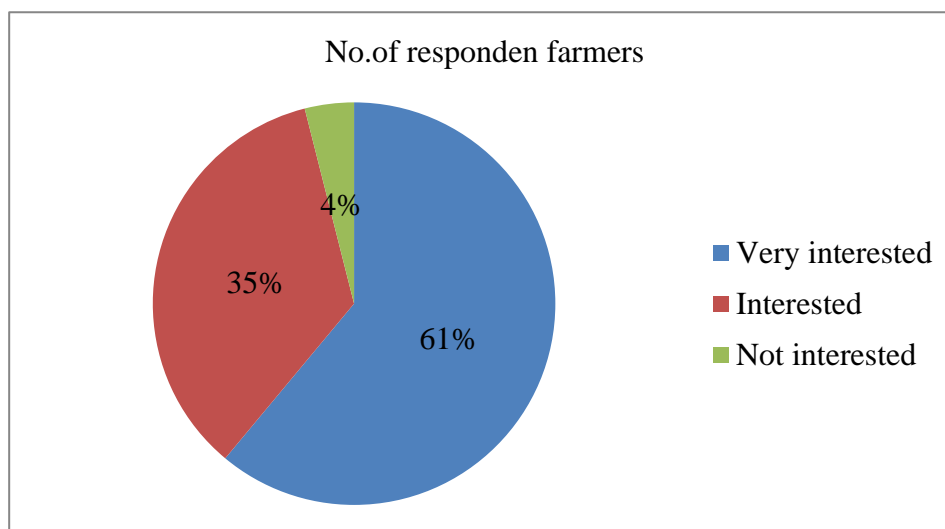


Figure 4.1. Percentage of farmers' motivations for using water pump

#### 4.1.2. Crop production in irrigable lands

The types of crops grown under irrigation in the Tarmaber district, North Shoa Zone include corn, wheat, onions, beans, barley and teff (Figure 4.2). Under the same zone in Kewet districts,

the types of crops grown are onion, teff, sorghum, mung-bean, mango, cabbage, papaya, tobacco and so on. The outcomes of interviews made with the farmers in the targeted districts, and questionnaires were that the farmers produced red onion, teff, wheat, sorghum, tobacco, maize, and other products described in 30% (N = 114), 25% (N = 95), 19% (N = 72), 11% (N = 42), 6.5% (N = 25), 5.5% (N = 21), 3% (N = 11), respectively. Other products include mango, banana, papaya, tomato, Mung-bean, and cabbage.

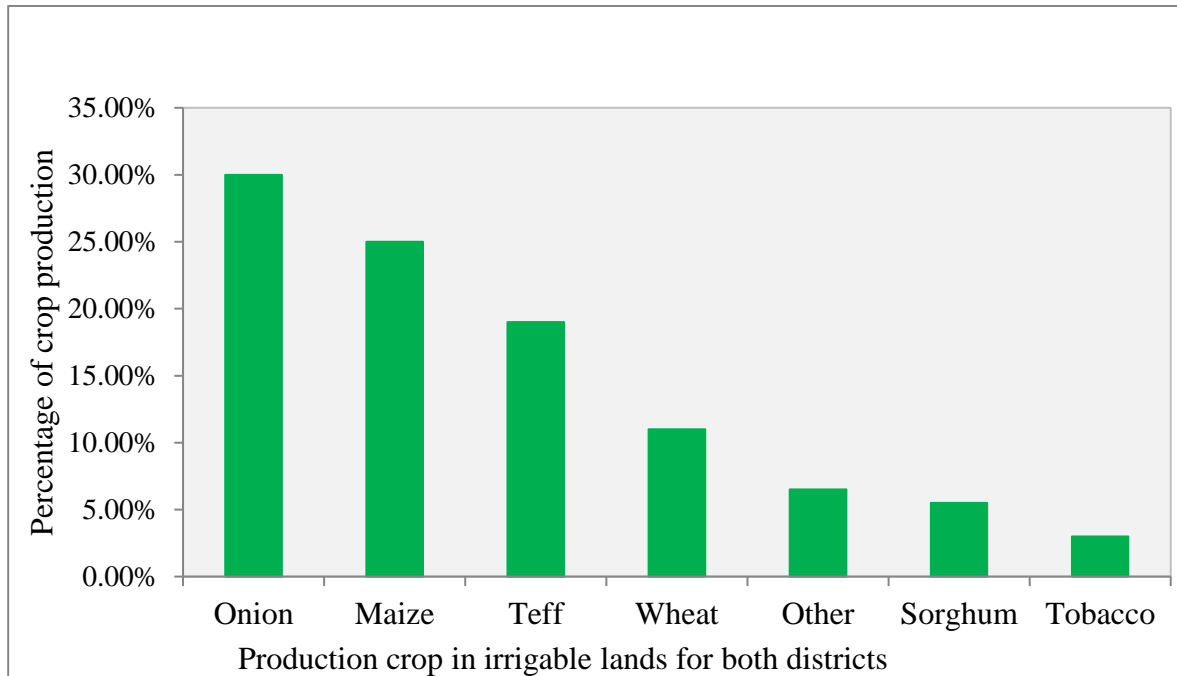


Figure 4.2. Crop production in irrigable lands

#### 4.1.3. The goal of producing crops

The majority of farmers in the targeted districts had between two and seven family members and between 0.25 and 3 hectares of irrigated land, according to their responses. While some farmers were provided properties by contract with permission, the majority of farmers in both areas stated that they farmed on their irrigated lands. All targeted areas' respondent farmers plant the crop, on average, for food (9%; N = 34), for food and market (76%; N = 289), and for market only (15%) (Figure 4.3). Because water pumps were not used much in the research area, only a few food crops were produced.

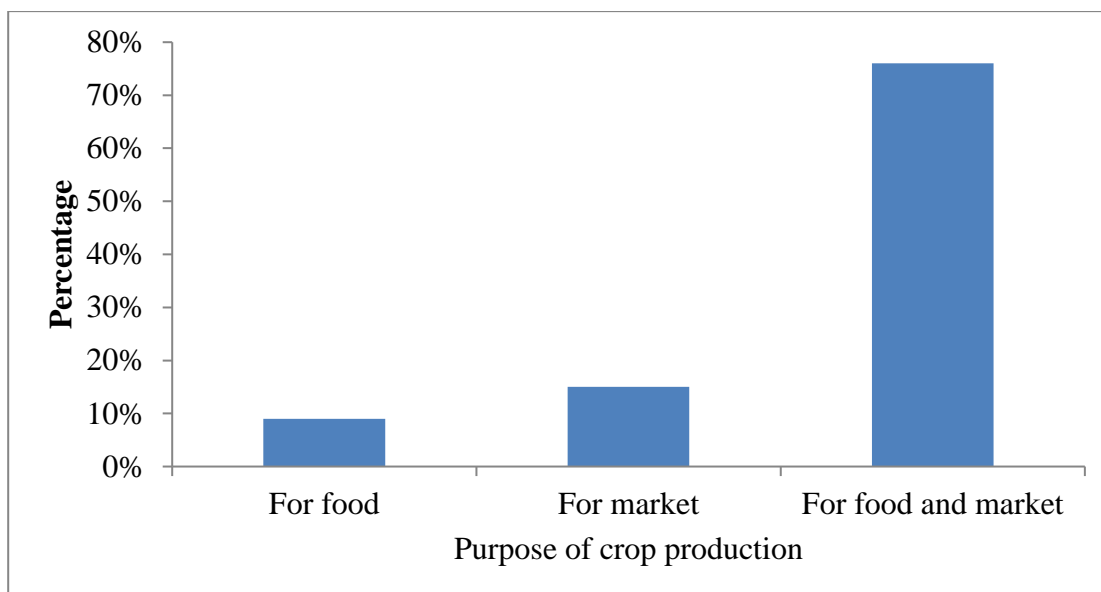


Figure 4.3. The percentage that goes into producing crops

#### 4.1.4. Water pump count in the designated districts

The total quantity of water pumps in each of the two districts under study, Tarmaber and Kewet was 84 and 585, respectively, depending on the district's irrigation and lowland area development office data on the distribution of water pumps.

Table 4.1. Number of water pumps for irrigation

Kewet Districts			Tarmaber Districts		
Kebeles	Functionality	Non functionality	Kebeles	Functionality	Non-functionality
Yelen	204	51	Mafud	2	3
Tere	123	43	Armaniya	8	2
Jimdere	64	12	Adoke	2	1
Birbira	58	11	Agamber	6	-
Alelo	11	4	Dokakit	4	2
Ayaber	3	1	Yta	16	3
Wefkele	2	1	Quash	2	-

Worasie and Qolomaya	2	1	Asfachewu	16	4
Menegist and Wodaji	3	1	Wanzaberet	3	3

#### 4.1.5. Water pump distribution in the designated districts

In the districts that were targeted, the water pumps were dispersed in various ways. The Lowland Development Office (MoIL) and the Ministry of Irrigation held one distribution method. Different organizations and projects work on small-scale irrigation development including SNV, AGP, and GIZ. They import the water pumps and distribute them to the users in two different ways: by giving them freely as a promotion and by facilitating credit opportunities. MoIL gave 300 water pumps to Kewet districts, and 200 farmers bought them with their own money. GIZ gave 50 water pumps for Kewut and 6 water pumps for Tarmaber district. SNV gave 20 water pumps for Kewet and 5 for Tarmaber districts. AGP gave 15 diesel engine-operated water pumps for the Kewet district and 9 for the Tarmaber district'. The Ministry of Irrigation and Lowland Area Development Office gave 50 water pumps to Tarmaber districts, and the 14 users directly purchased them from different importers.

The targets districts' lowland and irrigation offices provided the aforementioned data.

Table 4.2. Distribution of diesel engine operated water pumps in both districts

Years	Distribution in numbers	
	Kewet districts	Tarmaber districts
2010/2011	48	5
2011/2012	85	8
2012/2013	110	9
2013/2014	125	18
2014/2015	217	44

#### 4.1.6. Status of diesel engine-operated water pumps in targeted districts

The number of functional water pumps was 460 and 62 in the Kewet and Tarmaber districts, respectively, whereas the number of non-functional water pumps in the Kewet and Tarmaber districts was 125 and 22, respectively. Lack of training, inadequate infrastructure in governmental and non-governmental small-scale irrigation development institutions to support the users, a lack of technical staff, water pump parts failing quickly, a lack of spare parts, and a lack of maintenance services were the main causes of the non-functioning water pumps in all districts. Generally, by considering the total water pumps in two targeted districts, 22% were not functional and 78% were functional.

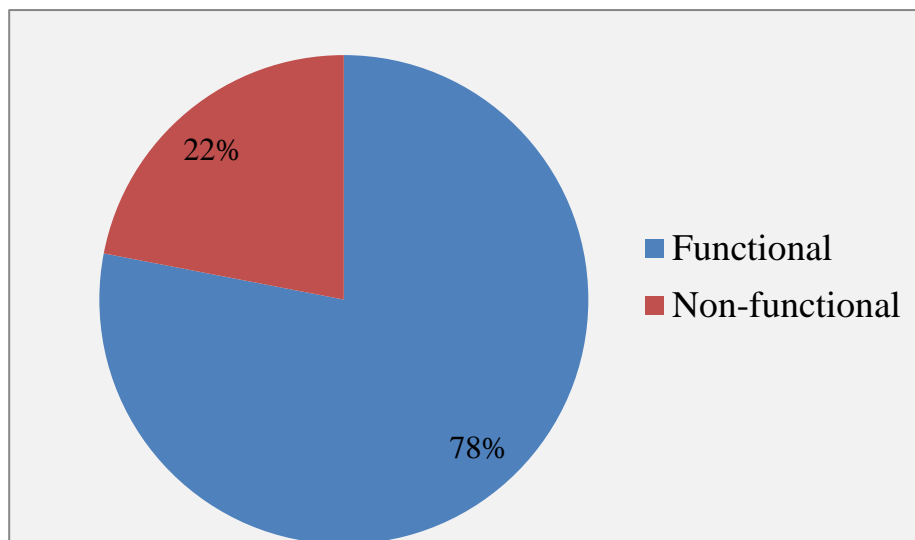


Figure 4.4. Functional and non-functional of water pumps

#### 4.1.7. Key operations performed by diesel engine operated water pump

Irrigation, water supply, and drainage are the most often carried out tasks in the targeted districts by farmers who use water pumps and by those who use water pumps with diesel engines (Figure 4.5). In contrast to the Tarmaber-targeted districts, the Kewet district's farmers currently have a favorable attitude toward water pumps and prefer them to conventional irrigation methods.

In comparison to the previous traditional watering system, the users of functional water pumps in the two targeted districts reported several benefits, including decreased time, increased productivity, decreased labor during irrigation activities, income generated from rental services,

and avoided carousel during the watering system. Due to the advantages, the users of diesel engine-operated water pumps accept the technology. Depending on each respondent's water pump users 71.428%, 23.8%, and 4.76% are used for irrigation, water supply, and drainage, respectively.

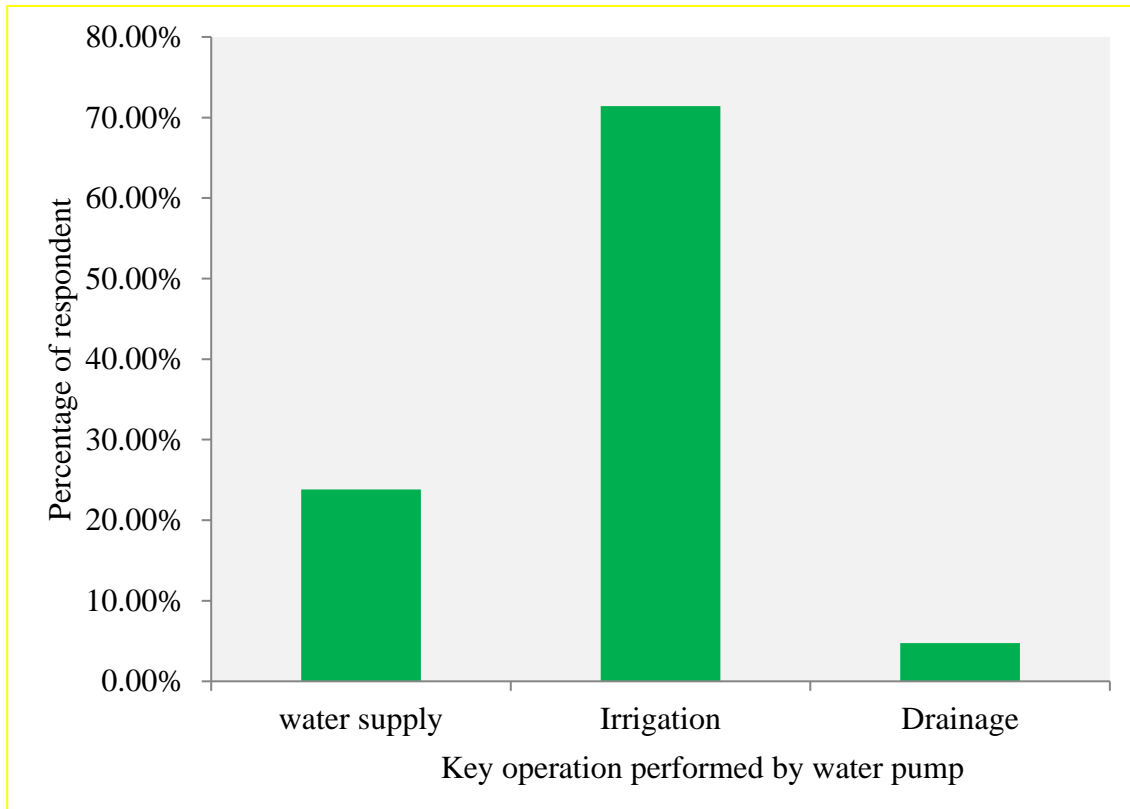


Figure 4.5. percentage of various tasks carried out by a water pump

#### 4.1.8. Water source and availability

Water for the Tarmaber district was primarily obtained from surface water sources, such as rivers and community ponds. There are three types of natural water: rain water, surface water, and ground water. The most accessible of the three types is surface water. Sources of surface water include ponds, rivers, lakes, streams, and canals (Bwire *et al.*, 2020). The above data may be analyzed using a variety of comparisons and computations. Here are some steps to follow:

- Compare Irrigation Potential: In this case, Kerkeha has the highest potential with 160 hectares, followed by Awadi with 140 hectares. Bret mitad, Mehal mesk, and Teterwuha have the lowest potential with 40, 40, and 78 hectares, respectively.

- Compare Arable Land: Awadi has the highest arable land with 450 hectares, followed by Robit debresina with 90 hectares. Setatit has the lowest arable land with 28 hectares, followed by Bret mitad with 30 hectares.
- Calculate the Irrigation-to-Arable-Land Ratio: Setatit, the irrigation-to-arable-land ratio would be  $60/28 = 2.14$ .

Table 4.3. Rivers that can be used for irrigation and their potential in Tarmaber districts.

S\no	The name of the river	Potential for irrigation in hectares (ha).	Arable land in ha.	Irrigation-to-Arable-Land Ratio
1.	Setatit	60	28	2.142857
2.	Robit debresina	90	90	1
3.	Awadi	140	450	0.311111
4.	Bret mitad	40	30	1.333333
5.	Mehal mesk	40	20	2
6.	Kerkeha	160	120	1.333333
7.	Teterwuha	78	50	1.56

In areas with limited surface water, groundwater is the primary supply of water utilized for agricultural and industrial purposes as well as human use. In this traditionally agricultural nation, about 40% of the farmland is irrigated by groundwater (Li *et al.*, 2013).

Table 4. 4. Rivers that can be used for irrigation and their potential in the Kewut district.

S\no	The name of the river	Potential for irrigation in hectares.	Arable land in ha.	Irrigation-to-Arable-Land Ratio
1.	Sewur	298	400	0.745
2.	Ashmaq	248.76	200	1.2438
3.	Gashabekndie	52	100	0.52

4.	Gunfata	194	300	0.647
5.	Jewuha	332	500	0.664
6.	Tkurwuha	182	200	0.91

#### 4.2. Effectiveness of Agricultural Water Pump

Evaluating the effectiveness of diesel engine-operated water pumps involves assessing their performance, efficiency, and reliability. Here are some steps they can follow to evaluate their effectiveness. The assessment standards for water pumps by identifying the critical elements that support the performance of water pumps powered by diesel engines. These criteria may include pump flow rate, pressure capability, fuel consumption, reliability, maintenance requirements, and environmental impact.

Table 4. 5. Manufacturer specification of HAOMAX diesel engine operated water pump

Pump	Model	WD30XB (80KB13-4)	WD40X(100KB16- 6)
	Inlet/outlet	80(3")	100(4")
		50	96
Capability	Max.capa(m <sup>3</sup> /hr)		
	Cont.capa(m <sup>3</sup> /hr)	36	64
Head		25	31
	Max.head(m)		
	Cont.head(m)	13	16
	Engine speed(rpm)	366	3600
	Self-priming time(s/4m)	120	180
	Max.suction head(m)	8	8
Engine	Model	HM178F	HM186F
Unit	Dry weight(kg)	52	69
	Dimension(L*W*H) (mm)	590*445*525	640*480*600

Manufacturer specification of diesel engine-operated water pump in both districts:

- Type of pump or model by 3" (HM80KB13-4(3"))
- Pressure capability or head=25
- Power output=6hp

- Flow rate or discharge=12-16l/s
- Number of motor Pump=HM2208008468
- Motor efficiency=80%

During Agricultural water pump operation, the following readings are measured from a diesel engine-operated water pump used for irrigation purposes:

- The flow rate of the pump (in cubic meters per second) =0.015
- The pumping fluid's density (water: 1000 kg/m<sup>3</sup>)
- Acceleration due to gravity (9.8m/s<sup>2</sup>)
- Head developed by the pump (Delivery head-suction head) =24m
- Measured motor power = 4.5kw
- Power input to pump shaft = 4.5kw×0.8=3.6kw

$$\text{Efficiency of the pump} = \frac{\text{Hydraulic power } Ph(KW)}{\text{Power input to pump shaft}} \times 100$$

Power input to pump shaft = Motor input power

$$\text{Hydraulic power } Ph (KW) = \frac{\text{Flow rate} \times \text{Density} \times \text{Acc. due to gravity} \times \text{Total head}}{1000}$$

$$Ph = \frac{0.015 \times 1000 \times 9.81 \times 24}{1000}$$

$$Ph = 3.5316kw$$

$$\text{Efficiency} = \frac{3.5316}{4.5} = 78.48\%$$

In this finding to evaluate the effectiveness of diesel engine-operated water pumps, a key factor should be measured and the efficiency of actual and manufacturer specifications should decrease by 1.52% due to the lack of technical experts, spare part availability, clogging, and mechanical wear and tear. Finally, compare the actual performance with the manufacturer's specifications to assess its effectiveness in delivering the desired water flow and pressure. Each of the engine speed, the hydraulic efficiency first increases as the pump flow rate increase, then reaches a maximum value; finally decrease as the pump flow rate increase. Regular maintenance, proper sizing, monitoring operating conditions, and addressing mechanical issues promptly can help maintain and improve the efficiency of a water pump.

#### 4.2.1. Effect of head-on different dependent variables

The working head affects the performance of diesel engine-operated water pumping systems significantly. Different total heads have been selected during testing and analysis purposes (2.2245m-23.4m). As mentioned in Table 4.20. below using ANOVA system analysis. Visualize the best-fit equation and correlation between the effects of head-on flow rate, pump efficiency, and power. The p-value represents the strength of the evidence against the null hypothesis in a statistical hypothesis test. In most statistical tests, a p-value of 0.000 means that the observed data is highly statistically significant, providing strong evidence to reject the null hypothesis in favor of the alternative hypothesis.

Table 4.6. One-way ANOVA analysis of effectiveness of water pump

Source	DF	SS	MS	F-value	P-value
Factor	4	60783229	15195807	19976.73	0.000
Error	40	30427	761		
Total	44	60813656			

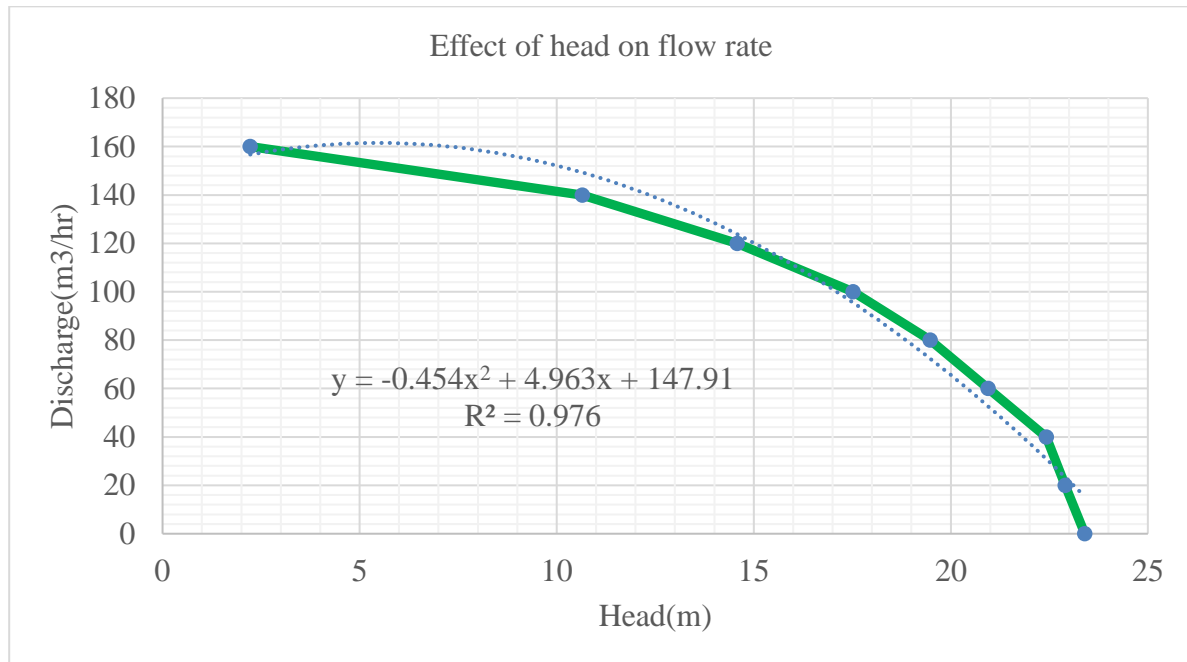


Figure 4.6. Regression effect of head on flow rate.

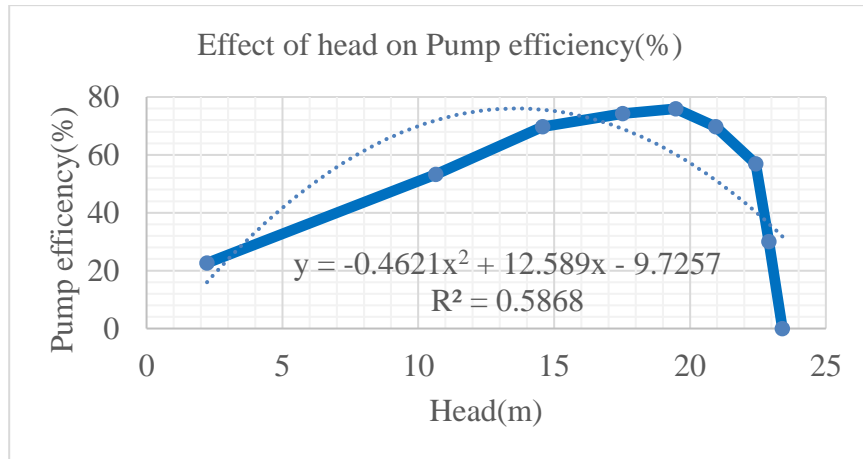


Figure 4.7. Regression effect of head on pump efficiency

An R-squared value of 0.5868 means that approximately 58.68% of the variation in the dependent variable can be explained by the independent variable(s) in the regression model. The remaining 41.32% of the variation is unexplained and may be due to other factors or random variation. Generally, higher R-squared values indicate a better fit of the regression model to the data, suggesting that the independent variable(s) have a stronger relationship with the dependent variable.

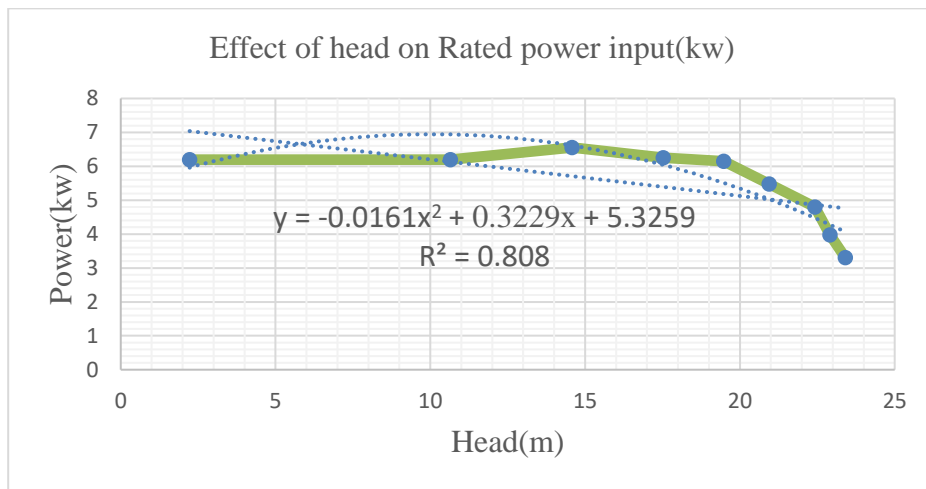


Figure 4. 8. Regression effects of head-on rated power input.

As shown in above Figure 4.8, the relationship between different total head levels and other variables is that as the head level increases from 2.2245m to 23.4m, all the pump efficiency and total system efficiency have decreased linearly, with a highly significant effect of  $P < 0.05$  and

$R^2 = 1$ . The percentage contribution of the coefficient correlation was above 0.9, or 90%, which means a high degree of effect.

#### 4.2.2. Water pump performance curve

A diesel engine-operated water pump performance curve was a graphical representation that shows the relationship between the pump's performance characteristics and its operating conditions. It provides valuable information about how the pump was perform under different flow rates and head conditions.

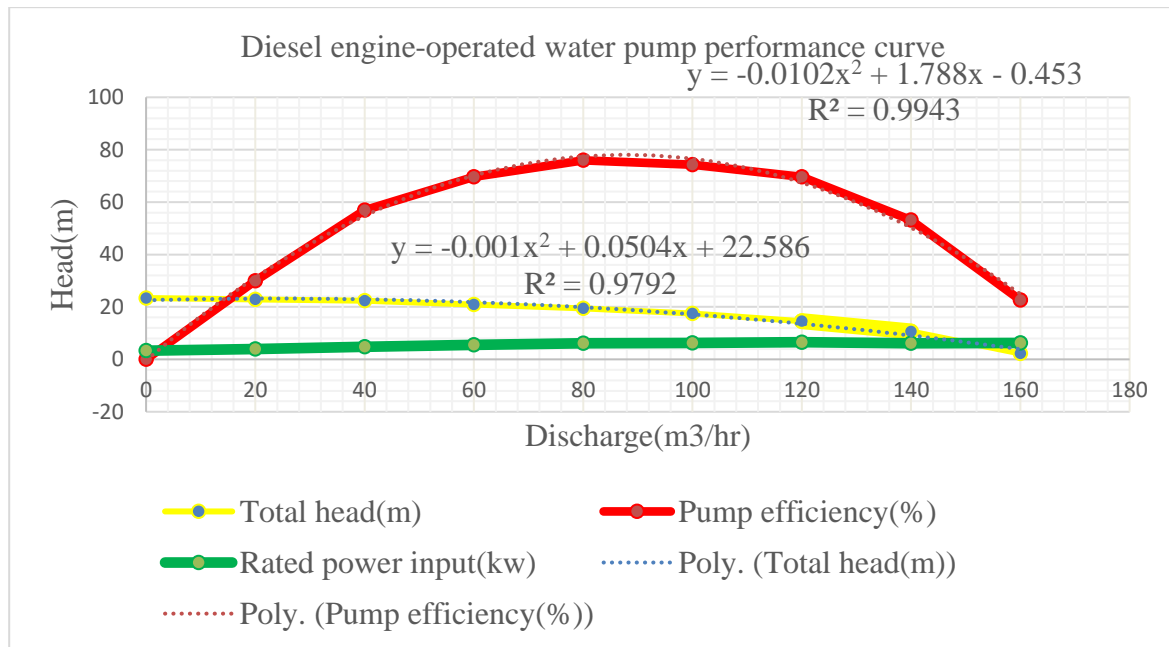


Figure 4.9. Water pump performance curve

From the above Figure 4.9, the efficiency of water pumps initially increases when they reach their maximum point and then decreases with increasing flow rates. In the second power or energy curve, it can also be seen that with the increase in head and flow rate, power consumption also increases. This is like when a pump has to do more work; it needs more power. In the third curve head, the relationship between the head and flow rate in a water performance curve for a pump is typically inverse. As the flow rate increases, the pressure head generated by the pump decreases, and vice versa. Generally, when looking at the above figure 4.8. the relationships indicate that as the flow rate increases, the pressure head generated by the pump decreases, and the power required by the pump increases. Conversely, as the flow rate decreases, the head increases, and the power requirement decreases.

### 4.3. Adoption of Diesel Engine-Operated Water Pump

Diesel water pumps are widely used in agricultural applications for irrigation purposes. They can efficiently pump large volumes of water over long distances, making them suitable for irrigating fields and crops. Some points help promote the adoption of diesel-engine-operated water pumps and the factors that influence this technology.

Table 4. 7. Adoption water pump: univariate and multivariate logistic regression analysis.

Variable	Adoption		COR	AOR	P-value
	Yes	No	95%CI	95%CI	
Education level					
Illiterate	19	180	RF	RF	
Adult education	32	130	2.332(1.266-4.295)	2.292(1.002-5.245) *	0.049
Above primary school	53	6	83.684(31.800-220.225)	42.303(10.744-166.556) ***	0.000
Irrigable Land size					
<0.5ha	5	96	RF	RF	
<0.5-1ha	58	151	7.375(2.856-19.044)	3.595(0.787-16.411)	0.099
>1ha	41	69	11.409(4.288-30.356)	6.430(1.311-31.528) *	0.022
Water pump training					
Yes					
No	17	2	30.678(6.594-135.345)	17.223(1.725-171.928) *	0.015
	87	314	RF	RF	
Affordable					
Yes	56	28	12.000(6.945-20.736)	2.539(1.060-6.080) *	0.037
No	48	288	RF	RF	
Reasonable cost					
Strongly disagree	14	198	RF	RF	

Disagree	10	97	1.458(0.625-3.401)	.487(0.157-1.517)	0.215
Agree	54	19	40.195(18.929-85.355)	9.425(3.659-24.276) ***	0.000
Strongly agree	26	2	183.857(39.535-855.02)	14.857(2.122-104.034) **	0.007
Farmers use WP by rent					
Yes	76	102	5.695(3.477-9.326)	3.537(1.439-8.690) **	0.006
No	28	214	RF	RF	

NB: -\* statistically significant variables at  $p < 0.05$ , \*\* statistically significant variables at  $p < 0.01$ , \*\*\* statistically significant variables at  $p < 0.001$ , Hosmer and Lemeshow test 0.913, RF=references

A binary logistic regression analysis was conducted both in univariable and multivariable aspects to identify the relationship between factors that affect the adoption of diesel engine-operated water pumps. Following the control of other variables, the association of various independent variables with the adoption of water pumps was observed. Factors like the education status of respondents, land size, training related to water pumps, rental service by water pump, affordable cost for diesel engine operated water pumps, and reasonable cost for diesel engine operated water pumps have had a statistically substantial link to variable outcome (adoption) (Table 4.7).

The level of education was significantly related to willingness to adopt diesel engine operated water pump, where participants who had primary and above education levels were forty-two or more times (AOR=42.303, 95% CI: (10.744-166.556)), more likely to adopt water pump than the illiterates as well as participants who had adult education were two and more times (AOR=2.292, 95% CI: (1.002-5.245)), more likely to adopt water pump than illiterates.

Another factor Irrigable land size was significantly associated with adopting water pumps, participants who have a land size of greater than half hectares were six times more likely to adopt water pumps than those who have less than one hectare of land (AOR= 6.430, 95% CI: (1.311-31.528)).

Respondents who gained training about water pumps were seventeen or more times (AOR =17.223, 95% CI :( 1.725-171.928)), more likely and have more interest in adopting water pumps than respondents who didn't gain training. Different governmental and non-governmental organizations who are responsible for irrigation technology give training to farmers before purchasing water pumps and create motivation for farmers to adopt water pumps. They didn't get the training they assumed the operation of the water pump was very difficult and also didn't have interest in adopting diesel engine operated water pumps.

Participants who used a water pump through a rental service were three more times to adopt a water pump than those who didn't use a water pump by renting at (AOR= 3.537, 95% CI: (1.439-8.690)). The farmers who use water pumps through rental service know the different advantages of water pumps and have a high interest in adopting diesel engine operated water pumps but the farmers who didn't use water pumps by renting do not know the advantages of water pumps. Irrigation professionals take home work from federal up to kebele levels on awareness creation about diesel engine-operated water pumps.

Participants who would afford the price of water pumps were two and more times more likely to adopt water pumps than those who could not afford at (AOR =2.539, 95 % CI:(1.060-6.080)). The government works with different small engine irrigation technology importers to reduce the cost of water pumps by encouraging the importers to import water pumps tax-free and the government controls importers to sale water pumps at acceptable costs and facilitate credit service for farmers.

Participants who strongly agree on the reasonable cost of the water pump were fourteen or more times (AOR=14.857, (95% CI: (2.122-104.034)) more likely to adopt water pump than those who strongly disagree with the reasonable cost of the water pump whereas Participants who agree on the reasonable cost of the diesel engine operated water pump were nine and more times (AOR=9.425, 95% CI:(3.659-24.276)) more likely to adopt water pump than those who strongly disagree.

The affordability of water pumps was one of the major factors influencing farmers' adoption of this technology. The majority of respondents claimed that the cost was extremely high in the districts that were being targeted. The respondents said the cost was cheap, affordable, expensive, and very expensive with percentages of 5% (N = 19), 10% (N = 38), 25% (N = 95),

and 60% (N = 228) respectively (figure 4.10). This result indicates that minimizing diesel engine-operated water pump costs leads to changing the traditional watering system to small-scale irrigation development and appreciates the use of irrigation technology.

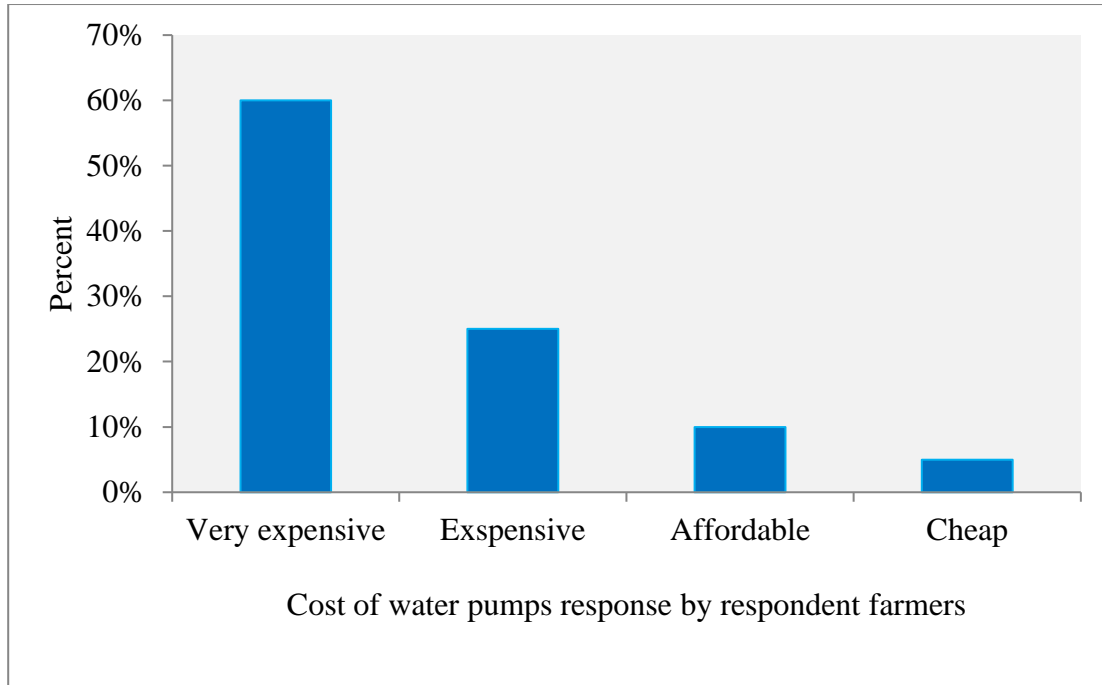


Figure 4. 10. Cost of water pumps expressed by respondent farmers

The challenge in developing irrigation technology was figuring out how to make diesel-powered water pumps more affordable. According to the responses of the respondents, which are displayed in Figure 4.10 below, in order to pay for the cost of water pumps, 15% (N = 57) were purchased by the group, 60% (N = 228) were purchased on credit, and the remaining 25% (N = 95) were acquired using a mix of both credit and group.

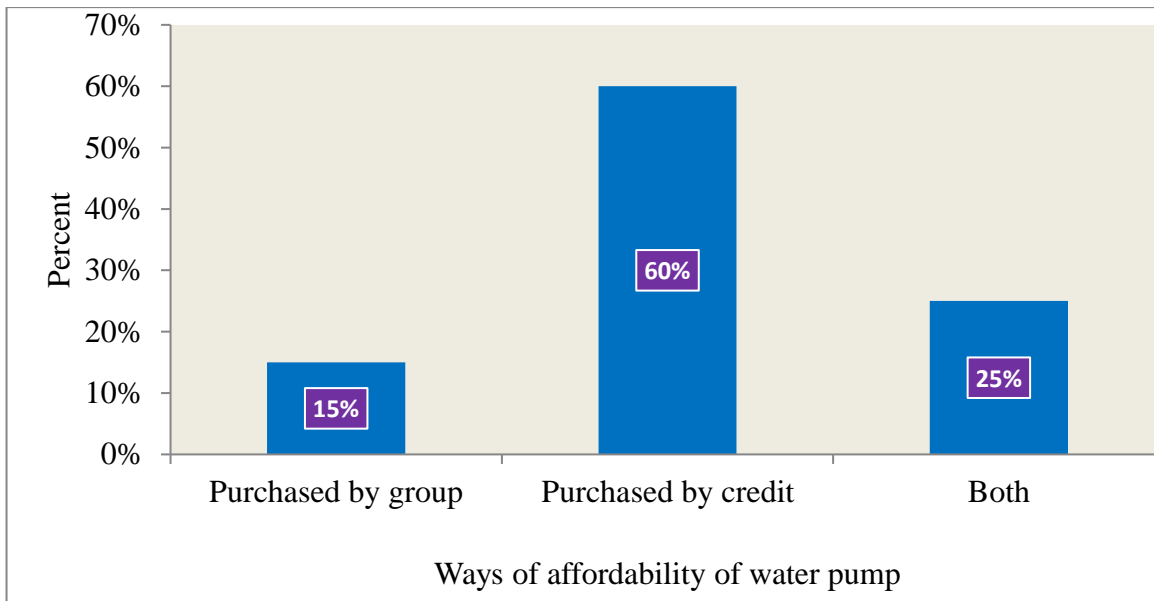


Figure 4. 11. Methods for bringing down the price of water pumps

The adoption of water pumps was also significantly impacted by the lack of maintenance and spare parts. Because it directly relates to users, the frequency table was created using their responses. Every user indicated that there was no maintenance or spare part service available in their area. Although some of the responding farmers who can afford the expense of water pumps and have big tracts of land expressed a strong desire to adopt water pumps, they also mentioned the lack of maintenance services and spare parts in the area. Although some respondents indicated there was no provider of water pumps with diesel engines in the targeted area, they nevertheless expressed a strong interest in adopting water pumps.

In order to fulfill their obligations, the Ministry of Irrigation and Lowland Development Office Directorate, along with various irrigation organizations, work to address the various issues preventing the widespread use of water pumps powered by diesel engines and to provide farmers with the means to implement small-scale irrigation. Because some users of water pumps claim not to have been able to find spares on the market, importers of water pumps also import spare parts for water pumps. In general, focus group participants said that the following factors contributed to the adoption of diesel engine-operated water pumps in both of the targeted districts:

- A general lack of knowledge about the water pump
- Inadequate spare part availability and maintenance;

- Insufficient expertise in small engine machinery;
- Lack of dedication to the agriculture industry; and
- The price of a water pump

Relationship between diesel engine operated water pump adoption and finance availability

A business needs capital to get off the ground and stay that way, whether it is agricultural or not. Credit is a vital institutional function that enables poor farmers to purchase supplies and eventually adopt new technology. However, only a small percentage of farmers have access to loans, and most participants did not have enough money for irrigation. The respondents' concerns about getting credit were brought on by a variety of situations. The percentages for water pumps with diesel engines that operate on low credit services, high interest rates, bureaucracy, and lack of collateral

Table 4.8. Government regulations and incentives for water pump sale price

Detailed description	scale	
	Di ese l(3 ")	Del ive ry hose (3")
The price of one	N o. 33042	102
Total price	33042	5100
Hand-to-Hand Selling Price (40%)		
commission (5%)		
Total hand-to-hand sales price		
One year loan sales rate (45%)		
commission (5%)		
Total one-year loan sales price		
Two-year loan sale price (50%)		
commission (5%)		
Total two-year loan sales price (50%)		
Three-year loan sales rate (55%)		
commission (5%)		
Total three-year loan sales price (55%)		
Four-year loan sales price (60%)		
commission (5%)		
Total four-year loan sales price		
Five-year loan sales price (65%)		
commission (5%)		
Total five-year loan sales price (65%)		

Suction hose (3")	m	490	3920																		
Total			42062	16824.80	841.24	17666.04	18927.90	946.40	19874.30	21031	1051.55	22082.55	23134.10	1156.71	24290.81	25237.20	1261.89	26499.06	27340.30	1367.02	28707.32

#### 4.3.1. Maintenance and repairs

The lack of maintenance and spare part services in the surrounding area was another factor in the adoption of the diesel engine-operated water pump in all targeted districts. This has a significant effect on water pump adoption. Table 4.9 findings indicated that 100% of diesel engine-operated water pump customers had no maintenance or spare part servicing.

Table 4.9. Maintenance and spare part frequencies

Variables	Frequencies (%)	
	No (%)	Yes(%)
Availability of maintenance services in the user's area	100	0
Spare part availability around the user's area	100	0

When a diesel engine-powered water pump breaks down, its customers can bring in a mechanic from Debrebrhan or visit Debrebrhan for maintenance and spare component servicing. This procedure takes a lengthy time and is directly related to irrigation technology's delay. Users of water pumps in all targeted districts also faced the issue of being largely ignorant of the tiny engine machines' maintenance and operation schedules.

In general, the respondent said during the group discussion that the following were the primary reasons why diesel engine-operated water pumps were effective in the targeted areas:

- Lack of maintenance services
- Insufficient availability of replacement parts
- Lack of training related to diesel engine-operated water pump
- The failure of water pump components cannot be fixed by a technical specialist.

- Specifically, district agricultural extension personnel paid no attention to water pump users powered by diesel engines.

#### 4.3.2. Income assessment

An assessment was conducted to find out how respondents and adopters felt and whether growing different crops, fruits, and vegetables with water pumps improved their revenue. 95.5% of the adopters' income increased, according to the assessment, while 4.5% did not. The reason why their income did not increase was due to: -

- There was some reduction in the cost of irrigation supplies.
- The water pump's fuel costs increased.
- There wasn't enough land for irrigation

Field crops, fruits and vegetables, tobacco, mung beans, tuber crops (potato, tomato, and onion), and off-farm activities accounted for the difference in revenue.

Table 4.10. Annual income of diesel engine-operated water pump user

End of Year(Y)	Annual/ Cash Flows (CF)	Cumulative Cash Flows (CCF)
0	77,101	
1	21,000	21,000
2	32,000	53,000
3	38,000	91,000
4	43,000	134,000
5	48,000	192,000

$$PBP = X_1 + \frac{(cost-y_1)}{y_2-y_1} (X_2 - X_1)$$

$$PBP = 1 + \frac{77101-21000}{53000-21000}(2-1) = 2.753 \text{ Years}$$

The rate of investment (RoI) or payback period of the initial capital was 2.753 years.

#### 4.4. Ways of Water Pump Handling

According to the interview, handling a water pump properly was crucial for its efficient operation and longevity (Figure 4.12). The respondents of each district irrigation experts help the farmers with some key ways to handle a water pump: -

- Read the manufacturer's instructions and interpret the local language.

- Proper storage and transportation:
- Installation:
- Check for blockages:
- Regular maintenance:
- Shutdown procedure:

The diesel engine-operated water pump is handled in the safest condition. When asked the respondent farmers to be the users of the water pump to make the shelter in both districts. An advantage that made the shelter of diesel engine-operated water pumps to prevent: -

- From rain
- From the sun
- From the thief
- From the wind.

Transporting systems of diesel engine-operated water pumps from the field to the shade are cart, mule, labor force, and car expressed in percentage below figure 4.12.

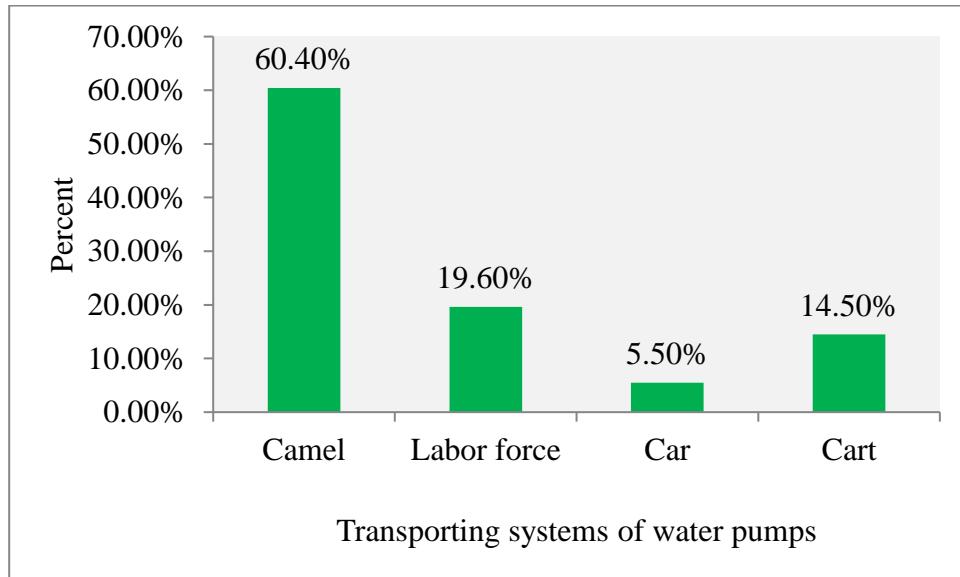


Figure 4. 12. Transporting systems of water pumps from the field to the shade

## **4.5. Economic Analysis**

A thorough cost analysis of the system's overall cost and an estimation of the system's yearly and monthly costs based on its projected service lifetime are required in order to assess the system's economic viability.

### **4.5.1. Economic comparison for solar and diesel pumping systems**

This analysis needs to achieve an economic evaluation and compare solar PV with the existing diesel pumping system technology for a feasibility study. The comparison is accompanied in terms of initial cost, life cycle cost, energy cost, and corresponding profitability per-determined volume of water. During economic evaluation, the following approximate values have been taken from the real field-testing results and the purchased importers. The costs of a pumping system have a certain lifetime in years and are the sum of all capital, operating, maintenance, and replacement costs. This method was used to access the total cost facility of ownership. It will need to consider all the costs of acquiring, possessing, and placing a system. In this research, we will need to implement LCC for the diesel engine pump and for the best alternative PV pump system, which gives the total cost of both, including all expenses over the life period of the systems.

This will make for two main reasons:

- 1) To evaluate various power options; and
- 2) To identify the most economical system design

### **4.5.2. Life cycle cost analysis of the system**

Analyzing a project's life cycle costs allows you to assess its financial performance. LCCA strikes a compromise between the system's initial financial outlay and ongoing operating and ownership costs. This is a way of determining the overall cost of facility ownership. MS Excel was used to calculate the life cycle costs study, which includes all system acquisition, ownership, and disposal costs. In this study, adopting LCCA for the current system (a diesel-driven pump) and the alternative that is being evaluated for replacement (a PV pump system) yields the total cost of both, including all expenses incurred over the systems' life cycles. The source of power has a considerable impact on the life-cycle cost of any water pumping equipment. Aside from the sun, which provides free energy, diesel is more expensive. Diesel fuel costs account for around 85% of total LCCs for DWPs (Figure 4.12), making the system costly in the long run of

the project unless initial investment costs and additional costs incurred during operation are relatively low (Nasir, 2016). The life-cycle cost of both alternatives listed in this project can be determined using the following formula:

The life-cycle cost can be calculated using the equation According to (Oehlert, 2010).

$$LCC = CC + MC + EC + RC - SC \dots \dots \dots (4.1)$$

Where, CC= Capital Cost

MC= Maintenance Cost

EC= Energy Cost

RC=Replacement Cost

SC=Salvage Cost

#### 4.5.3. Economic assessments for solar and diesel pump systems

The system's economic assessments were examined using a physical test, wherein the system's initial capital cost and life cycle expenses were compared to those of the diesel pumping system. The following major assumed considered factors have to be needed for an optimum cost analysis of the PVWP system using (Narale et al., 2013), and (G. Amare & Gebremedhin, 2020):

- The operating life of the diesel pump and solar pump has been considered 20 years and 10 years respectively.
- It is estimated that the annual maintenance costs for the PV system will be 0.1% of the total capital cost.
- For a diesel generator, the maintenance expense is estimated to be 10% of the initial cost.
- Five percent of the PV system's original purchase price is its salvage value.
- It is considered that the annual maintenance cost of a diesel engine is equivalent to 10% of the total capital cost.
- The salvage value of the diesel engine was assumed to be 20% of the capital cost of the engine and it is replaced every 10 years.

Specifically, in the assessment for the DWP system and the economic analysis, real information was gathered from the end users/ farmer's field. The 6.0 hp power diesel pump was tested for every 4 operating hours per day and its initial total cost with its component was birr 42062. From the field-testing result, the diesel pump has a capacity of fuel consumption of diesel pump

has been 0.8 lit/hr. By considering after three days of maximum irrigation schedule, the annual fuel cost can be determined using

$$AFC = \text{Specific fuel consumption} \times \text{Fuel Rate} \times \text{total operating} \frac{\text{hr}}{\text{year}}$$

$$= 0.8 \text{ liter/hr.} \times (4 \text{ hr/day} \times 360 \text{ day/year}) \times 70 \text{ birr/liter} = 80640 \text{ birr/year}$$

AFC-Annual Fuel Cost and the current price of diesel fuel in Ethiopia is 70birr/liter.

Diesel generator fuel consumed for 20 years ETB 1612800.

The total investment cost of the solar PV pumping system was:

PV module cost, including power cables and hoses with 15 % tax= birr 84000 Pump and controller cost with 15% tax=23000

Table 4.11. System cost comparison using LCCA

Sr.No.	Costs (ETB)	Solar PV system	Diesel engine (4")	Diesel engine (3")
1.	Capital cost	117,780	77,101	42,062
2.	Maintenance cost	2,332.04	154,202	84,124
3.	Fuel/energy cost	None	1,612,800	1,612,800
4.	Replacement cost	46,000	154,202	84,124
5.	Total cost	166,112.04	1,998,375	1,823,110
	Salvage cost	5,889	15,420.2	8,412.4
	Life Cycle Cost (LCC)	118,823.04	1,844,102.8	1,814,697.6

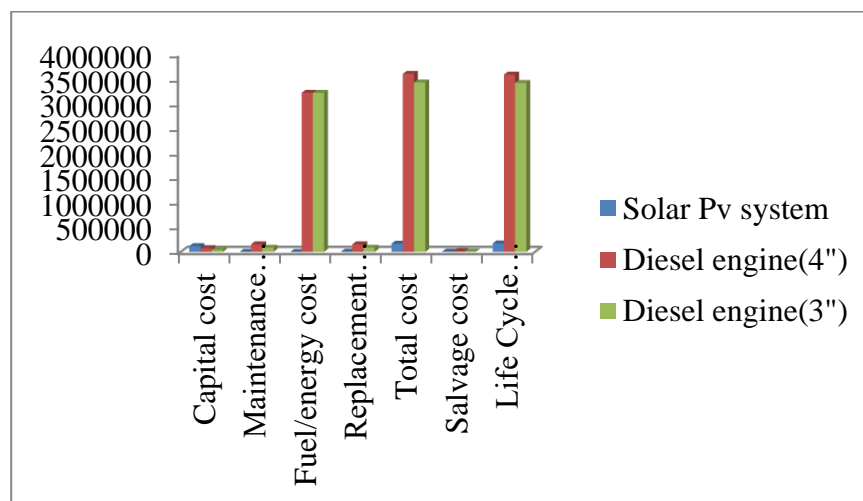


Figure 4.13. Comparisons of the present values of different costs.

As shown in the above Figure 4.13 solar PV water pumping systems have a higher initial investment cost than diesel pumping systems. Other than the capital cost, the PV system's other costs (maintenance, operation, and replacement) were significantly lower than those of the diesel pumping system. Additionally, there is no energy cost needed for the solar PV system, and as a result, the PV system is more reliable and has an expected long-term useful life. The above bar chart shows the maximum value of the energy cost of a diesel pump, and currently, fuel demand is increasing all over the world, as well as in Ethiopia. It will keep going up gradually and will have a much higher total cost as compared with the PV system. From the results above, 88.87% of the life cycle cost for DWPs was fuel cost, and this shows that the system cost in the long run for the project is due to energy cost, unless the initial and other costs during operation were very low. The total cost for both systems throughout their 20-year life cycle has been shown in Figure 4.14.

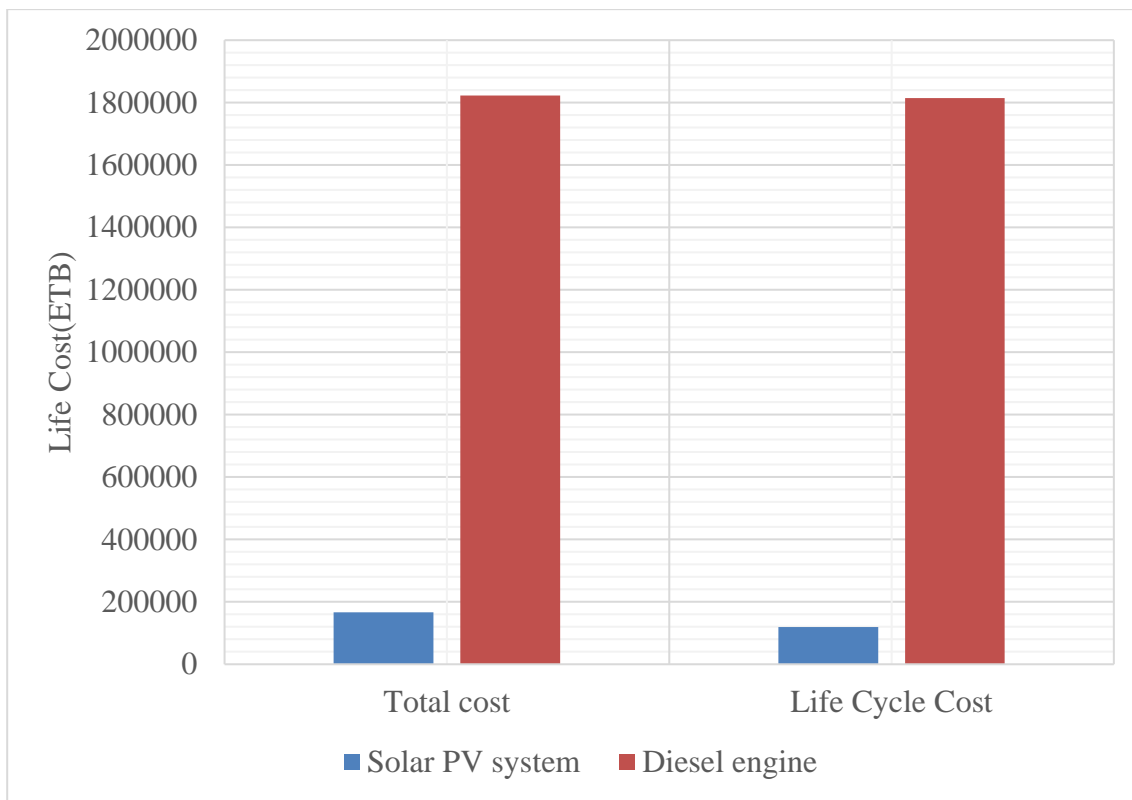


Figure 4.14. Total cost and life cycle cost of SPV and DP systems of 20 years

## 5. CONCLUSIONS AND RECOMMENDATION

### 5.1. Conclusions

This research work presents an evaluation of adoption and effectiveness of diesel engine-operated water pumps in the North Shewa Zone, Amhara Region, with two targeted districts, Tarmaber and Kewut. To assess the effectiveness of these pumps, several key factors were measured, and it was found by 1.52% compared to the manufacturer specification. This decrease can be attributed to factors such as the lack of technical experts, limited spare part availability, clogging, and mechanical wear and tear. Field data was collected at different heads to record flow rates, output power, and pump efficiency. The performance curve of the diesel engine-operated water pump showed that as the flow rate increased, the pressure head generated by the pump decreased, while the power required by the pump increased. The efficiency of the water pump initially increased to its maximum point before gradually decreasing.

The correlation between the head and different dependent variables was found to be high effect, with an  $R^2 = 0.9$ . In the economic analysis, the fuel cost of diesel engine-operated water pumps for 20 years period was evaluated. It was found that fuel cost accounted 88.87% of the life cycle cost for DWPs, and the fuel consumption of ETB1612800 was also examined. A comparative analysis between diesel water pumping systems and solar PV was conducted, considering investment and life cycle cost analyses. The result showed that solar PV water pumping systems were more cost-effective than diesel pumping systems for long-term services, particularly in using small-scale farmers. The rate of investment (RoI) or payback period of the initial capital was 2.75 years.

Factors such as limited training, lack of spare parts, and maintenance can affect the adoption and effectiveness of diesel engine-operated water pumps. Respondents who got training on diesel water pumps were more than 20 times more likely to adopt water pumps as well as effectively use them compared to those without training. Therefore, providing accessible training to farmers is crucial for familiarizing them with and effectively utilizing irrigation technologies. The availability of spare parts and maintenance services in proximity to the districts also enhances the evaluation of the adoption and effectiveness of diesel engine-operated water pumps. Other factors, including education level, land size, and the cost of water pumps, can hinder the adoption process. Participants with adult education, as well as primary and higher education levels, had a better chance of adopting water pumps compared to illiterates. This

highlights the importance of educated individuals supporting farmers in adopting water pumps. Additionally, participants with a land size greater than one hectare were seven times more likely to adopt water pumps compared to those with less than half a hectare of land.

## **5.2. Recommendations**

The following suggestions are made in light of the study's limitations and recommendations mentioned above:

- Planning long-term user education regarding water pumps.
- Encouraging consumers nearby to use replacement parts and maintenance services to extend the life of water pumps.
- To allow consumers access, importers should bring in extra parts in addition to the water pump.
- Various water pump importers create promotions on water pumps for farmers, open their outside services to the district level, and offer repair and maintenance services. Farmers can thus use water pumps efficiently and make purchases with cash or in installments.
- Importers of water pumps that have undergone testing and quality certification for diesel engine operation are bringing in water pumps that will enable farmers feel more confident and use them more frequently.
- Farmers can obtain financing without collateral from banks, marketing businesses, and other financial institutions powered by diesel engines. It is essential for the expansion of water pumps and the nation's water pump user base.

The efficiency of water pumps on farms that employ irrigation depends on the availability of farm roads and off-road pathways.

- Providing irrigation specialists to every district.
- Each district's lowland and irrigation offices ought to set up functional water pump management systems.
- The water pumps located in the Kewet district should have their performance evaluated before being replaced or given to the farmers.

The following recommendations are proposed for further investigation:

- More research needs to be done on the redesign of water pumps in the designated locations.

- Sizing applicable drip irrigation could be performed for better water savings and to improve quality.
- A smart irrigation system uses data recorders and a moisture sensor to automatically adjust water flow in addition to a solar-powered water pump.

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## APPENDIX

### Appendix 1. English version questioner for users

#### Part I. Socio-demographic information of farmers

Identification \_\_\_\_\_

Name of district: \_\_\_\_\_

Sex of respondent, 0. Female 1. Male

Age of respondent

Education status of respondent: 0. Illiterate 1. Adult education 2. Primary School 3. Secondary school 4. Diploma 5. Degree

Occupation of respondents 0. Farmer 1. Merchant 2. Others

Farming experience (Years): 0. <10years 1. 10-20 years 2. >20 years

Farming involvement: 0. No involvement 1. Part-time 2: Full-time,

How many people are in your family?

Does your family have access to education? 1. No 0. Yes

#### Part II. General information

1. What is the size of your irrigable land in a hectare?

2. What kind of crops are grown on your land that can be irrigated?

3. Why is a crop being produced? 0 for food 1. for the market 2. Both

4. Does your product have access to the market? 1. No 0. Yes

5. Have you ever heard about diesel engine-operated water pumps? 0. No 1. Yes

6. Where do you hear if you respond affirmatively to Question № 5? From a coworker, 0. From extension agents;2. From the media;3. From governments;4. From various projects

7. What is the primary function that the water pump typically performs?

#### Part III. Response on adoption of diesel engine-operated agricultural water pump

8. Is there any farmer in your village using a diesel engine-operated water pump? 0. No 1. Yes

9. Do you have a diesel engine-operated water pump? 0. No 1. Yes

10. If your answer is Yes for Question № 9, how many diesel engines operated agricultural water pumps do you have?

11. If your answer is No for Question № 9, why don't you purchase?

12. How do you get your diesel engine-operated water pump? 0. Own purchased 1. Donated

13. If you get a diesel engine-operated water pump by donation, who donates?  
0. MoIL 2. SNV 3. GIZ 4. AGP
14. Can you afford the cost of a water pump powered by a diesel engine? 0. No 1. Yes
15. If you answered "no" to Question №14, how was the price reasonable?  
0. Purchased by group 1. Purchased by credit 2. Both
16. What is the horsepower capacity of the water pump powered by your diesel engine?
17. Who operates the diesel engine-operated water pump? 0. Yourself 1. Operator
18. If you do not have a diesel engine-operated water pump, could you use it by rent?  
0. No 1. Yes
19. Is the amount you pay each month to rent a water pump that runs on a diesel engine for various uses reasonable? 0. No 1. Yes

Part IV. Response on effectiveness of agricultural water pump.

20. Would you list different activities carried out by diesel engine-operated water pumps?
21. Do you use your diesel engine-operated water pump for rent? 0. No 1. Yes
22. How many farmers used your diesel engine-operated water pump for rent?
23. Do you get training related to diesel engine-operated water pumps? 0. No 1. Yes
24. Where do you receive training if the answer to Question № 23 is yes?  
0. Dealers 1. Extension workers 2. Projects 3. All
25. Describe the level of difficulty of using a diesel engine-operated water pump.  
0. No difficulty 1. Low difficulty 2. Medium difficulty 3. High difficulty
26. What is the most common issue you run into while utilizing the water pump powered by a diesel engine?
27. How do you control the problem you face?
28. Does the village have a facility for fixing water pumps? 0. No 1. Yes
29. If your answer for Question № 29 is no, how many kilometers do you have to drive to get the water pump repaired?
30. Does the village have access to spare parts for the water pump powered by a diesel engine?  
0. No 1. Yes
32. If your answer for Question № 31 is no, how far do you have to go for the water pump spare part (km)

33. How do you transport the diesel engine-operated water pump from your home to the workplace or from one field to the other?

34. Do you prefer a diesel engine-operated water pump as compared to your previous trend?

0. No 1. Yes

35. The cost of a diesel engine-operated water pump is reasonable. 0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

36. Diesel engine-operated water pump can be used under different soil conditions.

0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

38. The operation of a diesel engine-operated water pump is simple.

0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

39. The dealer gives advice and training regarding the usage of diesel engine-operated water pump. 0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

40. The dealer gives maintenance service to the water pump near your area.

0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

41. I can maintain the diesel engine-operated water pump myself.

0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

42. Using a diesel engine-operated water pump is profitable.

0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

43. I recommend others to purchase diesel engine-operated water pump.

0. Strongly disagree 1. Disagree 2. Agree 3. Strongly agree

44. How many hours would it take you to irrigate one hectare of farmland with a water pump on sandy soil?

45. How many hours will it take you to irrigate one hectare of farmland with a water pump on black soil?

46. Have you made a shelter for a diesel-powered water pump motor pump?

0. We didn't work 1. Yes

47. If your answer to Question № 46 is yes, list the benefit of diesel-powered water pump diesel engine operated water pumps.

48. What does the built-in shelter protect the water pump motor from?

0. From the rain 1. From the sun 2. From the wind 3. From a thief 4. If there is another, please list it down

Appendix 2. Amharic version questioner for users

ክፍልአንድ፡ የተጠያቂው ግለሰብ ማህበራዊ እና ስነ-ህዘባዊ መረጃዎች መለያ ቁጥር

የሚኖሩበት ወረዳ

ጾታ

0. ሴት

1. ወንድ

እድሜ (በቁጥር ያስገቡ)

የትምህርት ደረጃዎት? 0. ያልተማረ 1. የጎልማሶች ትምህርት 2. የመጀመሪያ ደረጃ 3.

ሁለተኛ ደረጃ 4. ድፕሎማ 5. ድግሪ

የስራ ሁኔታዎት?

0. ገበሬ

1. ነጋዴ

2. ሌላ ካለ ይገለፅ

በግብርና የስራ ልምድዎት በአመት?

0. 0-10 አመት 1. ከ 10-20 አመት 2. ከ 20 አመት በላይ

በግብርና ስራ ላይ ያለዎት ተሳትፎ?

0. ምንም ተሳትፎ የለኝም 1. በከፊል እሳተፋለሁ 2. ሙሉ በሙሉ እሳተፋለሁ

የቤተሰብዎ ብዛት በቁጥር?

ለቤተሰብዎ በአቅራቢያ የትምህርት ተደረሽነት አለ?

0. የለም

1. አለ

ክፍል ሁለት፡ አጠቃላይ መረጃ

1. የእርሻ መሬት ስፋት በሄክታር?

2. በእርሻ ቦታዎ የሚያመርቱት ምርት

0. ጤፍ 1. ስንዴ 2. ማሽ 3. ሽንኩርት 4. ሁሉም 5. ሌላ ካለ ይገለፅ

3. የሚያመርቱትን ምርት ለምን አላማ ያመርታሉ?

0. ለምግብ ፍጆታ ብቻ 1. ለሽያጭ ብቻ 2. ለምግብና ለሽያጭ

4. ምርትዎትን የሚሸጡበት ገበያ በአካባቢዎት አለ

0. የለም

1. አለ

5. ስለ ወሃ መሳቢያ ፓምፕ ሰምተው ያውቃሉ? 0. አልሰማሁም

1. አወ

6. ለጥያቄ ቁጥር 6 መልስዎ አዎ ከሆነ ከየት ነው የሰሙት?

0. ከንደኛ

1.

ከግብርና ባለሙያ 2. ከመገናኛ ብዙሀን 3. ከመንግስት 4. ከተለያዩ ፕሮጀክቶች

7. በናፍጣ የሚሰራ ወሃ መሳቢያ ሞተር ምን ሊሰራ ይችላል?

8. በአካባቢዎ በናፍጣ የሚሰራ ወሃ መሳቢያ ሞተር የሚጠቀም አርሶ አደር አለ?

0. የለም

1. አዎ



26. በናፍጣ የሚሰራ ዉሃ መሳቢያ ሞተርን በተመለከት ስልጠና አግኝተው ያውቃሉ?

0. አላውቅም 1. አወ

27. በናፍጣ የሚሰራ ዉሃ መሳቢያ ሞተርን ስልጠና አግኝተው ከሆነ ስልጠናውን የሰጠዎት ማን ነው? 0. የዉሃ መሳቢያ ሞተር ሻጮች 1. የግብርና ባለሙያዎች 2. በአካባቢ የሚሰሩ ፕሮጀክቶች 3. ሁሉም አካላት

28. ዘመናዊ የዉሃ መሳቢያ ሞተሮች ባለመኖራቸው ምክንያት የመስኖ ስራ መስተጓጎል አጋጥሞዎት ያዉቃል ወይ? 0.አያዉቅም 1. ያዉቃል

29. ከሜዳማ ቦታዎች አንጻር በኮረብታማ ቦታዎች ምን ችግር ያጋጥመዎታል?

30. በናፍጣ የሚሰራ ዉሃ መሳቢያ ሞተርን ሲጠቀሙ የሚያጋጥመዎትን ችግር እንዴት ይገልፁታል?

0. ምንም አያጋጥመኝም 1. ትንሽ ችግር 2. መካከለኛ ችግር 3. ከፍተኛ ችግር

31. በናፍጣ የሚሰራ ዉሃ መሳቢያ ሞተርን ሲጠቀሙ በተደጋጋሚ የሚያጋጥመዎት ችግር ምንድን ነው?

32. የሚያጋጥመዎትን ችግር እንዴት ይፈቱታል?

33. በአካባቢዎ በናፍጣ የሚሰራ ዉሃ መሳቢያ ሞተርን የጥገና ማዕከል አለ?

0. የለም 1. አወ

34. በአካባቢዎ የጥገና ማዕከል ከሌለ ለማስጠገን ምን ያህል ይጓዛሉ?

35. በአካባቢዎ በናፍጣ የሚሰራ ዉሃ መሳቢያ ሞተር መለዋወጫ ዕቃ አለ?

0. የለም 1. አወ

36. በአካባቢዎ መለዋወጫ ዕቃ ከሌለ ለማምጣት ምን ያህል ይጓዛሉ?

37. የዉሃ መሳቢያ ሞተርን ከቤት ወደስራ ቦታ እና ከስራ ቦታ ወደ ሌላ የስራ ቦታ እንዴት ይወስዱታል?

38. የዉሃ መሳቢያ ሞተርን ከባህላዊ አጠጣጥ ዜዴ ይመርጡታል?

0. አልመርጠውም 1. አወ

39. በናፍጣ የሚሰራ የዉሃ መሳቢያ ሞተር ዋጋ ምክንያታዊ/ተመጣጣኝ ነው?

0. በፍፁም አልስማማም 1. አልስማማም 2. እስማማለሁ 3. ሙሉ በሙሉ እስማማለሁ

40. የዉሃ መሳቢያ ሞተርን በተለያዩ የአፈር አይነት ላይ መጠቀም ይቻላል?

0. በፍፁም አልስማማም 1. አልስማማም 2. እስማማለሁ 3. ሙሉ በሙሉ እስማማለሁ

41. በናፍጣ የሚሰራ ወ.ሃ መሳቢያ ሞተርን በተለያዩ የመሬት አቀማመጥ ላይ መጠቀም ይቻላል?

0. በፍፁም አልስማማም 1. አልስማማም 2. እስማማለሁ 3. ሙሉ በሙሉ እስማማለሁ

42. በናፍጣ የሚሰራ ወ.ሃ መሳቢያ ሞተርን አጠቃቀም ቀላል ነው? 0. በፍፁም አልስማማም 1. አልስማማም 2. እስማማለሁ 3. ሙሉ በሙሉ እስማማለሁ

43. የወ.ሃ መሳቢያ ሞተርን ሻጮች ስለአጠቃቀሙ ምክርና ስልጠና ይሰጣሉ? 0. በፍፁም አልስማማም 1. አልስማማም 2. እስማማለሁ 3. ሙሉ በሙሉ እስማማለሁ

44. የወ.ሃ መሳቢያ ሞተርን ሻጮች የጥገና አከልግሎት በአቅራቢያው ይሰጣሉ? 0. በፍፁም አልስማማም 1. አልስማማም 2. እስማማለሁ 3. ሙሉ በሙሉ እስማማለሁ

45. አንድ ሄክታር የእርሻ መሬት በወ.ሃ መሳቢያ ሞተር ለማጠጣት በአሸዋማ አፈር ላይ ስንት ሰአት ይፈጅበዎታል?

46. አንድ ሄክታር የእርሻ መሬት በወ.ሃ መሳቢያ ሞተር ለማጠጣት በ በጥቁር አፈር ላይ ስንት ሰአት ይፈጅበዎታል?

47. በናፈጣ የሚሰራ የወ.ሃ መሳቢያ ሞተር ፓምፕ መጠለያ ሰርታችሁለታል?

0. አልሰራንም 1. አዎ

48. የተሰራለት መጠለያ የወ.ሃ መሳቢያ ሞተር ፓምፕ የሚከላከለው ከምንድን ነው?

0. ከዝናብ 1. ከሙቀት 2. ከንፋስ 3. ከሌባ 4. ሌላ ካለ

ይግለጹ.....

Appendix 3. Questioner for targeted districts' irrigation and lowland bureau.

Personal information of respondent

Name: \_\_\_\_\_ Sex: \_\_\_\_\_ Age \_\_\_\_\_ Service \_\_\_\_\_ years

Academic level; Diploma \_\_\_\_\_ BA/B.Sc. \_\_\_\_\_ MA/M.Sc \_\_\_\_\_ PhD \_\_\_\_\_ Others \_\_\_\_\_

Responsibility: \_\_\_\_\_ Name of the institution \_\_\_\_\_

1. Which crops are cultivated most commonly in your district?
2. Does your district offer any opportunities for farmers to use various small engine machinery?

3. What perceptions did you have about farmers' attitudes on small-scale irrigation?
4. What is the state of small-scale irrigation in your district, in your opinion?
5. How might agricultural water pumps and other farm machinery be used to entice farmers to use them?
6. How do you encourage farmers who have diesel engine-operated water pumps for irrigation?
7. In your district, how many water pumps are there?
8. What role do you think farmers should play in using water pumps?
9. When it comes to traditional pumping systems that rely on human effort, how productive are farmers when they use water pumps?
10. Do you believe that your district's soil type directly affects water pumps?
11. Have you gathered issues from users of water pumps powered by diesel engines?  
If you answered "yes," enumerate the issues. \_\_\_\_\_  
\_\_\_\_\_.
12. Have you any information on the factors hindering the adoption of agricultural water pumps?  
\_\_\_\_\_  
\_\_\_\_\_.

Appendix 4. Questioner for water pump importers

Name: \_\_\_\_\_ Sex: \_\_\_\_\_ Age \_\_\_\_\_ Service \_\_\_\_\_  
 \_\_\_\_\_ years Academic level; Diploma \_\_\_\_\_ BA/B.Sc. \_\_\_\_\_  
 MA/M.Sc \_\_\_\_\_ PhD \_\_\_\_\_ Others \_\_\_\_\_  
 Responsibility of the respondent \_\_\_\_\_  
 Name of the institution \_\_\_\_\_

1. How many water pumps does your company import in total?
2. What varieties or models of water pumps do you import?
3. Which imported water pump model had the greatest sales?
4. Based on the brand and horsepower of each water pump you imported, could you kindly provide the price of each one?
5. Have you provided the consumers with a manual?

6. Have you instructed farmers on the use of water pumps?
7. Do you have a customer service center close to the farm area?
8. How many water pumps have been given to farmers overall?
9. How are the water pumps for the farms distributed?
10. How many farmers or end users now own agricultural water pumps?
11. If you respond in the affirmative to Question №10, could you kindly estimate the quantity?
12. Have you gathered issues from people who use water pumps?

\_\_\_\_\_

\_\_\_\_\_.

13. If your answer to Question № 12 is yes, please list down the problem.

\_\_\_\_\_

\_\_\_\_\_.

14. Which districts send you the majority of their problems?

Appendix 5. Questioners for irrigation and lowland development office directorate.

Personal information of respondent

Name \_\_\_\_\_ Sex; Male \_\_\_\_\_ Female \_\_\_\_\_ Age \_\_\_\_\_  
 \_\_\_\_\_ Service \_\_\_\_\_ years Academic level; Diploma \_\_\_\_\_  
 BA/BSc. \_\_\_\_\_ MA/M.Sc \_\_\_\_\_ PhD \_\_\_\_\_ Others \_\_\_\_\_

Responsibility of the respondent \_\_\_\_\_

Name of the institution \_\_\_\_\_

1. How much experience does the North Shewa Zone have with small-scale irrigation?  
 \_\_\_\_\_
2. What current plans do you have for zone-level small-scale irrigation development?  
 \_\_\_\_\_  
 \_\_\_\_\_.

3. Is the growth of small-scale irrigation supported by the sector you work in? If you say "yes," how can I help?  
 \_\_\_\_\_  
 \_\_\_\_\_.

3. How many water pumps does your industry import and distribute overall?

4. How many water pumps did you provide to the farmers in total?
5. How do you distribute water pumps and what are the criteria you used?
6. Do you know how many water pumps the farmers are using currently?
7. Have you given training for farmers on water pump operation?

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#### Appendix 6. Questioner for agricultural growth products

1. What area of small-scale irrigation development is your primary focus?
2. Do you have a program in place to give small-scale farmers access to small-engine machinery?
3. Do you have the nation's soil classifications?
4. How many water pumps does your organization import in total?
5. What kind of models of water pumps do you import? Could you help provide the price of water pumps according to their horsepower and model?
6. Which model of imported water pump saw the most sales?
7. How many water pumps did you provide to farmers in total?
8. How do you assign water pumps and what are the criteria you utilized to assign them?
9. How many farmers or end customers presently own water pumps powered by diesel engines?
10. Have you instructed farmers on how to operate water pumps?

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11. Have you gotten any feedback or issues from those who use water pumps?

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12. If your response is in the yes, kindly describe the issue along with the model, zone, and area from which you received the majority of the complaints.

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13. Do you have any publications on water pumps, such as books, journals, reviews, or videos?

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14. Has your center done any research on water pumps? If you said "yes," could you briefly list the main findings of the research?

Appendix 7. Key factor that contributes to the effectiveness of water pump

Discharge(m <sup>3</sup> /hr)	Total head(m)	Pump efficiency (%)	Rated power input(kw)	RPM
0	23.4000	0.00	3.310	2932
20	22.9050	29.98	3.975	2936
40	22.4195	56.89	4.800	2940
60	20.9445	69.67	5.480	2945
80	19.4795	75.93	6.150	2948
100	17.5215	74.29	6.250	2950
120	14.5785	69.69	6.555	2947
140	10.6470	53.20	6.195	2944
160	2.2245	22.58	6.200	2945

Appendix 8. SPSS analysis output

Univariable binary logistic regression analysis (crude odds ratio)

Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I forExp(B)	
							Lower	Upper
Education			80.945	2	.000			
Education(1)	.847	.312	7.381	1	.007	2.332	1.266	4.295
Education(2)	4.427	.494	80.415	1	.000	83.684	31.800	220.225
Constant	-2.249	.241	86.889	1	.000	.106		

Landsize			23.828	2	.000			
Landsize(1)	1.998	.484	17.041	1	.000	7.375	2.856	19.044
Landsize(2)	2.434	.499	23.771	1	.000	11.409	4.288	30.356
Constant	-2.955	.459	41.496	1	.000	.052		
Usebyrent	1.740	.252	47.767	1	.000	5.695	3.477	9.329
Constant	-2.034	.201	102.414	1	.000	.131		
Training	3.424	.757	20.437	1	.000	30.678	6.954	135.345
Constant	-1.283	.121	112.224	1	.000	.277		
Reasonable			132.454	3	.000			
Reasonable(1)	.377	.432	.761	1	.383	1.458	.625	3.401
Reasonable(2)	3.694	.384	92.420	1	.000	40.195	18.929	85.355
Reasonable(3)	5.214	.784	44.212	1	.000	183.857	39.535	855.021
Constant	-2.649	.277	91.768	1	.000	.071		

Multivariable binary logistic regression analysis (Adjusted odds ratio)  
Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for Exp(B)	
							Lower	Upper
Reasonable Reasonable(1)			41.862	3	.000			
Reasonable(2)	-.719	.579	1.540	1	.215	.487	.157	1.517
Reasonable(3)	2.243	.483	21.598	1	.000	9.425	3.659	24.276
	2.698	.993	7.385	1	.007	14.857	2.122	104.034

Training	2.846	1.174	5.878	1	.015	17.223	1.725	171.928
Usebyrent	1.263	.459	7.585	1	.006	3.537	1.439	8.690
Affordable	.932	.446	4.373	1	.037	2.539	1.060	6.080
Landsize			5.632	2	.060			
Landsize(1)	1.279	.775	2.727	1	.099	3.595	.787	16.411
Landsize(2)	1.861	.811	5.263	1	.022	6.430	1.311	31.528
Education			28.710	2	.000			
Education(1)	.830	.422	3.860	1	.049	2.292		5.245
Education(2)	3.745	.699	28.683	1	.000	42.303	10.744	166.556
Gender	.647	.260	6.206	1	.013	1.909	1.148	3.174
Age	.001	.010	.008	1	.927	1.001		
Farmerexperiance	.014	.166	.007	1	.934	1.014	.732	1.405
Farmerinvolvement	.014	.431	.001	1	.973	1.015	.436	2.363
Constant	- 5.170	.820	39.731	1	.000	.006		

a. Variable(s) entered on step 1: catreasonable, cattraining, catusebyrent, cataffordable, catlandsize, catEducation, Gender, Age, Farmerexperiance, Farminginvolvement

#### Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	3.316	8	.913

Appendix 9. Images during experiment testing of diesel pumping technologies



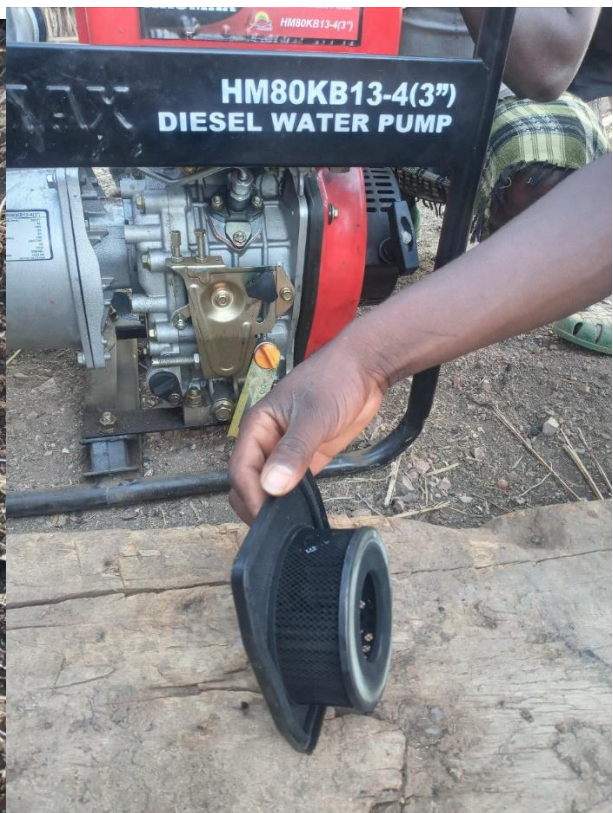
Wear and tear components of WP



Distribution of water pump to the farmers



Discharge of water from the field



Model number of water pump