ADDIS ABABA UNIVERSITY

COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR ENVIRONMENT AND DEVELOPMENT STUDIES

DETERMINANTS OF ADOPTION OF VERMICOMPOSTING TECHNOLOGY AMONG SMALLHOLDER FARMERS IN WALMARA WOREDA, OROMIA REGION, ETHIOPIA

BY

GETACHEW ALEMU DAMESSA

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This is to certify that the thesis prepared by Getachew Alemu Damessa, entitled: Determinants of Adoption of Vermicomposting Technology Among Smallholder Farmers in Walmara woreda, Oromia region, Ethiopia and submitted in partial fulfillment of the requirements for the Degree of Master of Arts in Development Studies (Environment and Sustainable Development) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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ACRONYMS

AE	Adult Equivalent
CO2	Carbon Dioxide
CSA	Climate Smart Agriculture
DA	Development Agents
FDGs	Focus Group Discussions
FYM	Farm Yard Manure
GA	Gibberellic Acid
IAA	Indole Acetic Acid
IRB	Institutional Review Board
KIIs	Key Informant Interviews
Mn	Magnesium
MOA	Ministry of Agriculture
N2O	Nitrous Oxide
SOP	Standard Operation Procedure
SWC	Soil and Water Conservation
WWAO	Walmara Woreda Agricultural Office

ABBREVIATIONS

C	Carbon
Fe	Iron
K	Potassium
N	Nitrogen
O	Oxygen
P	Phosphorus
Zn	Zink

DECLARATION

I would like to declare that the study conducted on *Determinants of Adoption of Vermicomposting Technology Among Smallholder Farmers in Walmara woreda, Oromia region, Ethiopia* is the original work of the investigator. The study also complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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DEDICATION

This thesis manuscript is dedicated in memory of my father Ato Alemu Damessa and my mother w/ro Ilfinesh Kecha whom I lost them in July 14, 2019 and October 23, 1997 G.C. respectively. Although they are no longer here physically, they will always be in my heart. They are the ones who laid the foundation of all of my life at my early stage of childhood. Let God keep their soul in Heaven.

I wish again to dedicate this thesis manuscript to my family for their moral and encouragement in the study period in particular and throughout my life in general.

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Getachew Alemu

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ABSTRACT

The majority of the workforce in Ethiopia is employed in agriculture, which also has the largest economic contribution. However, agriculture is relied small-scale subsistence farming systems which practiced on infertile soil. Because of this low agricultural production owing to infertility problem, many people have been facing food insecure. Using vermicompost is among important solution for reducing such soil fertility problem and vulnerability to food insecurity although the practice is not adopted by farmers at expected level. Therefore, the purpose of this study is to analyze factors influencing the adoption of vermicomposting technology in Walmara woreda. To achieve the objective of the study, data were collected from 184 householders (HHs) where (76 vermicompost adopters and 108 non-vermicompost adopters HHs). In addition, key informants and focus group discussions were conducted to support the survey data. The quantitative data analysis were analysed using both descriptive and econometric methods. Data analysis was done using both descriptive and econometric methods. A logistic regression model was used to estimate the determinants of adoption of vermicomposting technology. The analysis revealed that age, education status, field demonstration, distance to nearest farmland, access to credit and the extent of soil fertility problem were the variables that were significantly affected. The studies also showed that vermicompost has a positive role to increase soil fertility, and thereby boosted crop production and productivity. The analysis showed the main challenge of adoption of vermicomposting technology in the study area are lack of awareness, interest, labour, vermin box, access of technology, land, government support, and capital.

The study determined that vermicompost is the main possible solution to increase soil fertility and production in the study area. Thus, it is advised that vermicomposting technology be given priority by governments as well as other interested participants in order to increase soil fertility, production, and productivity.

Keywords: *adoption, fertility, Production, soil, technology, vermicomposting, walmara*

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

One of the most essential and fundamental resources that people cannot exist without is soil. Sometimes people don't realize how important soil is to them until it threatens agricultural productivity (Gomiero,2016). El-Ramady et al., (2014), states that a healthy soil is one that can supply the plant with enough nutrients. In Ethiopia, the issue of low soil fertility is also linked to the erosion of topsoil, the 40% of the country's soils being acidic, the loss of organic matter as a result of excessive manure consumption for fuel, the decline in macro and micronutrients in the soil, the deterioration of the physical characteristics of the soil, and salinity (Zelleke et al., 2019).

Agriculture means updating on soil and water. Naturally, soil is a valuable natural resource to increase agricultural production and productivity. Most Ethiopian farmers hold the view that soil is life for human being to live on the earth. As a result, its effective management is essential for economic growth and development in order to provide food, fiber, and other essentials. If managing natural resources is necessary, soil should be managed with priority for a number of reasons. Traditional farm management practices, poor utilization of external inputs, low output, and a restricted ability to adapt to environmental shocks are still prevalent in agriculture (Dadi et al., 2021; Abera et al., 2018).

Farmers now use more artificial fertilizers and less organic fertilizer to meet the growing demand for food. Chemical fertilizers may boost output momentarily, but over time they reduce output, degrade the soil's natural properties, contaminate the ecosystem, and have many other detrimental effects. The result has been a decline in agricultural productivity and output. Organic farming is therefore crucial for increasing soil fertility and creating sustainable agricultural production (Devkota et al., 2015).

The industrial revolution and green revolution improved the practice of artificial fertilizers in farming, leading to health problems and environmental pollution (Basit et al., 2021). Although fertilizers are necessary for contemporary agriculture, their excessive usage is leading to major environmental problems, including soil, water, and air pollution, to maintain healthy soil, it's crucial to use fewer chemical fertilizers and more organic additions, including organic manures (Kumar et al., 2019). According to Cooper et al. (2018), nitrogenous fertilizer produces CO2 and nitrous oxide, which can cause serious air pollution and is responsible for 60% of anthropogenic N2O emissions.

Organic fertilizers are leftovers from plants, animals, or minerals that decompose organically to enrich the soil with nutrients and minerals. They are crucial for maintaining the plants since they guarantee plant development, health, and nutritional balance. Organic fertilizers minimize over-fertilization and plant damage by having a slower nutrient-related process (Shaji et al., 2021). In combination with this, the growing global population is driving up consumption levels and producing a significant amount of household, agricultural, and industrial wastes that can be treated using sustainable methods (Hoornweg et al., 2013). Also, a portion of these wastes that is organic can be recycled and turned into nutrients and organic resources (Schott et al., 2016; Calabi-Floody et al., 2018). Good method for turning these wastes into nutrient fertilizers is through the biological decomposition of wastes through composting and vermicomposting (Barthod et al., 2018).

Vermicompost is among the finest options for using organic waste as an additional soil input. It includes simple raising techniques, a small initial expenditure, but a big benefit. This technique does not require a large initial investment as the input itself is trash. This technology may be useful for individual farmers and women who are able to establish such structures at the home level despite the need for specialized knowledge and practice. For sustainable agriculture output, it's imperative to increase both the quantity of vermicompost maker and the output of those who are already making it (Devkota et al., 2015).

Although vermicomposting technology has been around for a while, adoption has remained a problem. This suggests that maintaining the soil and increasing agricultural yield are challenging if the issue is not resolved. Even though numerous initiatives have been made to

promote and spread vermicomposting technology among farmers in different parts of the country including Walmara woreda, adoption of this technology is still quite low. Thus, the objective of this research is to analyze the determinants of adoption of vermicomposting technology among smallholder farmers in Walmara Woreda, West Shewa Zone, Oromia Region, Ethiopia.

1.2. Statement of the problem

Global interest of organic recycling techniques like vermicomposting technology has been restored by growing worries about soil infertility, soil acidity, soil erosion, air contamination and the like. Vermicomposting is an attractive idea because it has the ability to change waste from agriculture into an asset (Kamar et al., 2022). Vermicomposting has advantages like improved soil fertility and health, which lead to higher agricultural output (Baweja et al., 2020).

Vermicompost enhances the physical and chemical characteristics of soil, such as its structure, ability to hold water, resistance to penetration, total density, and organic matter in the soil. According to the findings of various long term research addition of vermicompost reduces the bulk density of the soil and increases the water holding capacity of soil (Moradi et al., 2014).

According to research by Aksakal et al., (2016), vermicompost increases the average overall density and average overall porosity of the soil, when wet aggregate strength and density of the bulk declined air permeability increased and barriers to penetration considerably decreased.

However, many farmers, particularly those in underdeveloped countries like Ethiopia, find themselves at a disadvantage since they don't take full advantage of their capacity for organic recycling utilizing earthworms. Farmers in Ethiopia's rural areas have been struggling with the problem of diminishing agricultural yield. One of the factors contributing to this is a decline of soil fertility and soil acidity. Agricultural productivity has decreased as a result of ongoing soil deterioration (Kopittke et al., 2019). Through promotion in various agricultural technology, such as organic fertilizer, the Ethiopian government has interfered in the agricultural sector since the 1970s to address this issue.

Despite its many advantages, vermicomposting is currently not extensively used because of a shortage of understanding and technological hurdles. Vermicomposting technology adoption is influenced by a number of other factors as well. The main factors affecting the adoption of vermicomposting technology includes financial variables, social variables, and institutional variables. Therefore, adequate extension expansion is required to fully explore the potential of vermicomposting technology.

On the other hand, agricultural production specifically, crop production is a big component of our farmer's life. This activity hinges on the land and soil. But this land or soil faces the challenge of soil health problem due to acidity, soil fertility loss, agricultural productivity decline and organic matter loss results in production loss. However, the government of Ethiopia applies chemical fertilizer as a crop production increasing strategy. This strategy has a side effect on the environment and nutrients in the soil. To solve this problem there is the application of vermicomposting technology which is eco-friendly for the environment and for organic crop production. Smallholder farmers in Africa in general, and Ethiopia in particular, face difficulties with it (Shanka, 2020).

There is strong agreement and acknowledgment among governmental and non-governmental parties about the application of the vermicomposting technology, but there is a gap in application and expanding to the local environment in Ethiopia (Fola and Getachew,2022). Additionally lacking in dedication and accountability are Ethiopia's local governments' efforts to introduce vermicomposting technology. Vermicomposting technology is constrained by a lack of funds, funding gaps, and acceptance issues. In the research area, it doesn't get particular emphasis. Therefore, the purpose of this study was to examine the factors that affect the adoption of vermicomposting technology supplied by both governmental and non-governmental organizations in Walmara woreda, Oromia region, Ethiopia, in order to close the knowledge gap that exists.

1.3. Research questions

1. What is the farmers perception towards vermicomposting technology in the study area?
2. What is the adoption level of vermicomposting technology in the study area?
3. What are the main factors that affect the adoption of vermicomposting technology in the study area?

1.4. Objectives of the study

1.4.1. General objective

The general objective of the study was to examine the determinants of adoption of vermicomposting technology among smallholder farmers in Walmara woreda, West Shewa zone, Oromia region, Ethiopia.

1.4.2. Specific objectives

1. To explore smallholder farmers perception towards vermicomposting technology in the study area;
2. To examine the adoption level of vermicomposting technology in the study area;
3. To identify factors determining the adoption of vermicomposting technology in the study area.

1.5. Significance of the study

This research assesses the causes of vermicomposting technology adoption in research region. The objective of this research is to gain important knowledge regarding the factors affecting smallholder farmers' adoption of vermicomposting technology in the study region. The findings of these research are crucial for governments as well as development planners who are interested in the factors that influence smallholder farmers' adoption of vermicomposting technology. The research results can also be utilized as a starting point for future academics to generate new knowledge related to vermicomposting technology. The study's setting may help to confirm already-known facts about the problem and encourage the implementation of additional solutions in the research region. To obtain further technology supply and extension services from the agriculture industry and all relevant organizations, it is crucial to investigate local households.

1.6. Scope of the study

This study scope includes one administration woreda and three kebeles. The data used in the study was based on a cross-sectional survey and quasi-experimental design. The study was focus on determinants of adoption of vermicomposting technology. It makes an effort to identify farmers' attitudes towards vermicomposting technology, assess its level of adoption, and identify the elements that affect vermicomposting technology adoption in the study area. The study area was experienced several natural disasters including land degradation, soil erosion, soil acidity and lower land productivity; these have also impact on the entire ecosystem of the woreda including affecting the major water sources and significantly affecting livelihood of the smallholder farmers. Therefore, the adoption of vermicomposting technology could contribute to halt the adverse impact of soil fertility related hazards in the study area at large. Demographic variables, socioeconomic variables, and institutional variables are among those being studied. Additionally, while agriculture includes a variety of activities, the study solely looks at crop farming agriculture.

1.7. Limitation of the research

The research was carried out in Walmara woreda of West Shewa one, Oromia region and concentrate on comprehending the factors that influence the implementation of vermicomposting technology. As a result, it was limited to figuring out what factors led smallholder farmers in the study area to adopt the vermicomposting technology. The study mainly relied on data from a cross-sectional sample home survey that was conducted during a single farming season. Vermicompost was chosen as the organic fertilizer for this study because it is crucial to improving soil fertility in the research area in order to increase production and productivity. It looks at regionally unique elements like access to agricultural extension services, social capital, and demographics. The results of this study can, however, be applied to other locations with a similar environment and, in particular, to those with similar traits.

1.8. Structure of the thesis

The structure of this thesis is comprised of five chapters. The majority of chapter one is taken up by the introduction to the study, which includes its background, statement of the problem, aims, significance, scope, restrictions, and thesis structure. Chapter two provides a summary of the literature on vermicomposting technology and associated subjects. The third chapter provides an explanation of the research methodology and design, target population and sampling, choice of sample size, instruments used to collect data, and method of data analysis. The study's results and conclusions were provided in the fourth chapter. The summary findings, conclusion, and recommendations were included in the final chapter.

CHAPTER TWO
LITERATURE REVIEW

2.1. Theoretical review

2.1.1. Operational definition of terms

Vermicomposting: is the method of using worms to break down organic wastes into vermicompost, a substance that like humus.

Adoption: in this study adoption of vermicomposting technology means accepting and implementing vermicomposting technology by small farmer families.

Adopter: a household head who accepts, uses, and maintains a particular vermicomposting method on his farm.

Non-adopter: are head of households who do not use vermicomposting technology on their agricultural land.

Household: is described as a group of individuals who live together under the direction of a household head and acquire their sustenance from communal sources, primarily farming operations. The head is often a man, though rarely there may be a woman. When both parents are deceased, grandparents and teenagers may also serve as the head of the household (Abdiyo, 2021).

2.1.2. Basic principles of adoption of innovation

With the adoption of innovation by people or groups, a social system can become more open to it. According to Badilescu-Buga (2013) adoption is the sustained incorporation of a technology into regular agricultural operations. According to Dasgupta (2012) adoption is not a constant behavior. This implies that a person may choose to quit using utilizing a certain invention for a variety of social, institutional, and personal reasons, among which might be the emergence of a rival technique that is more suited to meet the demands of farmers.

According to Worku (2019) a person may decide to quit using a new technology for a variety of personal, institutional, and social reasons, one of which could be the availability of an alternative strategy that is better suited to satisfying the needs of farmers. According to Feder et al. (1985), adoption was split into two categories as individual (farm level) adoption and aggregate adoption.

When a farmer has a thorough understanding of the new technology and its possibilities, adoption is defined at the level of the individual farmer as the extent of new technology application in the long term. Diffusion is referred to as the spread of new technology within an area in the context of general adoption behavior. This argues that the overall uptake of a specific new technology in a given location or among a given population determines adoption overall.

Adoption process: Straub (2009) defined the adoption process as the psychological stage a person experiences between first learning about a new innovation or technology and ultimately adopting it. This suggests that adoption was a process rather than an immediate event. Farmers take time to consider new ideas before accepting them; they do not do so right away.

Adoption of innovation: Innovation refers to brand-new concepts, techniques, procedures, or products that are seen as new and offer a means of improving farm output and income over the long term. Even while most people may not be unfamiliar with creativity, not everyone has yet adopted it. New concepts or practices are disseminated among a social system's members throughout time through a process called diffusion (Kee, 2017). Rejection is the decision not to implement an innovation, whereas adoption is the choice to do so as the most appropriate course of action. According to Wani et al., (2015), the decision stage in the decision-making process for innovations is when a person (or other decision-making unit) takes activities that result in a decision to embrace or reject the invention.

Rate of adoption: The rate of adoption is the proportion of farmers who use a particular practice. The amount of adoption is determined by how well a particular technology is received. The level of adoption of the suitable technology will be defined as the input utilized per hectare or the number of hectares planted with improved seed (also tested as the percentage of each farm planted to better seed) (Nkonya et al., 1997).

2.1.3. Basic principles of technology adoption

Adoption of technology: According to Dhrifi (2014), agricultural technology both directly and indirectly supports in the reduction of poverty. Immediate benefits from crop varieties with firmly established yield advantages come from lower cost per unit of output at the family level. Indirect impacts occur at the market level, changes in the unit cost of production are aggregated among numerous adopters, and market prices may fall as a result of greater supply. Consumers benefit from these improvements, but producers suffer, particularly those who don't implement them. According to Yokamo (2020) technology is the process and means of producing goods and services. The technology may already be in use in a particular area or among a certain set of farmers, while being new to them. The majority of people need a way to engage in a society where technology is taken center stage in our everyday lives and is experiencing rapid development, thus adoption of new technologies is essential. Those who are unable to adopt new technology will find it increasingly difficult to fully enjoy the financial and practical advantages of technology. We can forecast and manage who adopts technology, when, and under what circumstances by understanding the elements that influence adoption. It is unfortunate that there isn't a clear definition of technology adoption given the wide range of knowledge and circumstances in which people use it. Adoption and spread of technology are two distinct but related concepts. In contrast to technology adoption, which is recorded at a single point in time, diffusion of technology is the slow spread of an innovative technology throughout the community gradually (Pardey et al., 2010).

Agricultural technology adoption: Innovation spreads within a social system when it is adopted by individuals or groups. The choice to fully implement an idea as the best available course of action is known as adoption. Adopting an innovation includes a process that involves learning, choosing, and acting over time. Before deciding to accept an innovation, the adoption process, like a method for choosing options, passes through the variety of mental stages. A decision-making process has several stages, each of which is distinguished by a certain type of activity. In order to adopt an innovation, a person must pass through the following five stages: five phases: understanding, curiosity, assessment, testing, and acceptance (Rogers et al., 2014).

Level/intensity of adoption of agricultural technology: Degree of utilization of a certain technology is referred to as adoption level/intensity level. When a technology is adopted, it is crucial to comprehend how much the intended group has used the technology. Level/intensity of adoption was described by Tegegne (2017) as a measurement of depth of adoption in terms of elements like the amount of fertilizer used per hectare or the total number of hectares planted with improved seed.

2.1.4. Fertilizer

Any item that is given to soil or plant tissues in order to supply one or more nutrients required for plant growth or to make up for nutrient deficiencies is considered a fertilizer, whether it be natural or manufactured (apart from liming compounds). Chemical elements can be found in fertilizers, which can be either natural or manmade substances that help plants grow and produce more. Any substance, organic or inorganic, that contains at least 5% of each of the three essential elements—nitrogen (N), phosphorous (P), and potassium (K) is considered a fertilizer. Industrially generated fertilisers are sometimes referred to as "mineral" fertilisers. The major and minor plant-essential elements (N, P, K, etc.), as well as pollutants and other non-essential elements, are all present in fertilisers in varying concentrations. This idea includes both inorganic (mineral) and organic fertilisers as well as soil enhancers like lime and gypsum that may encourage plant growth by increasing the availability of nutrients already present in the soil or by altering the physical composition of the soil (Kumar et al., 2019). Additionally, fertilizer is the phrase used to describe the chemical make-up of several vital minerals and components designed for the regular as well as rapid growth and sustenance of all plants. Agricultural fertilisers are what they are called because they are always used to stimulate and increase the production of commercial crops. Fertilizers increase the soil's richness and provide it with the necessary nutrients. Fertilizers enhance soil quality, increasing crop yield in the process. Fertilizers are nutrient-rich sources that give plants the nutrients they require, and the soil acts as a conduit between the crops and the fertilizers (Holle, 2022). It is a substance that is given to soil to aid plant growth (such as manure or a unique chemical (Merriam-Webster.html, 2016).

2.1.5. Types of agricultural fertilizers

Fertilizers are made up of one or more chemical compounds or nutrients, hence they have been divided into the following groups based on how they release their constituent compounds and nutrients:

2.1.5.1. Organic agricultural fertilizers

According to Voigt et al. (2016), organic fertilizers are those that are created naturally. Organic fertilizers, also known as naturally occurring fertilizers and soil nutrient enhancers, are those fertilizers that are produced utilizing organic materials that are biodegradable (Holle, 2022). Any chemical that is rapidly biodegradable and occurs naturally is therefore referred to as organic, and if it improves soil fertility, it is called organic fertilizer. These organic molecules are further broken down and broken down into smaller, soluble pieces by several microorganisms. These fertilisers are converted into soluble, less complicated molecules before being absorbed by the roots. Manure, slurry, worm castings, peat, seaweed, sewage, and guano are examples of natural green manures. Synthetic organic fertilizers include compost, blood meal, bone meal, and seaweed extracts. Crops are also produced to enrich the soil with nutrients.

2.1.5.2. Inorganic agricultural fertilizer

The term "inorganic agricultural fertilizers" refers to fertilizers made up of inorganic chemical compounds, such as potassium chloride, granular triple superphosphate, urea, anhydrous ammonia, etc. The majority of these nutrients are not recyclable. Additionally, they broken down hooked on other groups according on their ingredients besides preparation techniques. Due to the fact that they are produced in factories utilizing latest technologies, these fertilizers are sometimes known as synthetic or artificial fertilizers. These fertilizers have an irregular texture due to artificial manufacturing procedures, which also make them strong and very effective (Batool and Iqbal, 2019).

2.1.6. Sources of organic fertilizers

Primarily used natural nutrients can be obtained from sludge, by products of animals and plant wastes after agriculture too sewage sludge (Sharma and Chetani ,2017). Animal byproducts from the meat industry, peat, and slurry are examples of naturally occurring organic fertilizers. Carbon-based chemicals known as biological nutrients increase the development and production of plants. Organic fertilizers are complex substances that contribute a variety of secondary and micronutrients, far from being simplified and purified chemicals. Blood meal, bone meal, wood ash, and compost are all examples of organic materials that contain considerable micronutrients and whose texture would improve rather than impair the quality of the soil (Parnes, 2013). These materials are also powdered rocks (such as lime, rock phosphate, and greensand).

2.1.7. Importance of organic fertilizer

Consumers in the horticultural industry are becoming more and more interested in products that are long-lasting and environmentally friendly. Natural nutrients have numerous benefits. Those nutrients are made entirely from organic, plant- or animal-derived source ingredients. The main distinction between natural and synthetic fertilizer is that the former enhances the fertility of the soil by enhancing its health and condition (Badar et al., 2015). Fertilizers made exclusively from natural, plant- or animal-derived source ingredients are known as organic fertilizers. Natural nutrients, which are mostly based on manure or compost, release nitrogen, phosphorous, and potassium when soil organisms like good bacteria and fungus break down the pellets of the fertilizer. Soil life is another name for these soil-dwelling microorganisms (Abebe et al., 2022).

Natural fertilizers, as opposed to synthetic nutrients, make use of residual parts from plants, animals, or minerals. The soil would receive nutrients and minerals from the naturally decomposing material from these sources. It was crucial to make sure the plants obtained all the nutrients necessary for growth in order to sustain a healthy plant life. Even though nutrients are available in typical soil, fertilisers can provide a plant with a balance of nutrients and ensure that it has the right access to them. Taking care of the well-being of the farm is part of proper grass maintenance. One advantage of organic fertilizers is that nutrient interactions occur more slowly than with chemical fertilisers. This delayed method allows the plant to consume the fertilizer in a more natural way and prevents overfertilization, which could harm the plant (Hossain et al., 2022).

With the use of artificial fertilizers and pesticides, groundwater is contaminated in many agricultural areas. Using more biodiversity, improving the structure of the soil, and increasing the penetration of water are all ways that natural fertilisers are more effective. Pollution of groundwater is drastically reduced by organic systems that are kept up and have superior nutrient retention abilities. Carbon may be stored in the soil through natural farming, which helps to lessen the impact of greenhouse gases and global warming. Numerous management strategies used in organic farming increase soil carbon absorption, hence increasing productivity and improving carbon storage (Babu et al., 2020). Households are less likely to choose pricey fertilizers if they have enough labor available to apply manure. In addition to their mutual effects, other factors can have a similar or a distinct impact on how manure and fertilizer are used. It demonstrates that as parcel size increases, the probability of using both compost and fertilizer increases (Ketema et al., 2011).

2.1.8. Vermicomposting

Naturally, soil is a valuable natural resource. For the production of food, fiber, and other essentials, as well as for economic growth and development, soil is essential. So, to increase soil fertility using vermicomposting technology is important. Earth worms are one of the principal species found in soil and an essential part of tropical and subtropical habitats (Kumar et al., 2020). By creating cast, pellets, and galleries, earthworms enhance the soil environment. The earth worm's gut secretes mucus, which promotes microbial activity (Lemtiri et al., 2014).

Earthworm species are generally utilized in the organic and biological process of vermicomposting making manure out of organic waste or recyclable garbage. Vermicompost is created, and because it is nutrient-rich, it is frequently employed in sewage treatment facilities and organic farming as a bio fertilizer. Vermicomposting is a natural way to turn the expense of improper waste disposal into profit. As an alternative to chemical fertilizers, the manufacture of vermicomposting offers a more reasonably priced bio fertilizer (Kaur, 2020). It increases productivity and improves the nutritional value and food security of the soil. Vermicomposting is a chemical and biological method that uses microorganisms and earthworms to recycle nutrients (Chattopadhyay, 2012).

Vermicomposting is a method for dealing with organic waste that is neither burned nor dumped but is instead seen as a resource that could be recycled. As a result, it has been described as a bio fertilizer with a high nutrient content and a variety of microbial communities (Pathma et al., 2013). Vermicomposting has similar effects on plant development and yield to inorganic fertilizers since it is a rich source of carbon (C), hydrogen (H), and oxygen (O). It contains humic compounds such humic acids, fulvic acids, and humin, all of which offer a variety of sites for chemical reactions (Tiwari et al.,2023).

On the one hand, vermicomposting with earthworms produces the most beneficial organic manure, while on the other, it reduces environmental pollution and health risks. In the long run, frequent application of vermicomposting enhances the physical, chemical, and biological characteristics of soil (Pilli et al., 2019). Additionally, it eliminates the soil of excess amounts of toxic metals including copper and lead (Pilli et al., 2019).

2.1.9. General properties of vermicompost

As soon as people understand the importance of organic inputs in crop fields, vermicompost acceptance in terms of sustainable crop production has been rising quickly. The primary product, vermicompost, which is regarded to be earthworm excrement, has a number of qualities. These are categorized into physical and chemical properties. The physical properties include a quality vermicompost is always safe for the environment, decomposes well, and is environmentally and aesthetically appropriate; any kind of green waste, including industrial waste, sewage sludge, municipal trash, and agricultural waste, can be converted by earthworms; when soil is turned properly, it is a sign of aerobic decomposition, which will result in a typical odor after preparation. A bad odor may develop if the aeration is not done properly; vermicomposting will ultimately produce fine, granular-structured particle matter that used as fertilizer to increase the soil's productivity by increasing its porosity, drainage, and water-holding ability, vermicompost serves as a "soil conditioner"(Saha et al., 2022).

The chemical properties include about all of the vital macro and micronutrients for plants are abundant in vermicompost. Vermicompost has a higher average nutrient content than typical compost made using other methods, according to several experiments; vermicompost has a higher calcium concentration than regular compost among all the secondary nutrients; compared to other types of compost, vermicompost has worm mucus, which helps to keep the nutrients there from being washed away. Additionally, since these heavy metals accumulate in worm tissue, vermi-conversion has been shown to reduce the amount of these metals in earthworm cast. The rate of heavy metal removal in vermicomposting systems varies depending on the feed utilized. Due to this characteristic, vermicompost is less contaminated than other types of compost. Thus, vermicompost becomes more environmentally friendly (Saha et al., 2022).

2.1.10. Use of vermicompost for soil fertility

Vermicompost is utilized extensively in farming to improve the fertility of the soil and yield. It is ecologically sound. Vermicompost is an eco-biotechnological method that converts complex organic materials with high energy content into a stabilized humus-like product (Hossain et al., 2018). Vermicomposting is an effective and simple method of creating compost that may be used in any situation.

According to studies by Lazcano and Domnguez (2011) and Hema and Rajkumar (2012) a considerable amount of organic waste can decompose using a composting system. This decomposition helps to maintain composted materials with higher nutrient status. The bio-physico-chemical qualities of soil are decreasing due to the frequent application of chemical fertilizers. This is causing a decrease in crop yield per area, in turn. Utilizing organic manures, such as vermicomposting, farm yard manure (FYM), and others, may provide crops with an adequate number of micronutrients in usable form and enhance the quality of agricultural outputs (Ahirwar et al., 2015).

According to Gautam et al., (2022), soil quality is the ability of organisms in the soil to survive within the limitations of an unmanaged or natural environment. The terms "soil health" and "soil quality" refer to the soil's suitability for supporting plant and animal productivity, maintaining the standard of the water and air, and fostering plant and animal health. One way to think of soil quality is as a barometer of soil health (Gautam et al., 2022).

It is impossible to overestimate the role that vermicompost plays in boosting soil fertility. Organic amendments are becoming more important recently for nutrient management and sustainable crop production because the continuous use of inorganic fertilizer without organic additives has the potential to impair soil quality (Diacono and Montemurro, 2011). When balanced over a long period of time, inorganic fertilisers can decrease soil bulk density, enhance overall porosity, and improve soil's ability to retain water. According to Saha et al., (2022), inorganic fertilizers also promoted soil aggregation in deeper soil layers and boosted maize and wheat grain and straw yields,. They discovered that using organic fertilizer farmyard manure instead of inorganic fertilizer had a similar favorable effect on soil properties. Additionally, compost greatly raises soil organic carbon and some plant nutrients when compared to mineral fertilizers (Adugna, 2016). As a result, adding vermicompost enhances a variety of soil properties on a physical, chemical, and biological level.

Generally, vermicompost is used in organic farming and small-scale sustainable farming to increase soil recycling, enrich the soil with microbes, support the livelihoods of rural unemployed people, improve soil texture, aeration, and water retention capacity, act as a soil conditioner, and enhance the biological, physical, and chemical properties of the soil. Domestic wastewater control can also be accomplished using this technique. It is an excellent organic fertilizer since it is nutrient-rich, which promotes healthy plant growth and higher harvests. It is also abundant in organic compounds, which increase productivity and can be used to control development because they have the proper proportions of all essential plant nutrients. As a result, it is an all-inclusive and balanced plant food. Vermicompost extract regularly applied encourages plant development, keeps plants healthier, and fights plant diseases.

2.1.11. Vermicomposting technology as CSA practice

The main challenge in agriculture today is sustainability in terms of maintaining soil productivity and balancing cultivation of crops year after year because of the serious condition of soil degradation and decreasing crop yields. In order to alter solid organic materials (agricultural waste from plants and animals) in chemical, physical, and biological ways, a process known as vermicomposting is used (Sharma et al., 2018).

It is a straightforward and environmentally beneficial substance that relies on earthworms to quickly transform organic waste. In comparison to typical compost, vermicomposting is more abundant in vital plant nutrients including nitrogen, phosphorus, and potassium. It also contains microbes that help plants growth. Vermicomposting has been used to improve the management of plants and to enhance plant growth (Moradi et al.,2014). Vermicomposting as a form of climate-smart agriculture (CSA) increases the effectiveness of resource usage on farms (Smith, 2017). A CSA approach takes the farm and landscape into account holistically. By addressing agricultural production, adaptation, and mitigation in concert, CSA can enhance livelihoods and resilience. Each of these CSA pillars may be addressed by vermicomposting technology (Smith, 2017).

Productivity: Food security is strongly correlated with enhanced agricultural production brought on by vermicomposting production soil enrichment, and worm sales' economic potential also benefit livelihoods;

Adaptation: Vermicomposting can increase fertility and the ability of a plant to store moisture, both of which are necessary for adaptability. Farmers' economic resilience is increased by resource use efficiency and system integration;

Mitigation: Reduced use of fertilizers based on fossil fuels or the direct application of manure to fields minimize greenhouse gas emissions.

2.1.12. Theories of adopting agricultural technologies

In the 1920s, when the first research on the spread of agricultural advances was done, the U.S. Department of Agriculture examined its efforts to help farmers adopt better farming practices. For the first time, research conducted in 1943 by Byre Ryan and Neal Gross demonstrated that a variety of procedures were involved in farmers' adoption of innovations. Research has typically demonstrated that when an innovation adoption curve is plotted, it takes the shape of a normal, bell-shaped curve. There have been theories put out to explain why the diffusion curve has a S shape. A new concept should be given time to spread throughout a social structure, and there are always differences in how different social system members react to an innovation.

According to Dissanayake et al., (2022), adopting a new idea requires a decision to be made, followed by confirmation of the choice. This process takes place over a period of time, starting with the individual learning about the invention and ending with the decision to adopt or reject it. The diffusion of all technologies is not uniform; for example, the technology that merely modifies an existing thought or practice slightly will disseminate more quickly than one that significantly departs from it. Economical and environmental limitations, expert-oriented methods, and the lack of farmers' active participation in the technology development process all affect or assist in the use of modern technology. Focusing on the neighborhood and the overall environmental conditions there will help to close the adoption gap among farmers. This will make it easier to recognize the situational aspect and value local technical skills. There are three types of theories that are basically used to explain adoption behavior and factors that influence technology adoption. These theories are included: (i) the model of economic limitations; (ii) model of technological attributes and user context and, (iii) the model of innovation and dissemination;

(i) The model of economic limitations: The fundamental tenet of this model, often referred to as the factor allocation approach, is that the distribution of resource endowments among potential users in a nation or region determines the pattern of adoption of a technical innovation. According to Negatu and Parikh (1999), market prices (or substitute prices brought about by institutional and policy interventions) represent the relative scarcity of the elements, thereby implying the necessity of (or existence of) effective markets as well as the significance of price policies.

(ii) Model of technological attributes and user context: This model incorporates theories that hold that the diffusion and adoption of a technology depend largely on factors related to the socioeconomic, institutional, and agroecological environments in which it is used (Thompson et al., 1994). This model can also take into account how potential users perceive a technology's features as a factor in adoptive judgements and, ultimately, the dissemination of innovations (Shiferaw et al., 1998).

(iii) Innovation-diffusion (transfer-of-technology (TOT) model: According to this model, a technology is transferred from its creators (research systems) to its consumers (final users) via an agent medium (extension systems), and the diffusion of the technology in potential user communities is significantly influenced by the individual user's personal characteristics (Koutsouris, 2018).This method operates under the presumption that technology may be used effectively unless it is constrained by inefficient communication. Using those three theories to explain technology adoption increases the model's explanatory power compared to using only one theory, according to recent studies. The model indicates the significance of including farmers in the process of developing technologies in order to produce those with suitable and acceptable qualities. It also suggests the importance of institutionalizing research policies and practices that make it easier for farmers and other key stakeholders to participate. This study is mainly depending on the innovation-diffusion (transfer-of-technology (TOT) model theory.

2.1.13. Key elements in diffusion of innovations

According to Rogers (2003), the four main factors that influence how innovations are disseminated are include invention, means of communication, time, and the social environment. It starts with invention. A person or other unit of adoption who recognises the idea, practise, or endeavour as novel is said to have engaged in an innovation (Rogers, 2003). An invention may seem brand-new to some people even though it has already been available for some time due to the way they perceive it. Second, dispersion happens within or among groups of people. Channels of communication allow knowledge to be transmitted from one device to another. For distribution to occur, at the very least, communication capacities or patterns between parties must be established. Third, time. Innovations are scarcely fast adopted; rather, they typically take time to catch on. The selection procedure for innovations along with their innovativeness and pace of acceptance, all take time. Fourth, Social system. The social system combines internal factors with external factors (such as mass media, surfactants, organizational or governmental mandates There are several functions in a community, and the combination of these affects an applicant for adoption is represented by the total of these influences. Rogers (2003), defined a social system as "a group of interrelated components that use collaborative problem-solving in order to achieve a shared goal." The social framework of the community has an effect because diffusion of innovation takes place within the framework of society.

2.1.14. The innovation-decision process

According to Rogers (2003), there are five processes involved in adopting new technologies: (1) information, (2) argumentation, (3) choices, (4) application, and (5) verification. These stages frequently take place in the order in which they occur across time. A person obtains knowledge of a new innovation and a basic comprehension of how it functions at this stage. The argumentation process shapes a person's perspective on the invention. A person conducts actions that lead to a decision to accept or reject the idea during the decision-making stage. Person applies an invention during the application stage, and person evaluates the results of a decision regarding an innovation that has already been taken during the choice of adoption verification stage (Rogers, 2003).

2.1.15. Adopter categorization on the basis of innovativeness

According to Rogers (2003), the adopter categories are divides depending on how creative a member of a social system is. Innovators, early adopters, the early majority, the late majority, and laggards are all members of this category. People in each adopter category are equivalent in terms of inventiveness. According to Sahin (2006), innovation is the extent to which a person or other unit of adoption adopts new notions far earlier than other system participants.

2.2. Review of empirical studies

2.2.1. Factors affecting adoption of vermicomposting technology

Empirical studies on acceptance and spread of agricultural inventions have been done by individuals and institutions both inside and outside of Ethiopia. However, the studies mostly focused on different types of important cereals, therefore the number of studies on the use of vermicompost is extremely small. The factors that have been linked to adoption thus far can generally be divided into three categories: demographic, institutional and socioeconomic factors.

Ethiopia is endowed with a variety of underutilized resources that could improve agrarian life for all time. Vermicomposting technology is new in Ethiopia and hasn't been widely implemented yet. The understanding of vermicomposting technology and vermi-culturing among development planners, professionals, extension agents, researchers, and academics is still too low to be promoted on a broad scale (Dadi et al., 2021).

A study on the significance, untapped potential, and difficulties of vermicomposting technology in Ethiopia was undertaken by Dadi and Gebirehiwot (2021), examine the potential and challenges of creating and utilizing vermicompost in farming is the study's goal. The researchers have employed both qualitative and quantitative data for the same objective. The study identifies two potentials for producing vermicompost: utilizing biodegradable waste materials and turning invasive plants into vermicompost resources. According to the research, reusing biodegradable waste items for the production of vermicompost and turning invasive weeds into vermicompost resources are two prospects.

According to finding the major resistance to adopting the vermicomposting technology is the extension approaching since experts and extension agents favors chemical fertilizers over organic fertilizers, vermiworm predators, parasites, and diseases, handling issues with vermiworm, and the influence of environmental factors on vermiworm growth are among the challenges to implementing vermicomposting technology in Ethiopia. Last but not least, the researcher recommends identifying the best local vermin species that farmers can readily access, examining the relationship between agroecology features and vermicomposting technology, concentrating on cereal crops residue characters to vermiworm relation in central Ethiopia, and biological characterization of vermiworm is not yet further identified.

Devkota et al., (2015), released a paper titled Evaluation of Adoption-Related Factors and Total Vermicompost Production Income in Chitwan, Nepal. The purpose of this study was to evaluate the 2015 vermicompost production and commercialization situation in the Chitwan district. All 32 producers of vermicompost in the research area were contacted using an interview schedule, and 32 nearby those who don't produce were chosen using a snowball's chance. There were 64 responders in all. Farmers who weren't producers included a small number of vermicompost consumers. The quantity of earthworms raised and labor use had a significant impact on vermicompost production's overall income, whereas adoption of the technology was significantly influenced by manufacture of vermicompost training, social connections and farming practice. Efficiency in resource utilization showed that labor was underutilized while the quantity of earthworms raised and material costs were overused. To get the greatest economic benefit, it was necessary to increase labor utilization by 1.48 percent and the number of earthworms raised by 300%, respectively.

Effects of vermicompost and plant growth enhancers on the exomorphological properties of Capsicum annum (Linn.) Hepper is the title of an article written by Rekha et al. (2018) for the International Journal of Recycling of Organic Waste in Agriculture. The study's objective was to improve soil health and plant development, which would further support using natural improvements as opposed to fertilisers.

The mix of macro- and micronutrients found in vermicompost benefits plant development, nutrition, photosynthesis, and the amount of chlorophyll in the leaves. Ten replicates of pot tests with four soil amendment treatments were conducted. 100 milliliters of distilled water were used as the control, along with 50% soil-based vermicompost and Gibberellin Acid (10 milliliters) and 90 milliliters of deionized water (GA + 100 g/ml). 10 ml of pure acetic acid and 90 ml of deionized water. The research features (shoot length, internode length, number of leaves, and number of branches) of C. annum were measured after the plant was transplanted into pots.

Lastly, the researchers discovered that the impact of plant growth promoters such GA and IAA was compared to applications of 50% vermicompost. By the end of the third, fourth, and fifth weeks of treatment, plants showed a significant improvement in all the metrics, including length of shoot, length of inter node, number of leaves, and number of branches. The authors concluded by stating that plants treated with 50% vermicompost grew substantially more than plants treated with gibberellic acid (GA) and indole acetic acid (IAA). Vermicompost can be employed as an effective bio fertilizer, according to their studies.

Beshir et al. (2012), looked at the variables affecting the usage of chemical fertilizer technology in Ethiopia's north-eastern highlands. Cross-sectional data from 252 randomly selected farmers served as the study's basis. In this study, a two-hobby model was used to identify the factors impacting the likelihood of adoption and the degree of use of inorganic fertilisers. There were about 207 (97%) non-adopters and 45 (3%) adopters. The possibility that chemical fertilizer technology will be implemented is significantly positively impacted by access to extension services, distance from the development agent, and credit services, but market distance, input supply distance, and credit distance are significantly negatively impacted. In contrast to the active labor force, distance to market, distance to road, number of plots, distance to input supply, DA distance, credit service, and credit distance, which all have a significant negative impact on the adoption of chemical fertilizer technology, are age, education, adult equivalent, amount of cultivated land, livestock owned, off-farm income, and access to extension services.

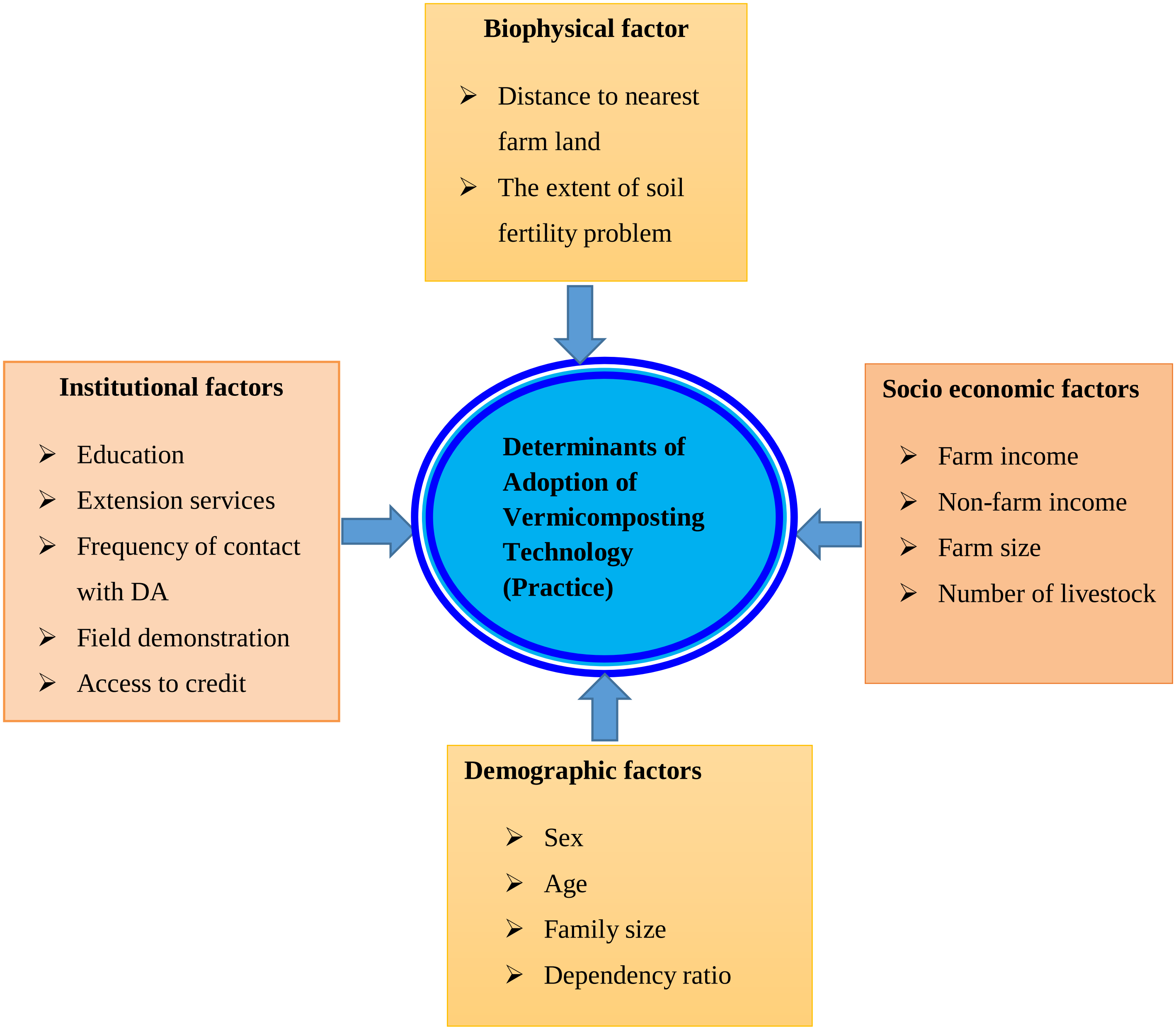
In their study on the factors influencing the adoption of fertilizer in Ethiopia, Adugna et al. (2006) demonstrated that extension service, the number of oxen owned, availability to financing, and hired labor were among the major predictors of the choice to adopt fertilizer. The adoption rate was calculated taking into account factors including farm size, family size, loan availability, hired labor, and off-farm income (Degnet et al., 2001).

2.3. Conceptual framework of determinant factors of vermicomposting technology

The use of vermicomposting technology improves agriculture by boosting production, improving soil fertility, and generating cash. Farmers that use vermicompost can increase their revenue or output while also being better able to deal with soil fertility effects and contributing to the solution of the world's soil fertility issues (Devi et al., 2022). Adoption of vermicomposting technology and the results are affected by a variety of issues (Rahman and Majumder,2021). The figure two below shows that the linkage between adoption of vermicomposting technology and variables assumed that affect adoption of vermicomposting technology in the research region.

The factors include demographic factors (age, sex, family number, working force, and education level), institutional (access to extension, access to credit, field demonstration, and distance from farm land), socio-economic (farm income, non-farm income, size of land, and number of livestock) and biophysical factor (distance to nearest farmland and the extent of soil fertility problem). So that age, sex of household, family size, family labor, educational status, access to extension, access to credit, field demonstration, income from farming, non-farm income, land size and number of livestock affected the household vermicomposting technology adoption status positively while farm land distance was affected the household vermicomposting technology adoption negatively. That is, households have land far from his home have less opportunity to adopt vermicomposting technology.

The key economic variables influencing household adoption of vermicomposting technology were the earnings from various activities. The key institutional variable that favorably influences household adoption of vermicomposting technology is availability to financing. In general, the conceptual framework showing the factors affecting adoption of vermicomposting technology is shown by the following diagram:



Source: Own sketch based on literature review, 2023

Figure 1: Conceptual framework of the study

CHAPTER THREE

METHODOLOGY

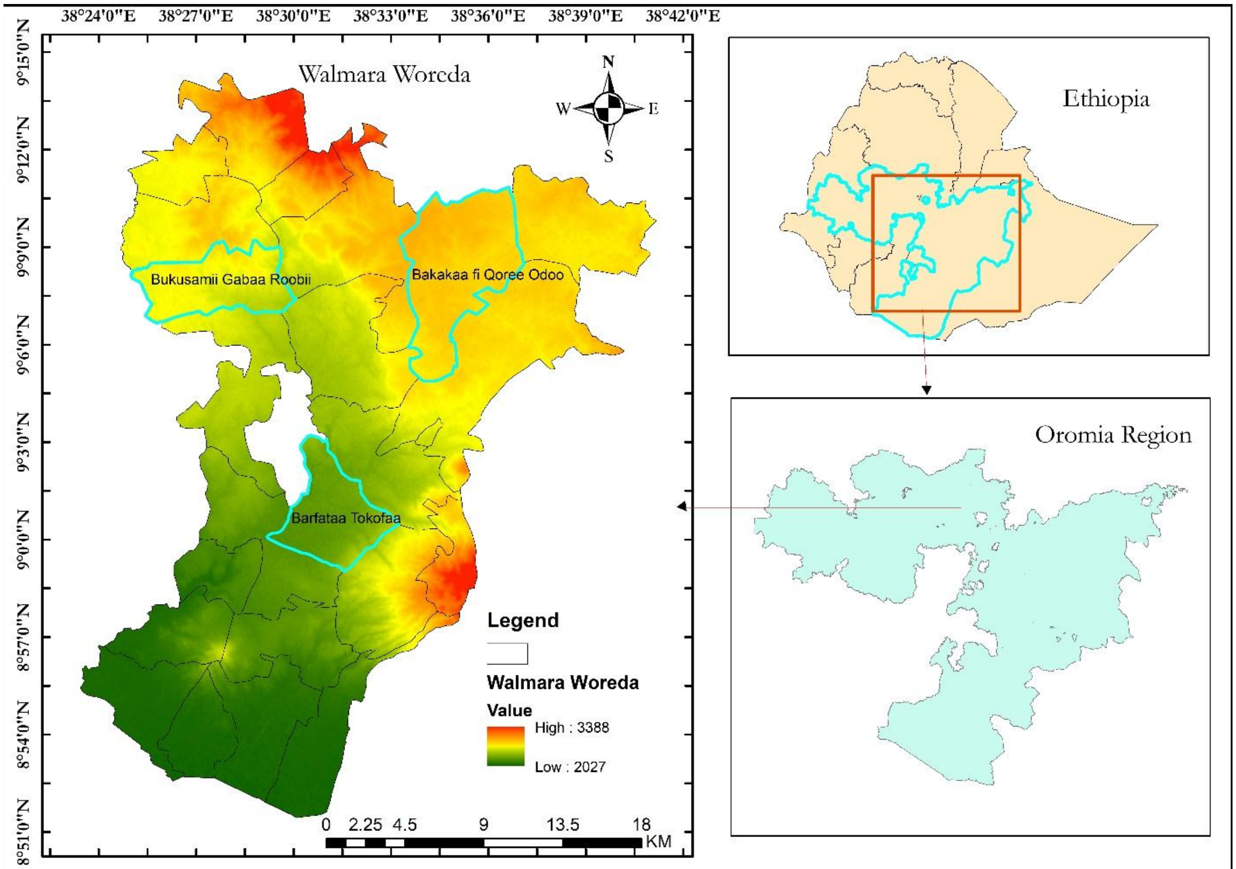
3.1. Description of the study area

The research was carried out in Walmara woreda, West Shewa zone, Oromia regional national State, Ethiopia. The woreda is located at 29 km to the west of Addis Ababa and geographically located between 8°50'-9°15' N and 38°25'-38°45' E. Holeta town serves as the woreda's administrative center. This woreda is bordered to the east by Shager City (kolobo woreda), to the west by Ejere woreda, to the north by Mulo woreda, and to the south by Sabata Hawas woreda. Administratively, there are 19 kebeles in the woreda, 18 of which are rural and 1 urban (WWAO,2023).

The woreda is located in a region with a total area of 755 square kilometers (75500 hectares), of which the majority (61%) is classed as highland and the remaining (39) as mid-highland. The bimodal rainfall pattern consists of a short-wet season from March to May and a protracted rainy season from June to September. The district's average elevation, which ranges from 1800 to 3380 meters above sea level (masl), is 2590 meters. The district receives between 834 and 1300 millimeters of rain year, with an average of 1067 millimeters. The district's average annual temperature is 22.5 oc, with a temperature range of 18 to 27 oc. Loam soil makes up the majority of the soils (60%), followed by sand (37%), and clay (3%) (WWAO,2023).

According to the WWAO (2023), there are 84,179 people living in Walmara woreda's rural and urban areas, with 45,426 males and 38,753 females. According to the 2007 census conducted by the Ethiopian Central Statistics Agency, the majority of people in Walmara Woreda were assessed to practice Ethiopian Orthodox Christianity (86.72%), followed by traditional beliefs (6.36%) and Protestantism (4.61%). Currently, in Walmara Woreda about 415 (279 Male and 136 Female) have been started producing and using vermicomposting technology in their agricultural farm land (WWAO, 2023).

The economic activities of the district propel is characterized by mixed farming system, where both crop and livestock production. The major crops grown in the district during the main season are wheat, barley, teff, pulses, oilseeds, and potatoes respectively. These crops are the major staple food crops in the study area. Similarly, the major vegetable crops grown during the off-season in the district using irrigation are potatoes, cabbages, tomatoes, carrots, and onions respectively (WWAO,2023).



Source: Own computed GIS based on literature review, 2023

Figure 2: Location map of study area (Walmara Woreda)

3.2. Research design

A research design can be defined as the strategy, the plan, and the structure of conducting a research project majority (Mtonga, 2014). The research design for this particular study was cross-sectional survey study and quasi-experimental with both quantitative and qualitative components were conducted. It is appropriate and suitable to use data collection tools such as questionnaires and focus group discussions (FGD).

3.3. Research approach

Since this study bases its analysis on a household survey, it utilized as a survey research method. In order to create a thorough analysis of the study, a mixed method that incorporates both quantitative and qualitative components was employed in the study design to effectively address the study's aim.

A qualitative method was employed to get a thorough understanding of the vermicomposting technique, including its key functions, contribution to enhancing soil fertility and boosting productivity, and its drawbacks. To gather qualitative data, semi-structured interviews, focus groups, and observation were conducted.

To quantify and analyze the relationships between the variables, a quantitative technique was adopted. Using a household survey, a cross-sectional study was conducted to gather information on the socioeconomic traits and demographics of households, the income status of smallholder households, the farmers' activities, and respondents' opinions regarding the preparation, use, and spread of vermicomposting technology.

Therefore, the study employs cross sectional study design with qualitative and quantitative approaches to identify factors determining adoption of vermicomposting technology in Walmara woreda of Oromia region. Such design is commonly used when the primary interest is to estimate prevalence than studying cause-effect relationship.

3.4. Sampling design

3.4.1. Target population

Smallholder farmers in rural areas make up the study's population. The target population is the entire group of persons from which a sample could be drawn. In the study area 162 rural households have been adopted vermicomposting technology in contrast 1689 rural households did not adopt vermicomposting technology, where,1851 households in the study area make up the two target groups of the overall population.

3.4.2. Sampling techniques and procedure

In this research, a three-stage sampling process were followed to choose the area of research and the respondent household. In the first stage, the study woreda from, West Shewa zone, Oromia region was selected purposively based on information obtained from woreda agriculture office on vermicomposting technology potential and the prevalence of improving soil fertility status in the area (WWAOR, 2023).

Three rural kebeles (lowest administration structure of Ethiopia below woredas/districts) were randomly selected from the potential kebeles of the research area for vermicomposting technology in the second stage. Through this random selection, each possible kebele for vermicomposting technology had an equal opportunity. The selected kebeles were Berfeta 1ffaa, B/Q/Oddoo and B/G/Roobii. After randomly selecting, the study kebeles vermicompost users and non-users' groups living in the kebele were identified (listed).

In the third stage, systematic random sampling technique was employed to draw sample households from the selected 3 kebeles grouped into adopter and non-adopter. The analysis revealed 184 sample households for the survey. A simple random sample method was used to select the respondents.

3.4.3. Sample size determination

The determinants of vermicomposting technology adoption are the primary focus of this study. The only reliable source of data on the population in question is a census survey. Sampling is one of the approaches that enables the researcher to look at a relatively small number of units due to time and financial restrictions (Sarantakos, 1998). The sampling frame was 1,851 households who are living in the three kebeles. The required sample size for this investigation was calculated using a simplified version of Yamane's (1967) formula, which is presented below. It has a 93% confidence level, a degree of variability of 0.5, and a level of accuracy of 7% (0.07). Due to time constraints, resource limitations, and difficulties with the data collection process because of security concerns, the researcher must employ this degree of precision.

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = Desired sample size,

N =Total population size (1851) and

e = Accepted error limit (0.07) on the basis of 93 percent degrees of confidences put into decimal form.

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{1851}{1 + 1851(0.07)^2}$$

$$n = \frac{1851}{10.0699}$$

$$n = 184$$

Therefore, based on Yamane (1967) simplified sample size determination formula the number of samples kebele is 3, the target sample size is 184 household heads, with a total population of 1851. Table 1 below includes the proportionate sample sizes for each kebele calculated using this method, as well as the population of each stratum for each of the three kebeles.

Table 1:Number of sample households for two strata from each kebele

No	Sample kebeles	Adopters		Non-adopters		Total sample	Percent
		Total population	Sample	Total population	Sample		
1	Barfataa 1ffaa	85	39	828	45	84	45.65
2	Bakaka fi Qoree Oddoo	43	21	364	30	51	27.72
3	Bukusami Gaba Roobii	34	16	537	33	49	26.63
Total		162	76	1689	108	184	100

Source: Own computation, 2023

The selection of the KII and FGD participants strictly follows the purposive sampling techniques. An interview with a key informant (KII) was done with the agriculture office of Walmara woreda (team leaders, experts, development agents (DAs), youth, women group, village administrations and representatives who have enough and long experience of agriculture were used as a key informant interview. In order to gather relevant and useful information to complement the survey data and to develop meaning derived from the analysis of the survey data, three focus group discussions (FGDs) were purposefully conducted with farmers who are assumed to be model/experienced farmers, women, and farmer's association groups in the study area. There was a total of 3 FGDs, one from each selected kebeles. Each FGD had 8 study participants.

3.5. Data collection method and tools

Surveys were utilized as the information gathering strategy. This survey strategy included key informant interviews, focus groups, and structured questionnaires. The quantitative data was collected using household survey questionnaire and mainly emphasize on collecting socio economic profiles, vermicomposting technology practices of household members, positive impacts and adverse consequences of adopting vermicomposting technology by household farmers. Through a home survey, focus group talks, key informant interviews, and field observations, primary data were gathered to gain both qualitative and quantitative data. A structured questionnaire was used to conduct a household survey among smallholder farmers in Walmara woreda. The questionnaire was included open-ended and closed-ended questions. These was assisted respondents in exploring their thoughts, feelings, and beliefs. Areas of inquiry was included individual information and socio-economic characteristics of farmers, experience with vermicomposting technology, access to and use of vermicomposting technology, and awareness and perceptions towards vermicomposting technology.

3.6. Data type and sources

3.6.1. Primary sources of data

There are two types of sources that can be employed for a study: primary and secondary data sources. According to the chosen research design, the researcher employs both primary and secondary data sources for the study. Primary data are data that a researcher acquires specifically for the goal of examining the study subject at hand. Kothari (2004), claims that questionnaires and interviews are methods for gathering primary data. Primary information was gathered directly from respondents in each chosen kebele who were either adopters or non-adopters of vermicomposting technology Therefore, the initial information was gathered using a variety of data collection tools, including field observations, focus groups, interviews with key informants, and household survey questioners.

Structured questionnaires were utilized to collect quantitative data, and key informant interviews and focused group discussions were employed to collect qualitative data. The quantitative information was utilised to evaluate the socio-demographic, socio-economic, institutional, and vermicomposting technology adoption status of the homes in both the vermicomposting technology adopter and non-adopter groups. Data on local perception and opinions of the factors influencing the adoption of vermicomposting technology on households were gathered using a qualitative method.

A. Household survey questioner

Using both open-ended and closed-ended questions, respondents' quantitative data was gathered. Quantitative information on the socioeconomic and demographic traits of smallholder farmers was gathered through the survey tool. In order to gather quantitative information at the household level, a structured questionnaire was utilised in the household survey. The household survey included questions about vermicomposting practises, personal information, household resources, productivity, and income. In order for the respondents to comprehend the questions, the questionnaire is initially written in English before being translated into Afan Oromo. Five small-holder farmer homes were used as pre-test subjects for the survey in order to assess the produced questions. After the pre-test, pertinent questions were omitted. 184 homes in the research areas participated in the survey. Based on their proficiency in the local language and culture as well as their prior experience conducting in-person interviews to gather data, three enumerators—one for each kebele were hired. The data collectors had completed their bachelor degrees by agriculture. Before the survey began, the enumerators received training on the protocol to follow while interviewing respondents, and a thorough discussion was held to make the questionnaire clear to prevent confusion while asking and filling it out.

B. Focus group discussions (FGDs)

In order to supplement the data gathered through surveys, FGD was undertaken. FGDs were held with selected and knowledgeable community representatives in respective selected sample study sites. Focus group discussions were held to learn more about farmers' practices and attitudes towards vermicomposting technology, to gauge its level of adoption, and to pinpoint the variables influencing its uptake in the research area. Additionally, focus groups are employed to collect firsthand information from local populations.

The results of the FGD were utilized to help create a household questionnaire and gather more qualitative data in support of the findings. Members of the FGD, which included both men and women, were not contacted for the individual interviews. Each study area had one focus group discussion, with each group consisting of eight people. The conversation's outcomes were put to use to create a home survey and acquire further qualitative data that supported the usage of vermicomposting technology in households and the challenges that farmers have faced in doing so. This made it possible for the researcher to gather qualitative information to describe the factors influencing vermicomposting technology uptake in the study's target region.

C. Key informant interview (KIIs)

Interview is a tool for gathering data that uses thoughtfully created questions. Interview guidelines (a written set of open-ended questions) was created for this interview. Additional information received from key informants needs to be added to the original data collected from sample farms. Thus, intensive interview was conducted with key informants. As a result, a key informant interview was conducted with representatives from the village administrations, youth organizations, women's groups, team leaders, development agents (DA), and the district level agricultural office of soil fertility experts. The points of discussion focused on key issues of concern, related to determinants of adoption of vermicomposting technology among smallholder farmers. The interviews took place in the research areas' native tongue and were then translated into English for analysis.

D. Field observation

Field observations are initiated when the proposal is being written and continue throughout the data gathering process. While on the walk, the researcher takes notes on the determinants of vermicomposting technology adoption in the research region. Understanding the local community's situation provides the foundation for the adoption of vermicomposting technology.

3.6.2. Secondary sources of data

The study will include secondary data that was gathered from a variety of sources, including a review of published and unpublished materials that are important to the study, including reports, articles, books, legal documents (proclamation, plan), study-related theses, and dissertations. A range of resources, including the internet, libraries, and organisations, were used to collect the data

3.7. Method of data management and analysis

Data was entered into a computer using SPSS version 26 after it had been collected, edited, and coded. The gathered data were subjected to various analyses for the goals of this particular study. Depending on the objectives of the study, both descriptive and inferential statistics as well as an econometric model were utilized.

3.7.1. Descriptive statistics

The descriptive analysis of the survey data produced by the sample respondents was primarily focused on the descriptive statistics. The information that was extracted from the data using descriptive analysis mainly relates to the socio-demographic characteristics of the sample households, their resource endowment, and their institutional characteristics using means, percentages, and standard deviations. Furthermore, the chi-square test and t-test were used to determine whether categorical variables and continuous variables were associated with the dependent variable. Additionally, KII and FGD data were qualitatively analyzed utilizing narrative and interpretation

3.7.2. Econometrics model

Determinants of vermicomposting technology adoption were identified using logistic regression model. Quantitative variables and qualitative variables were included in the model as variables. U is a disturbance term, and it is assumed that it has a constant variance and a mean of 0.

3.7.3. Model specification

The logit model was used to determine the link between the dichotomous dependent variable and set of independent variables that are influencing the outcome in order to analyze the factors that influence households' adoption of vermicomposting technology (Wooldridge, 2010). Adoption of vermicomposting technology is influenced by a variety of factors, including socioeconomic, demographic, and other characteristics. This is a dummy variable by nature. The dependent variable Y (determinants of vermicomposting technology adoption) in this study is a dichotomous variable with a value of 1 if the household adopts this technology and 0 otherwise. Probability regression models are best suited to examine the relationship between dependent and independent factors when the dependent variable is dichotomous.

The probability of the dependent variable given the independent variable is calculated when the response variable is qualitative. The logit model is one of the most used qualitative regression models (Gujarati, 2004). In order to estimate the likelihood that an event will occur or not, a multivariate method known as logit regression must first predict a binary result for a set of independent variables.

Models with a dependent variable of the yes-or-no variety are referred to as dichotomous or dummy variable regression models. These models roughly represent the mathematical relationships between independent explanatory variables and the dependent variable, to which qualitative response variables are always allocated (Gujarati 1988; Feder et al., 1985). The outcome variable in these functions is binary or dichotomous, which is a key difference between them and the linear regression model (Hosmer et al., 2013).

Models like the Probit and Logit models are frequently employed. The cumulative normal probability function is related to the Probit probability model. The Logit model, however, makes an assumption about the cumulative logistic probability distribution. Because the probabilities are limited to values between 0 and 1, the binary logit model has an advantage over the linear probability model. These models benefit from having probabilities that are limited to the interval between 0 and 1. Additionally, they provide the greatest fit to the non-linear connection between the probabilities and the independent variables, i.e., one that approaches zero at slower and slower rates as an independent variable (Xi) shrinks and approaches one at slower and slower rates as xi increases (Train, 1986).

Practical considerations like computer programme availability and adaptability, individual desire, experience, and other amenities play a role in deciding between these two types. In actuality, it resembles the cumulative normal distribution very closely. According to Hosmer et al., (2013), a logistic distribution has an advantage over other types of distributions for analyzing dichotomous outcome variables. The logistic distribution is preferred for two main reasons. These are: (1) It is a very adaptable and simple function from a mathematical perspective; and (2) It is amenable to a meaningful interpretation. According to Hoetker (2007), the logit model has a simpler estimating process than the probit model. As a result, the binary regression method is employed to assess the relationship between the independent factors and the outcome variable. To estimate the relationship, it requires the use of qualitative response models. Specification of model as follows.

According to Gujarati (1995), the functional form of logit model specified as follows.

$$P_{i=\epsilon}\,(Y=\frac{1}{xi}) = \frac{1}{1+e^{-(\beta 1+\,\beta 2xi}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

In the logistic distribution, Pi is the dependent variable, xi is the data, and i is the likelihood that an individual would respond (the likelihood that ith individual will have a value of either 1 or 0). When β1+β2Xi in equation 2 is obtained.

$$Pi = \frac{1}{1+e^{-Zi}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Zi is between -∞ and +∞, and Pi is between 1 and 0 when Pi shows the possibility of vermicomposting adopter, the possibility of not vermicomposting adopter is 1-Pi (Harrel, 2001). Then the possibility of not vermicomposting adopter explained as in equation 3 as follows:

$$1- Pi = \frac{1}{1+e^{Zi}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Equation 4 is obtained by dividing the vermicomposting adopter by not vermicomposting adopter:

$\frac{Pi}{1-Pi} = \frac{1+e^{Zi}}{1+e^{-Zi}} = e^{Zi}$ ……………………………………... (4)

When the natural logarithm of both sides of the equation is written, Equation 1 is obtained:

Li = ln $(\frac{Pi}{1-Pi}) = Zi = \beta 1 + \beta 2Xi$ …………………………………. (5)

As a result, the non-linear logistic regression model's parameters and variables have been liberalized. "L" is referred to as "logit," and models like this are referred to as "logit models" (Gujararti, 1995, 2004). When there is more than one independent variable, (X1, X2....... XK), binary and logistic models apply. Equation 1 is applied in these cases to perform the necessary transformations: Pi=ϵ $(Y=\frac{1}{xi}) = \frac{1}{1+e^{-(\beta 1+ \beta 2x1+ \beta 3x2+\cdots+ \beta kxk}}$ … … … … … … … . . (6)

In logistic regression models involving a binary code, categorical dependent variable has the following assumptions (Agresti, 1996 & Tuzunturk, 2007):

i) Conditional mean of logistic regression has a value between 0 and 1

ii) If the data is X, the possibility of Y's being 1 is Pi, that is, $E\ (Y=1|\ X\ i....Xk) = Pi$

iii) N number of observations about dependent variable is statistically independent

iv) Defining variables are independent of each other

$Zi = \beta 0 + \beta iXi + Ui$ … . (7)

Where Zi= the dependent variable (Adopting vermicomposting technology)

Xi = a vector of explanatory variables

βi =a vector of estimated coefficient of the explanatory variables

Ui = disturbance term

3.8. Descriptions of variables and working hypothesis

The prospective independent variables must be identified, together with their measurements, after the analytical technique and its requirements are recognized. The research area's adoption of vermicomposting technology is anticipated to be influenced by a variety of factors.

Following is a presentation and explanation of the key factors that are anticipated to have an impact on how widely vermicomposting technology is adopted by households:

3.8.1. Dependent variables

The dependent variable of the study is factors affecting adoption of vermicomposting technology. The dependent variable for the logit analysis, factors affecting household heads' adoption of vermicomposting technology (FAAVT), is a dichotomous dependent variable in the model, taking a value of 1 if the household uses vermicomposting technology and 0 otherwise.

3.8.2 Treatment variable

The treatment variable was adopting vermicomposting technology taking If the farmer used vermicomposting technique, the value would be 1, otherwise it would be 0.

3.8.3. Independent variables

The independent variables are those that influence the dependent variables, which in this particular study are the elements that influence vermicomposting technology adoption. Based on the literature that is currently available, the independent variables that are hypothesized to have association with adoption of vermicomposting technology were chosen for binary logit regression. The demographic, socioeconomic, and institutional elements that may have an impact on the study population's dependent variables serve as the study's independent variables. Therefore, the following independent variables were presented to test whether they could account for households' adoption of vermicomposting technology in the study area, using the factors impacting household vermicomposting technology adoption as a dependent variable.

Sex of the household head (SOHH): A dummy variable called "sex" has a value of 1 if the household head is a man and a value of 0 otherwise. A household head is a person who provides financial assistance for the household. It might be a man or a woman. One of the elements impacting the adoption of new technologies, such as vermicomposting technology, is discovered to be the gender gap. In comparison to homes headed by men, those headed by women are less effective and less able to adopt new technologies (Asmelash, 2014). Therefore, sex is proposed that male household heads tend to adopt new technology more frequently such as vermicomposting technologies to increase soil fertility and productivity than female headed households.

Age of the household head (AOHH): Age is a constant explanatory factor that is expressed in years. In Ethiopia, decisions about farm operations are made by the household. Age of household may have negative or positive factors that affect adoption, in one of many different ways. The advantages of older farmers making decisions more easily than younger farmers because they may have more expertise, resources, or power, which would provide them more opportunities to experiment with new innovations. On the other hand, it's possible that younger farmers are more inclined to adopt new innovations since they may have received a better education than older farmers and have had more exposure to innovative concepts, making them more willing to take risks (Admassie and Ayele, 2010). Therefore, it is hypothesized that the age of the household head will either favour or hinder the adoption of vermicomposting technology.

Education status of household spouse (EDUSOHS): It is a continuous variable determined by the number of formal schooling years the household spouse has finished. It is predicted that a person will be more opened to new ideas the longer they are exposed to education. The advantages of current technologies may also be better understood by educated farmers, who may also be better able to understand new information and, as a result, more readily accept new technologies. In order to boost domestic production and satisfy family consumption needs, it was believed that households with greater levels of education would be better equipped to apply scientific knowledge and better manage their farm activities. Therefore, adoption of household vermicomposting technology benefits from education. As a result, the level of education of the household head positively affects the status and rate of adoption of technology (Gedefaw, 2019).

Family size of the household (Family size): The size of the household that resides together under one roof is indicated by this variable. The Adult Equivalent (AE) unit of measurement is a continuous variable. Since improved agricultural technologies involve more labor, it is projected that households with larger adult equivalent household sizes will adopt agricultural technologies in this case, vermicomposting than households with smaller adult equivalent household sizes. Therefore, family size was hypothesized to positively related with adoption of vermicomposting technology.

Dependency ratio (DEPRATIO): The dependence ratio was calculated by dividing the number of household members who are dependent by the number of household members who are between the ages of 15 and 64 (John, 2002). Due to their lack of economic activity, these groups become dependent on other family members to meet their urgent food needs. As a result, it is anticipated that the reliance ratio will negatively affect the household's adoption of vermicomposting.

Access to extension (ACCETN): This dummy variable tracks the availability of agricultural extension services for the household. It is possible that the extension service's access to farmers will hasten the information's spread among them. The adoption of vermicomposting technology by the farmers is predicted to be positively influenced by this characteristic.

Frequency of contact with extension agents (FRECONEAs): The number of interactions the respondent had with extension agents per month is indicated by this. The endeavour to propagate new agricultural technologies is made in the extension agent's area of contact with the nearby farmers. In this instance, it is hypothesized that the extension agent's regular contact with the farmers will likely speed up the efficient dissemination of important agricultural information to them and affect their decision to use vermicomposting technology. The adoption of vermicomposting technology was thus positively hypothesized to be influenced by the frequency of contact with an extension agent.

Access to credit service (ACCCRS): This dummy variable has a value of 1 when a household has access to credit and 0 when it does not. Depending on the amount and use of the credit, it can be used to engage in activities that generate money and enjoy benefits. Access to financing increases a household's likelihood of using inputs and implementing agricultural innovations. Farmers may overcome their financial challenges and buy inputs if they have access to financing. The availability of credit has a beneficial impact on the adoption of new technology (Tiamiyu et al., 2014; Gebresilassie and Bekele, 2015). Therefore, it was hypothesized that having access to financing and acquiring it would influence households' decisions to embrace vermicomposting technology positively.

Livestock holding (TLU): The number of animals possessed by the household, expressed as tropical livestock units (TLUs), is a continuous variable. Households with a lot of animals can profit more from the sale of animal products. These funds can subsequently be used by smallholder farmers to purchase agricultural inputs. Livestock is a significant source of money, food, and draught power. It also serves as a financial resource and a sign of the household's wealth and social standing. According to Gebresilassie and Bekele (2015), more cattle owners adopt new agricultural methods at a higher rate. Therefore, it is hypothesized that livestock ownership will influence families' adoption of vermicomposting technology in a positive way.

Cultivated land size (CULTLS): This is the entire area of cropland that a household has grown crops on over the last years' worth of produce. It is directly related to the growth of crops. The availability of food grains and the use of vermicompost are both correlated with the area of the farmed land. Therefore, it was anticipated that the amount of the cultivated area would have a favorable or negative impact on whether a household used vermicomposting technology.

Non-farm income (NOFINCO): This is a dummy variable that has a value of 1 when the household engages in non-farm activities and a value of 0 when it doesn't. Off-farm income, derived from sources other than farming, influences the adoption of new technology. Family members who engage in both on- and off-farm activities increase their income, enabling them to employ vermicomposting technology. This extra income is crucial for meeting family needs and purchasing necessary components for the technology's application. The availability to additional income for input purchases is better for households engaged in non-farm activities. The adoption of new technology is positively influenced by participation in non-farm income-generating activities, as studied by Olalekan and Simeon (2015). Therefore, it is hypothesized that household adoption of vermicomposting technology will be positively influenced by participation in non-farm income.

Participation in demonstration (PDEMON): It is a dummy variable with a value of 1 if the participant in the demonstration had participated, and 0 otherwise. According to Mulugeta (2011) and Hagos et al. (2018), field days are anticipated to positively influence farmers' adoption of new technology. Participation in a demonstration is therefore anticipated to have a positive impact on vermicomposting technology adoption.

Table 2:Summary and hypothesis list of independent explanatory variables for dependent variables (Adoption of vermicomposting technology)

Variables	Definition of variables (Description)	Variable type	Unit of measure (Value)	Anticipated sign
Dependent variable	Factors affecting adoption of vermicomposting technology	Dichotomous	1 if adopter;0 otherwise	
Independent Variables				
Demographic Factors				
Sex	Farm household leader's sex	Dummy	1 if male; 0 if female	(+ve)
Age	Farm household leader's age	Continuous	Years	(+ve/-ve)
Family size	Number of families living in the house	Continuous	AE	(+ve)
Institutional Factors				
Education	Years of education for the Head of household	Continuous	Years	(+ve)
Access to extension	Access to different agricultural extension services	Dummy	1 if male; 0 female	(+ve)
Frequency of contact with extension agents	The number of contacts the household head had with extension agents each month.	Continuous	Number	(+ve)
Access to credits	Household access to credits services	Dummy	1 if male; 0 female	(+ve)
Field demonstration	Household head access to field visit demonstration	Dummy	1 if male; 0 female	(+ve)

Socio Economic Factors				
Livestock	Household heads livestock ownership	Continuous	TLU	(+ve)
Land size	The size of cultivated land in hectares	Continuous	Hectare	(+ve)
Income from farming	Income from obtained from farming	Continuous	Birr	(+ve)
Off-farm income	Income from off-farm activities	Continuous	Birr	(+ve)
Biophysical factors				
The extent of soil fertility problem	The perception of farmers towards soil fertility problem	Dummy	Slight Moderate High Severe Very severe	(-ve)
Distance to nearest farm land	Distance from vermicompost preparation area to nearest farm and (at least one plot)	Continuous	Kilometre	(-ve)

Source: own computation for survey data, 2023

3.8.4. Multicollinearity test

To ascertain the correlation between the independent variables, a test for multicollinearity has been carried out. Multicollinearity, as defined by Mendenhall et al., (2003), is the degree to which new independent variables can account for one independent variable in the analysis. Regression may be negatively impacted if it is set too high. Multicollinearity occurs when more than one predictor in the model is linked together and provide duplicate information about the response. In this case, the variables are too closely related. After the construct correlations were checked for multicollinearity, the variance inflation factor (VIF) was employed to assess the correlations between explanatory variables. As the VIF is under 10, (average vif=1.48), this demonstrates that the analysis is free of multicollinearity issues.

3.9. Ethical Considerations

Before the study was conducted the proposal was reviewed and approved by the academic commission of the center for environment and development studies some time before the approval of the standard operation procedure (SOP) of the college. Therefore, the center institutional review board (IRB) has reviewed the content of the proposal, data collection instruments (tools) and observance of informed consent of the respondents. Accordingly, after thorough review of the submitted documents, it is decided to award certificate of ethical clearance.

In conducting a study ethical issue has a vital role. To guarantee that respondents are protected from any potential harm that could result from engaging in the study, the researcher takes into account the research values of voluntarily participating, privacy, and identity. As a result, the researcher first asks the respondents for their consent to participate in the study after describing its goal, purpose, and character as a component of a Master's degree programme. Therefore, the writer has respected the respondent`s right, dignity, promised to preserve confidentiality and anonymity. Measures will be taken to uphold ethical principles, and the researcher was ensuring that the research results are communicated honestly and completely. The data is collected based on the willingness and freedom of participants.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1. Descriptive statics

First before going to the econometric analysis of determinants of adoption of vermicomposting technology, it is imperative to consider the descriptive analysis of sample data. Accordingly, below the descriptive analysis of demographic and socio-economic characteristics of sampled households were discussed in detail. In this study the analysis of means, percentages, standard division and frequencies were used. Inferential statistics such as t- test and chi- square tests are also conducted to compare treatment group and comparison with respect to different variables in order to analyze whether there is a significant difference between vermicomposting technology adopter and non-vermicomposting technology adopter.

Response rate of the respondents: Out of total 184 households all were participated in the study (questionnaire return rate was 100%). Furthermore, 7 KII have participated and 3 FGD was used.

4.1.1. Description of demographic characteristics of respondents for categorical variables

Sex of the household head: The results in Table 3, show that out of 184 respondents, 78.8% and 21.2% were males and female headed respectively with very few differences among vermicomposting technology adopter and non-adopter households. This showed that both adopters and non-adopters' female households are small compare with males. The findings showed that male and female participation in farming activities is not equal in the study area. The chi-square test revealed statistically insignificant difference among vermicomposting technology adopters and non-adopters with headship of the respondent. The result of this study supports earlier research conducted by Dube (2016).

Marital status of the household headed: As shown in Table 3, the marital status of the survey respondents ranging from 86.41% were married, followed by 5.43% divorced, 2.73% separated, 2.72% single and 2.72% widowed respectively with very limited difference between vermicomposting technology adopters and non-adopter farmer households. Grate majority, 92.6% non-adopter and 96% adopter farmers were married. This may imply that vermicomposting technology adopters were more likely practiced in married households as such families have relatively better agricultural labor. This supports farming operations with a large labor force as confirmed by statistically significance (5% level), chi-square test among adopters and non-adopters considering marital status. This finding also aligned with analysis result Dube (2016).

Table 3: Summery of demographic categorical variable

Variables	Adopters (N=76)		Non-adopters (N=108)		Total (184)		X2
	N	%	N	%	N	%	
Sex							0.11
Male	59	77.6	86	79.6	145	78.8	
Female	17	22.4	22	20.4	39	21.2	
Total	76	100.0	108	100.0	184	100.0	
Marital status							14.74**
Married	59	77.6	100	92.6	159	86.41	
Single	3	3.9	2	1.9	5	2.72	
Divorced	4	5.3	6	5.6	10	5.43	
Widowed	5	6.6	0	0	5	2.72	
Separated	5	6.6	0	0	5	2.72	
Total	76	100.0	108	100.0	184	100.0	

Source: Field survey, 2023 ***, ** and * Significant at 1%, 5% and 10% respectively

4.1.2. Description of demographic characteristics of respondents for continuous variables

Age of the household head: The sample's household heads had an average age of 43.88 years (SD=8.01), with minimum and maximum ages of 30 and 67, respectively with statistically insignificant. Average age difference of adopter 43.45 years, compared to non-adopter (44.30 years) households (Table 4). Therefore, the results, show that, the majority of households were in productive age. This analysis result contradicts the argument of Mwangi and Kariuki, (2015) that younger farmers are more likely to use organic fertilizer on their farms due to their propensity to be less risk-averse and more open to experimenting with new technologies.

Family size of households: According to Table 4, the average number of family size was 4.46 (SD=1.42), with a ranging 2 to 9, where adopter and non-adopter households had insignificant (chi-square test), family size, i.e., 5.46 (SD=1.41) and 5.73 (SD=1.44), respectively. Therefore, family size doesn't determine adaptation of vermicomposting technology. However, this contradict the report of Ajewole (2010), which claimed that the extra work needed to apply organic fertilizer and vermicomposting technology application, may require be doable for larger family size to overcome additional workload.

Dependency ratio: According to the field survey findings shown in Table 4, the sampled households' average mean dependency ratio is 2.29 (SD=1.23) which statistically significant (Chi-square test) difference in the dependency ratio of 2.25 (SD=1.34) for adopting and 2.32 (SD=1.12) non-adopting households. This analysis revealed that households' dependency ratio doesn't have effect on vermicomposting technology application.

Table 4: Summery of demographic continuous variable

Variables	Adopters (N=76)		Non-adopters (N=108)		t-value
	Mean	Std.Dev.	Mean	Std.Dev.	
Age of the household head	43.45	8.96	44.30	7.06	-0.72
Family size of households	5.46	1.41	5.73	1.44	-1.08
Dependency ratio	2.25	1.34	2.32	1.12	-0.41

Source: Field survey, 2023 ***, ** and * Significant at 1%, 5% and 10% respectively

4.1.3. Description of institutional characteristics of respondents for categorical variables

Access to credit services: The survey showed that 35.3% of overall respondents of which, 43.4% of adopter and 44.4% and 29.6% of non-adopter households have access to credit services (Table 5). This indicate that, households who adopted vermicomposting technology have had more credit than the non-adopter households. The chi-square test revealed that vermicomposting technology adopted households had significantly high access to credit service a 5% difference than non-adopter households. In connection to this, Gedefaw (2019) found that maintaining, other constant, credit access significantly and positively affected the intensity of adoption of improved maize BH540 variety.

The FDG also confirmed that the majority of vermicomposting technology adopters, used credit to purchase agricultural inputs to increase agricultural production, while the majority of non-vermicomposting technology adopters used credit for personal consumption. Adoption of vermicomposting technology has a good association with credit as the credit enabled households have a better chance of obtaining farm inputs and technologies. Thus, the credit accesses enabled the farmers to hire labor, rent land, and buy inputs like vermicomposting preparation boxes. As a result, there was a higher likelihood that vermicomposting technology would be adopted.

Contacts with DA: The survey showed that grate majority (91.85%) respondents (94.7% of adopter and 89.8% non-adopter) had contact with development agents (DAs) on agricultural activities (Table 5). Both adopter and non-adopter farm households got equal agricultural technical advices from agricultural extension agents as verified by statistically insignificant chi-square test. Therefore, from this it can be deduced that the extension service might not include proportion of vermicomposting technology as extension is intended to has an immediate impact on farmers' adoption behaviors. The more often a farmer interacts with an extension agent, the more likely it is that they will be influenced to adopt new agricultural technologies.

Frequency of contacts with DA: This has to do with how frequently the family interacted with extension agents each month. The connection between kebele-level farmers and the extension agent includes the effort to spread innovative agricultural technologies. The results for farmers' frequency of contact with extension agents were used to calculate the results for farmers' frequency of contact with development agents. Farmers who have no relation with extension workers received a result of zero; those who have contact once a month received a result of one; those who have contact twice a month received a result of two; those who have contact three times a month received a result of three; those who have contact four times a month received a result of four. and those who have contact five times a month received a result of five.

According to the field survey, a farmer could produce a maximum of 5 and a minimum of 0. The outcomes of the field investigation also revealed that 89.8% of non-adopter household heads had monthly interaction with extension agents compared to 94.7% of adopter household heads who have frequent contact with them. Furthermore, the results of the field study show that 5.3% of adopters and 10.2% of non-adopters do not communicate with the development agent on a monthly basis. This demonstrates that households with more regular interactions with extension agents are more adoptive than non-adopter households. The chi-square test revealed a significant difference between adopter and non-adopter households in the frequency of contacts with DA at the 5% significant level. This indicates that there is a statistical difference in the frequency of encounters with DA between adopters and non-adopters. The results of the study given by Negash (2007) and Gebrelibanos (2007) are consistent with this outcome.

Access to extension services: As shown in Table 5, 90.7% of non-adopter and 94.7% of adopter households have access to extension services. Access to extension service among vermicomposting technology adopter and non-adapter farm households don't have statistically significant as per a chi-square test result. The adoption of vermicomposting technology is positively correlated with the use of extension services, which suggests that households who frequently utilize extension services may have superior skills and knowledge regarding current technology, input utilization, and vermicomposting technology adoption.

Participation on training: The field survey result indicates that, 97.4% of adopters and 71.3% of non-adopters' participants were participated in agricultural training in 2021/2022 cropping season. The mean difference was likewise statistically significant at the 1% probability level, according to the chi-square test. However, as per FGD finding the training doesn't have sufficient content on uses of organic fertilizer and vermicomposting technology.

Participation on field demonstration: The field survey result indicates that, 63.59% of survey households in general out of which 97.4% of adopter and 39.8% of non-adopter households participates in field demonstration in 2021/2022 cropping season with statistically significant difference among the two groups at the 1% probability level, according to the chi-square test.

Access in non-farm (off-farm) activity: According to the results of the field survey, for the entire sampled household population, there were approximately 70.7% of households without access to non-farm activity. Comparison of adopting and non-adoptive households showed relatively, adopter households had more (36.8%) access than non-adopting (24.1%) households to non-farm activities. The findings indicate that households using vermicomposting technology have adopted non-farming activities at a higher rate than households not using the technology. The results show that increasing farm households' annual income and access to food may depend more on their involvement in non-farm activities. The chi-square test revealed a difference between adopter and non-adopter household's participation in non-farm activities is statistically significant at a 10% level. The outcomes of this study support earlier conclusions made by Gedefaw (2019) and Dube (2016).

Table 5: Summery of institutional categorical variables

Variables	Adopters (N=76)		Non-adopters (N=108)		Total (184)		X2
	N	%	N	%	N	%	
Access to credit services							3.71*
Yes	33	43.4	32	29.6	65	35.33	
No	43	56.6	76	70.4	119	64.67	
Contacts with DA							1.44
Yes	72	94.7	97	89.8	169	91.85	
No	4	5.3	11	10.2	15	8.15	
Frequency of contacts with DA							12.51**
No contact	4	5.3	11	10.2	15	8.15	
Once a month	7	9.2	19	17.6	26	14.13	
Twice a month	36	47.4	50	46.3	86	46.74	
Three rounds a month	22	28.9	16	14.8	38	20.65	
Four rounds a month	5	6.6	10	9.3	15	8.15	
Five rounds a month	2	2.6	2	1.9	4	2.17	
Access to extension services							1.01
Yes	72	94.7	98	90.7	170	92.39	
No	4	5.3	10	9.3	14	7.61	
Participation on training							20.60***
Yes	74	97.4	77	71.3	151	82.07	
No	2	2.6	31	28.7	33	17.93	
Participation on field demonstration							63.82***
Yes	74	97.4	43	39.8	117	63.59	
No	2	2.6	65	60.2	67	36.41	

Non-farm activity							3.51*
Yes	28	36.8	26	24.1	54	29.35	
No	48	63.2	82	75.9	130	70.65	

Source: Field survey, 2023 ***, ** and * Significant at 1%, 5% and 10% respectively

4.1.4. Description of institutional, socio-economic and biophysical characteristics of respondents for continuous variables

Educational status of the household spouse: According to the results of the field survey given in Table 6, adopter and non-adopter households had average education status of 3.16 (SD=0.46) and 1.88 (SD=0.47) years, respectively. Hence, adopter households had a higher mean education status than non-adopter households. This indicates that use of vermicomposting technology is positively correlated with education status of respondents.

The t-test results showed that, the household head's education status of adopters was statistically significantly higher than the non-adopters at the 1% level of significance. Literate farmers are therefore more open to adopt new technology than the illiterate ones probably as they have better opportunity to get information and new technology. Therefore, education may enable farmers to make effective decisions and early adopters (Orinda, 2013).

Livestock holding (TLU): Adoption of vermicomposting technology is positively influenced by the quantity of cattle owned. According to the results of the field survey (Table 6), the average number of cattle owned by adopters and non-adopters were 8.58 and 7.84 (SD=3.91 and 3.3), respectively. The t-test comparing livestock holding between adopters and non-adopters produced was statistically insignificant indicating that the livestock holding doesn't caused difference for the vermicomposting technology adoption.

Cultivable land size: The result of the descriptive analysis shows that the mean cultivable land size calculated for the total sample households in the study area was 1.6 ha, with minimum and maximum cultivable land size of 0.25 and 3.63 ha, respectively. On the other hand, the mean cultivable land size of the household for adopter was found to be1.63 ha, with 0.25ha minimum and 3.63 ha maximum cultivable land holding size for adopter and non-adopter households don't have significant difference (insignificant t-test result), i.e., the mean farmland holding were 1.63 ha and, 1.57 ha respectively. Although land holding of household is positively related to household vermicomposting technology adoption, however farmland holding of the two groups doesn't have difference to see the difference.

Farm income: Table 6 displays the average income of households who have adopted vermicomposting technology and those who have not. The average annual income for vermicomposting technology adopter households was 99,723 Birr and 57,134 Birr, for non-adopter households. The chi-square test revealed statistically significantly higher average income of vermicomposting technology adopter compared to non-adopter households at a 5% significance level. These findings align with the conclusions drawn by Dube (2016).

Distance to the nearest farm land: It is the distance travel (kilometer) from vermicompost production (mostly homestead) to the farmland where farmers apply the vermicompost. As depicted on Table 6, the average distances adopted and didn't adopt households were 0.33 (SD=0.28) and 0.63 (SD = 2.34). The descriptive analysis showed insignificant difference between adopter and non-adopter households concerning in distance between places of vermicompost preparation to the farmland where farmers apply vermicompost. Although, the t-test showed insignificant difference among the two groups on the distance between vermicompost making (homestead) and application (farmland) of adopter (average of 0.33 km) households were nearer than non-adopter households (0.63 km).

Distance from farmland impacted the adoption of vermicomposting technology negatively. More farm land distance from production area to application area low adoption of vermicomposting technology and near farm land to production area and application area high adoption of vermicomposting technology.

The extent of soil fertility problem: Is the farmer's perception on farmlands soil fertility level, which range from slight (1), moderate (2), high (3), severe (4) and very severe (5). Accordingly on average farmers rated soil fertility problem of their farmlands between high and severe with some difference between vermicomposting technology adopted and didn't adopt households with mean liker scale rating of 3.53 (SD =1.33) and 3.96 (SD =1.28), respectively. The descriptive analysis showed significant difference between adopter and non-adopter households regarding the extent soil fertility problem of their farmlands.

Table 6: Summery of Institutional, socio-economic and biophysical continuous variables

Variables	Adopters (N=76)		Non-adopters (N=108)		t-value
	Mean	Std.Dev.	Mean	Std.Dev.	
Institutional continuous variable					
Education status of the household head	3.16	0.46	1.88	0.47	18.32***
Socio-economic continuous variables					
Livestock holding	8.58	3.91	7.84	3.3	1.17
Cultivable land size	1.63	0.85	1.57	0.61	0.56
Farm income	99723.68	124932.34	57134.26	25949.86	3.44**
Biophysical continuous variables					
Distance to the nearest farmland (kilometers)	0.33	0.28	0.63	2.38	-1.09
The extent of soil fertility problem	3.53	1.33	3.96	1.28	-2.24**

Source: Field survey, 2023 ***, ** and * Significant at 1% level, 5% and 10% respectively

4.2. Smallholder farmers perception on use of vermicomposting technology for soil fertility improvement

Perception on status of farmlands soil fertility status: The respondents were enquired their perception on their farm lands soil fertility status. Accordingly, the survey result revealed that, 40.8%, 25%, and 34.2% of adopter household heads respectively responded slight, moderate and severe soil fertility problems whereas 27.8%, 20.4% and 51.9% of non-adopter household heads respectively responded slight, moderate and severe soil fertility problem. The chi-square test showed that statistically significantly higher proportion of vermicomposting technology adopting households reported less soil fertility problem on their farmlands compared to the non- adopting households at a 5% significance level. FDG and KII revealed that farmlands of households adopting vermicomposting technology have less soil fertility problem compared to non-vermicomposting adopting households. The discussants indicated that vermicomposting technology adopted households known their farmlands soil fertility problem and use vermicomposting technology to reduce soil fertility problem.

Perception on solution of soil fertility problem: The respondents were asked about their views on addressing soil fertility issues. Accordingly, the survey revealed that 100% respondents from vermicomposting technology adopted endorsed use of organic fertilizers (such as vermicompost, compost, and FYM) is solution to soil fertility problem rejected uses of chemical fertilizer and practice of Soil and Water Conservation (SWC). In convers, non-vermicomposting technology perceived SWC (51.9%), use of chemical fertilizer (14.8%) and use of organic fertilizer (33.3%) as solution for farmlands soil fertility problem.

These results indicate that households who have adopted vermicomposting technology tend to rely more on organic fertilizers to enhance soil fertility and increase productivity, while non-adopter households have a more varied perception of soil fertility solutions, including the use of chemical fertilizers and application of SWC beside use of organic fertilizer. The chi-square test for the perception of soil fertility problem solutions between adopters and non-adopters was found to be significant at a 1% significance level, demonstrating a substantial difference in how adopters and non-adopters perceive solutions to soil fertility issues. FDG and KII also showed that, the adopters have used vermicomposting technology than non-adopters to reduce soil fertility problem.

Motivation factor for adopting vermicompost: The respondents were asked about motivating factors attracted adoption of vermicompost on their farm land. According to the field survey result (Table 7) shown that 71.1% of vermicomposting technology adopter household heads responded that they adopt and use vermicompost to increase crop productivity and 28.9% to improve soil fertility. This indicates that the farmers used vermicompost to increase productivity than to improve their farm lands soil fertility. As shown by the household survey and qualitative data generated through FDG and KII, the farmers basically used vermicompost to increase crop productivity than to improve their soil fertility.

Perception of understanding the benefits of vermicompost before adopting it: The respondents were asked their perception on vermicomposting technology before adopting it. The field survey result discovered that, 2.6% of vermicomposting technology adopters stated that benefit of vermicompost before adopting it is unimportant at all, 36.8% a little bit good, 42.1% I don’t know and 18.4% very important. This indicates that farmers have not understand advantage of vermicompost technology very well before adopting and using it practically. According to the FDG and KII, teaching the importance of vermicomposting technology for the farmers to adopt it is very important.

Perception of extent of vermicompost importance in farmers farming activities: The respondents were asked about their perception to what extent is vermicompost important in their farming activities. The field survey result revealed that, 53.3% of adopter household heads stated that the vermicompost is important in very large extent and 44.7% in medium extent in their farming activities whereas 30.6% of non-adopter household heads stated that the vermicompost is important in very large extent,26.9% in medium extent and 42.6 in small extent in their farming activities. This indicates that vermicompost is very important in farmers farming activity to increase soil fertility status and increase production and productivity in the study area. The chi-square test comparing adopters and non-adopters' perceptions of the extent of vermicompost importance in farming activities revealed a significant difference at the 1% level of significance. Also, according to the FDG and KII, there are considerable differences between adopters and non-adopters in terms of how much vermicompost is valued by farmers in their farming operations.

Perception of importance of vermicompost to increase soil fertility and production: The respondents asked their perception on importance of vermicompost to increase soil fertility and production The field survey result in the study area revealed that, 100% of vermicomposting technology adopter household heads responded that vermicompost is very important to increase soil fertility and production whereas non-vermicomposting technology adopter households did not understand very well the importance of vermicompost to increase soil fertility and production. The chi-square test show that there are notable differences in how farmers perceive the importance of vermicompost to increase soil fertility and production at 1% significant level.

Source of vermicompost: The respondents were asked the source of vermicompost for their farmland. The field survey result revealed that, 81.6% of vermicomposting technology adopter household heads responded that the source of vermicompost for their farmland is own, 12.3% from purchase and 5.3 from agricultural office. This indicates that most of the households' source of vermicompost is own preparation. The results of the chi-square test demonstrate an important distinction in the sources of vermicompost among farmers at a 1% significance level.

Source of material for vermicompost preparation: The respondents asked the main source of material that they used as an input for the preparation of vermicompost. According to the field survey result 81.6% of vermicomposting adopter household heads stated that the source of material for the preparation of vermicompost is livestock's waste material, 13.2% crop residue and 5.3% leaf of a tree. This indicates that livestock's waste material is very important source for vermicompost preparation for farmers in the study area. The chi-square test results indicates that there is significant variation to source of material for the preparation of vermicompost at 1% significant level.

Accessibility of water in terms of distance: The respondents were asked how they feel about accessibility to water in their village in terms of distance they walk. The field survey result in the study area stated that 36.8% of adopter household heads responded that accessibility of water is very close, 50% close and13.2% far whereas 28% of non-adopter household heads responded that water accessibility is very close, 18% close and 62 far. This result indicates that households that have more access to water source adopt vermicomposting technology than that have less access to water source since water is important for preparation of vermicompost. The chi-square test of accessibility of water in terms of distance between adopters and non-adopters was shown to be significant at 1% level significance. Also, according to the FDG and KII, there are considerable differences in the accessibility of water in terms of distance between adopters and non-adopters.

Land ownership motivate farmers to adopt vermicomposting technology: The respondents asked their perception whether land ownership motivate farmers to adopt vermicomposting technology or not. The field survey result revealed that, 100% of adopter household heads responded that land ownership motivates farmers to adopt vermicomposting technology whereas 81.5% of non-adopter household heads respond that land ownership motivates farmers to adopt vermicomposting technology and 18.5% respond that land ownership did not motivate farmers to adopt vermicomposting technology. This indicates that land ownership motivates farmers to adopt and use vermicomposting technology if the farm land is their own property to increase production and productivity by improving their soil fertility status in the study area. The farmers were not use vermicompost on the farmland they rent since the land is not their own property. The chi-square test evaluating whether land ownership influences farmers' decisions to use vermicomposting technology was significant at the 1% level of significance. According to FDG and KII, farmers that have their own land adopt vermicomposting technology than farmers that have not their own land.

Perception on health implication of vermicompost preparation: The respondents were asked about their perception on human health implication of vermicompost preparation. In accordance with the field research result 100% of vermicomposting technology adopter and non-vermicomposting technology adopter household heads responded that vermicomposting preparation did not harms the health status of the one who prepares it. Therefore, this indicates that preparation of vermicompost did not affect the health of the one who prepare it. Also, according to FDG and KII, vermicomposting preparation did not harm the health status of the one who prepares it.

Table 7: Perception of farmers towards vermicomposting technology use

Variables	Responses	Adopters (N=76)		Non-adopters (N=108)		Total (184)		X2
		N	%	N	%	N	%	
Perception on status of farmlands soil fertility status	Slight	31	40.8	30	27.8	61	33.2	5.82**
	Moderate	19	25.0	22	20.4	41	22.28	
	Severe	26	34.2	56	51.9	82	44.57	
Perception on solution of soil fertility problem	Practicing SWC	0	0	56	51.9	56	30.4	83.2***
	Use chemical fertilizers	0	0	16	14.8	14.8	8	
	Use organic fertilizes	76	100	36	33.3	112	60.87	
Motivation factor for adopting vermicompost on farmland	To increase crop productivity	54	71.1	0	0	54	29.35	
	To improve soil fertility	22	28.9	0	0	22	11.96	

Source of vermicompost	Own	62	81.6	0	0	62	36.7	15.8***
	Purchase	10	12.3	0	0	10	5.43	
	Agricultural office	4	5.3	0	0	4	2.17	
Source of material for vermicompost preparation	Livestock's waste material	62	81.6	0	0	62	33.7	184***
	Crop residue	10	13.2	0	0	10	5.43	
	Leaf of a tree	4	5.3	0	0	4	2.17	
Perception of extent of vermicompost importance in farmers farming activities	Very large extent	42	55.3	33	30.6	75	40.8	43.2***
	Medium extent	34	44.7	29	26.9	63	34.2	
	Small extent	0	0	46	42.6	46	25	
Perception on the importance of vermicompost to increase soil fertility and production	Very useful	76	100	0	0	76	41.3	184***
Water accessibility in terms of distance from homestead	Very close	28	36.8	28	25.9	56	30.4	40.4***
	Close	38	50.0	18	16.7	56	30.43	
	Very close	10	13.2	62	57.4	72	39.13	
Do you think that vermicomposting preparation harms the health status of the practitioner?	yes	0	100	0	100	0	0	
	No	76	100	108	100	184	100	
Do land ownership motivate farmers to adopt vermicomposting technology?	yes	76	100	20	18.5	96	52.2	184***
	No	0	0	88	18.5	88	47.83	

Source: Field survey, 2023

4.3. Vermicomposting technology adoption in the study area

Adoption level/status of vermicomposting technology in the study area: The findings of the field survey reveal that out of the total household respondents from the three selected kebeles, 41.3% have adopted vermicomposting technology, while 58.7% have not. This data is corroborated by information gathered through key informant interviews and focus group discussions, which also highlight the limited adoption of vermicomposting technology in the study area.

Relative to the previous year, farm size under vermicompost: The field survey result revealed that, 89.5% of vermicomposting technology adopter household heads responded that the farm size under vermicomposting technology is larger than last year and 10.5% is the same to last year. This indicates that the farm size of households under vermicomposting technology have increased from previous year. This shows that the level of adoption of vermicomposting technology is increased relative to previous year in the study area.

Produce vermiworm and vermicompost for income: The field survey result discovered that, 19.7% of vermicomposting technology adopter household heads responded that they did produce vermiworm and vermicompost to sell and generate income in the study area whereas 80.3% of vermicomposting technology adopter did not produce vermiworm and vermicompost to sell and generate income. The chi-square test findings indicate a substantial disparity in generating income through the production of vermiworms and vermicompost at a 1% significance level.

Why not produce vermiworm and vermicompost to sell and generate income? The survey result stated that, 1.3% of vermicomposting technology adopter household heads responded that they did not produce vermiworm and vermicompost to sell and generate income because of lack of income, 40.8 % labor, 27.6% time, 2.6% waste material and 7.9% preparation area and preparation box. This indicates that the primary problems for producing vermiworms and vermicompost for the purpose of selling and income generation in the study area include lack of labor, time, preparation area and preparation box, waste materials, and income. The chi-square results, on the other hand, reveal that there is no significant difference in the decision not to produce vermiworms and vermicompost for sale and income generation.

Support needs to better adoption of vermicomposting technology: The field survey result revealed that, 93.4% of adopter household heads responded that they need theoretical and practical training and 6.6% need awareness about the vermicomposting technology to adopt and use the technology while 90.7% of non-adopter household heads responded that they need theoretical and practical training,9.3% need awareness about the vermicomposting technology to adopt and use the technology. This indicates that giving theoretical and practical training for households for better adoption and use of vermicomposting technology is very important in the study area. This is also crucial for enhancing the adoption rate of vermicomposting technology among farmers in the study area. The chi-square results show that there is no significant difference between adopters and non-adopters when it comes to supporting the need for improved adoption of vermicomposting technology in the study area.

Table 8: Vermicomposting technology adoption in the study area

Questions	**Responses**	**Adopters (N=76)**		**Non-adopters (N=108)**		**Total (184)**		**X2**
		N	%	N	%	N	%	
Level of vermicomposting technology adoption in the study area	Yes	76	41.3	0	0	76	41.3	
	No	0	0	108	58.7	108	58.7	
Relative to the previous year, what is the farm size under vermicompost?	Larger than last years	68	89.5	0	0	68	36.9	
	The same	8	10.5	0	0	8	4.35	
Do you produce vermiworm and vermicompost to sell and generate income?	Yes	15	19.7	0	0	15	8.15	17***
	No	61	80.3	108	100	169	91.9	
Why not produce vermiworm and vermicompost to	Lack of income	1	1.3	0	0	1	0.54	
	Lack of labor	31	40.8	0	0	31	16.9	
	Lack of time	21	27.6	0	0	21	11.4	
	Lack of waste material	2	2.6	0	0	2	1.09	

	Lack of vermicompost preparation area and preparation box	6	7.9	0	0	6	3.26
Support you need to better adoption of vermicomposting technology?	Give theoretical and practical training on the vermicompost	71	93.4	98	90.7	169	91.9
	Create awareness about vermicompost technology	5	6.6	10	9.3	15	8.15

Source: Field survey, 2023

4.4. Factors determining the adoption of vermicomposting technology

The field survey result revealed that, 1.3%, of adopter household heads responded that the main problems to adopt vermicomposting technology are lack of capital, 19.7% technology access, 9.2% land, 7.9% government support, and 43% lack of awareness, interest, labor, and lack of vermi boxes whereas 5.6% of non-adopter household heads responded that the main problems to adopt vermicomposting technology are lack of capital, 14.8% technology access, 18.5% land, 19.4% government support, and 41.7% lack of awareness, interest, labor, and lack of vermi boxes.

These findings reveal that the primary challenges associated with adopting and utilizing vermicomposting technology in the study area are lack of awareness, interest, labor, vermi box, technology access, land, government support, and capital. The statistical analysis, specifically the chi-square test, indicated that the disparities in major problems related to vermicomposting technology adoption and usage between adopters and non-adopters are statistically significant at a 10% significance level. This suggests that there is a notable difference between these two groups regarding the main obstacles they encounter when it comes to adopting and using vermicomposting technology in the study area.

Table 9: Factors determining the adoption of vermicomposting technology

Questions	Responses	Adopters (N=76)		Non-adopters (N=108)		Total (184)		X2
		N	%	N	%	N	%	
The major problems in vermicomposting technology adoption and use	Lack of capital	5	6.6	6	5.6	11	5.98	12.7*
	Lack of access of technology	15	19.7	16	14.8	31	16.85	
	Lack of land	7	9.2	20	18.5	27	14.67	
	Lack of government support	6	7.9	21	19.4	27	14.67	
	Lack of awareness, lack of interest, lack of labor and lack of vermin box preparation	43	56.6	45	41.7	88	47.83	

Source: Field survey, 2023

4.4.1. Econometric estimation results of factors determining the adoption of vermicomposting technology in the study area

In this section, we present and discuss the empirical findings derived from an econometric model. Table 9 displays the parameter estimates for the variables expected to impact the adoption of vermicomposting technology. The econometric model incorporated a total of fourteen independent variables, comprising five dummy variables and nine continuous ones. Among these variables, six were identified as having a significant influence on farmers' adoption of vermicomposting technology.

The selection of these explanatory variables was based on theoretical reasoning and the outcomes of previous empirical studies, as detailed in the variable definitions and hypothesis section. Before applying the logit regression model, all hypothesized explanatory variables were assessed for potential correlation issues. The model's goodness-of-fit was evaluated using the Log Likelihood Ratio (LR) test. The results indicate a chi-square value of 216.23 with 14 degrees of freedom and a p-value of zero. In simpler terms, the model demonstrates a reasonably good fit, and the χ^2 statistic is statistically significant.

Furthermore, the model's Pseudo R^2 is calculated at 86.67%, affirming that the model effectively accounts for significant variations in the factors influencing the adoption of vermicomposting technology.

The model exhibited statistical significance at 1%, 5%, and 10% levels, confirming its adequacy in estimating at least one of the explanatory variables. Both the hypothesized continuous and dummy variables were incorporated into the model based on the outcomes of the aforementioned tests. Ultimately, the analysis of factors affecting household adoption of vermicomposting technology involved employing a dummy-dependent variable along with 14 independent variables.

Out of the 14 explanatory variables included in the model, six (age, education status of the household head, participation in field demonstrations, distance to the nearest farmland, access to credit, and the extent of soil fertility problems) were found to significantly and statistically influence the adoption of vermicomposting technology in the study area. Conversely, the remaining eight explanatory variables did not demonstrate statistical significance. Notably, the education level of the household head and participation in field demonstrations were statistically significant at a 1% probability level, while age of the household head, distance to the nearest farmland, access to credit, and the extent of soil fertility problems were significant at a 10% probability level.

Age of the household head: Initially, it was anticipated that the age of the household head could have a positive or negative influence on the adoption of vermicomposting technology. Nonetheless, the results from the logit regression model demonstrate a noteworthy and positive impact of the age of the household head on the adoption of vermicomposting technology, with statistical significance at the 10% level.

This positive effect can be attributed to the fact that younger farmers tend to exhibit greater receptiveness to novel ideas and concepts and possess a higher level of knowledge compared to their older counterparts. This heightened knowledge base equips them to readily adopt new technologies. Consequently, within the study area, younger farmers are more inclined to adopt vermicomposting technology compared to their older counterparts.

In practical terms, while keeping all other variables constant, the odds ratio of 1.19 implies that as the age of the household head decreases by one year, the likelihood of becoming an adopter of vermicomposting technology increases by a factor of 1.19. This underscores the notion that younger individuals are more likely to adopt vermicomposting technology than their older counterparts. This finding aligns with prior research on technology adoption, consistent with the conclusions drawn by Duressa (2015) and Gedefaw (2019). However, it's worth noting that research conducted by Abebe and Bekele (2014) and Debebe (2016) revealed a negative correlation between respondents' ages and their adoption of technology.

Education status of household spouse: The educational background of the household head plays a crucial role in determining the adoption of vermicomposting technology. According to the logit model, the status of education of the household head exhibited significant importance at a 1% level of significance and displayed a positive correlation with the adoption of vermicomposting technology in the study area.

The substantial odds ratio of 29129.72 suggests that, while keeping other factors constant, a one-unit increase in the education status of the household head, such as advancing by one grade, enhances the likelihood of becoming an adopter of vermicomposting technology by an extraordinary factor of 29129.72. This signifies that households with educated heads are better equipped to access information regarding the adoption of vermicomposting technology and are more inclined to adopt innovative technologies compared to households led by individuals with limited education. These findings align with those of previous studies conducted by Gedefaw (2019), Sisay (2016), and Solomon et al. (2014), all of which assert that education has a positive and substantial impact on the adoption of new technologies.

Field demonstration: Farmers have the opportunity to acquire new skills through practical demonstrations, thereby enhancing agricultural productivity and overall output. The results obtained from the field survey reveal that participation in field demonstrations had a highly beneficial and statistically significant impact on the likelihood of adopting vermicomposting technology, reaching a 1% level of significance.

The substantial odds ratio of 1903.21 implies that, when all other factors remain constant, an increase of one unit in household head participation in field demonstrations, for example, attending one session, amplifies the probability of a household becoming an adopter of vermicomposting technology by a remarkable factor of 1903.21. This underscores the critical role of utilizing field demonstrations as an effective strategy for successfully transferring innovations aimed at boosting agricultural productivity to farmers.

This discovery underscores the notion that farmers who engage in demonstrations are more inclined to adopt vermicomposting technology compared to those who do not. Consequently, it is recommended to expand the current, limited demonstration practices, as doing so can expedite the adoption of technology. This observation is consistent with the findings of Bezabih (2012) and Gedefaw (2019), who arrived at similar conclusions.

Distance to nearest farmland: According to the findings from the field survey and the logit model, the proximity of farmland to a household has a positive influence on the adoption of vermicomposting technology, with statistical significance at the 10% level. The substantial odds ratio of 261.28 suggests that, while keeping all other variables constant, a one-unit change in the distance of the household head's farmland, for instance, a difference of one kilometer, increases the probability of becoming an adopter of vermicomposting technology by a significant factor of 261.28.This implies that households with farmland located closer to their homes are more likely to adopt vermicomposting technology than households with farmland located at a greater distance from their residences.

Access to credit: As anticipated, it was observed to have a favorable and statistically significant impact on the adoption of vermicomposting technology by households, reaching a 10% level of significance. This positive relationship suggests that households with access to credit are more likely to become adopters of vermicomposting technology. In essence, those households that can access credit services have a higher likelihood of adopting vermicomposting technology compared to those without access. The substantial odds ratio of 12.95 indicates that, while keeping other factors constant, the probability of adopting vermicomposting technology increases by a factor of 12.95 when the household has access to credit services.

This is primarily because access to credit enables households to obtain the necessary inputs and adopt agricultural technologies. With access to credit, farmers can overcome financial barriers and obtain the essential inputs, thereby facilitating the adoption of new technologies. This finding aligns with the conclusions drawn by Gedefaw (2019), Tiamiyu et al. (2014), and Gebresilassie and Bekele (2015), highlighting the positive impact of credit availability on the adoption of new technologies.

The extent of soil fertility problem: As expected, extent of soil fertility problem affected household vermicomposting technology adoption status negatively and significantly at 10% significance level. The odds ratio of 0.34 indicates that, when controlling for other redressers, a change in the severity of the soil fertility issue will increase the likelihood that people will use vermicomposting technology by a factor of 0.34. This suggests that households with greater soil fertility issues are more likely to use vermicomposting technology than are households with lesser issues.

Table 10: Factors determining household vermicomposting technology adoption in the study area (Maximum estimates of logit model)

Independent variables	Odds ratio	Std.err.	Z	P>|Z|
Sex of HH	0.182841	0.3198157	-0.97	0.331
Age of HH	1.192989	0.1273576	1 .65	0.098*
Education level of HH	29129.72	81898.4	3.66	0.000***
Family size of HH	0.7111328	0.2712166	-1.89	0.371
Dependency ratio of HH	0.8189098	0. 3516698	-0.47	0.642
Farm income	0.9999875	0.0027492	-0.01	0.996
Non-farm income	4.503257	5.814225	1.17	0.244
Number of livestock	1.280791	0.2500838	1. 27	0.205
Total land size in ha	0.1448221	0.1918497	-1.46	0.145
Access to extension	0.5181505	4.822629	- 0.07	0.944
Field demonstration	1903.209	5470.852	2.63	0.009***
Distance to nearest farm land	261.2769	866.581	1.68	0.093*
Access to credit	12.94629	18.65573	1.78	0.076*
The extent of soil fertility problem	0.3374456	0.219897	-1.67	0.095*
_Cons	2.40e-15	6.46e-13	-0.12	0.901
Number of obs 184				
LR chi2 (13) 216.23				
Prob > chi2 0.0000				
Pseudo R2 0.8667				
Log likelihood -16.629354				

Source: Field survey result, 2023. Note: ***, **and * show the values statistically significant at 0.01, 0.05and 0.1 level respectively.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMENDATIONS

In this chapter, we provide an overview, draw conclusions, and offer recommendations based on the findings of our survey. Ethiopian agriculture is marked by the utilization of insufficient production methods, challenges related to soil fertility, erratic weather conditions, disease prevalence, uncertainties, and food shortages. In response to these challenges, policymakers have implemented a range of strategies and investments aimed at boosting agricultural productivity, particularly in relation to essential food crops necessary for poverty alleviation.

As a result, it is imperative to thoroughly assess the accessibility, availability, and utilization of enhanced production technologies, with a particular focus on the adoption status of innovations like vermicomposting technology, which is designed to enhance soil fertility.

5.1. Conclusion

The objective of this study was to examine determinants of adoption of vermicomposting technology among small holder farmers. Vermicomposting has played a key role in enabling sustainable soil fertility where it is well managed by lowering the risk of soil fertility problem. Both primary and secondary data were used. Cross sectional data was gathered using structured questionnaires from three randomly selected kebeles from a total of 184 households (76 adopter and 108 non-adopter). Secondary data were collected from different sources. Descriptive and econometric data analyses were performed.

The descriptive result showed that, marital status, level of education, access to credit services, access to training, access to demonstration, non-farm income and income from farming were the variables that showed significant relation with adoption of vermicomposting technology. The logistic regression result revealed that six variables significantly affected adoption of vermicomposting technology. These variables were age, education level, field demonstration, distance to nearest farmland, access to credit and extent of soil fertility problem.

According to the findings lack of awareness, lack of interest, lack of labor, lack of vermin box preparation, lack of access of technology, lack of government support, lack of land and lack of capital are important obstacles to vermicomposting technology adoption in the study area.

The adoption of vermicomposting technology was negatively and insignificantly impacted by the age of the household head. Adoption of vermicomposting technology was positively influenced by the level of education of the household head. Statistics show that distance to nearest farmland has a beneficial influence on the decision to utilize vermicomposting technology. The adoption of vermicomposting technology was insignificantly and positively affected by extension services. The participation of the head of the family in the demonstration was found to be crucial for vermicomposting technology adoption. Vermicomposting technology adoption was found to be positively and significantly influenced by participation on field demonstration. Vermicomposting technology adoption has been significantly impacted by off-farm earning activity.

The adoption of vermicomposting technology is significantly and positively influenced by marital status, level of education, access to credit, access to training, participation in demonstrations, income from farming and non-farm income participation whereas it is insignificantly and negatively influenced by the age of the household head, family size, dependency ratio and distance to nearest farmland. On the other hand, the level of vermicomposting technology adoption was influenced by level of education, household head age, field demonstration participation, and distance to nearest farmland.

Finally, the results of this study indicate, the main constraints for vermicomposting technology adoption in the study area were lack of awareness, lack of interest, lack of labor, lack of vermin box preparation, lack of access of technology, lack of land, lack of government support and lack of capital.

5.2. Recommendations

The following recommendations are put forth to formulate an effective intervention strategy and reinforce the existing successful approaches aimed at promoting the adoption of vermicomposting technology.

Gender plays a positive role in the adoption of vermicomposting technology. In the study area, female involvement in agriculture, especially in the context of vermicomposting technology, remains limited. Given the essential role women play in society and agriculture, it is imperative to encourage their active participation in agricultural extension services. As such, women should be incorporated into the educational and training programs of local extension organizations. To enhance the likelihood of smallholder farmers adopting modern agricultural technologies like vermicomposting technology for improved soil fertility, policymakers should prioritize empowering female-headed households, making them active participants and catalysts for comprehensive and integrated national development.

The age of the household head was found to have a negative and statistically insignificant influence on the adoption of vermicomposting technology. Younger household heads are more likely to adopt new technologies, such as vermicomposting. This is possibly because younger farmers tend to have higher educational levels and are more open to new ideas and concepts, making them more adaptable to new technologies compared to older farmers. Older farmers have a tendency to rent out their land and switch to less labor-intensive farming methods. Compared to older people, younger people are less risk-averse and more open to new ideas. Therefore, if new agricultural technology in the study area focuses more on young farmers, it may be effective.

The adoption of vermicomposting technology is positively and significantly influenced by the level of education. Hence, it is essential to enhance educational opportunities for rural farming households in the study area. Walmara Woreda should ensure the availability of essential resources to improve the educational levels of rural households. It's crucial to reduce the distance between vermicompost production areas and the farmland where farmers apply vermicompost, as a longer distance was found to have a negative impact on the level of adoption.

Extension services positively influenced adoption of vermicomposting technology. Therefore, policies and strategies should put more of an emphasis on improving the current agricultural extension service delivery by offering incentives, short-term and long-term training, raising educational standards and giving extension workers non-overlapping and congruent responsibilities. Oromia Agricultural Office and Walmara Woreda Agricultural Office also need to pay proper consideration to the establishment of farmer training centers in each kebeles.

Non-farm activities have significantly and positively influenced the decision to adopt vermicomposting technology of household heads. According to this, farmers that used vermicomposting technology got access to extra sources of income from non-farm activities. Demonstration on vermicomposting technology was discovered to have been positively and seriously impacted adoption of vermicomposting technology. Therefore, Walmara Woreda Agricultural office should offer suitable and useful vermicomposting technology demonstrations to rural farming households.

Farmers who are implementing new technologies may assess the benefits and drawbacks of the new technology, which may speed up adoption and help farmers in correctly adopting the new technology. Oromia Agricultural Office and Walmara Woreda Agricultural office should be concentrated on educating farmers about vermicomposting technology in this regard. Training on vermicomposting technology was discovered to have a good and significant impact on adoption. of vermicomposting technology. Therefore, Walmara Woreda Agricultural Office should offer sufficient and useful vermicomposting technology training to rural farming households. Additionally, trials in the field and field days should be planned with a number of farmers in the study area. Vermicomposting technology demos should also occur at farmers' training centers (FTC) and on-farm sites.

The following recommendations are made in order to increase vermicomposting technology adoption in the study area based on the study's findings.

- ➢ The finding reveals that adoption and use of vermicomposting technology positively and significantly related by increasing soil fertility and production in the study area. Adoption of vermicomposting technology helps the households to generate additional income and diversification of household food consumption by improving soil fertility and production. Therefore, development strategies and programs related with vermicomposting technology through agricultural production should think about the importance of vermicompost. Hence, the governmental and non- governmental organization should expand access of vermicomposting technology to households to improve soil fertility and increase production.

- This study discovered that there are problems with soil fertility and productivity in the study area. To increase soil fertility and production in the study area, Walmara Woreda Agricultural Office and all other relevant organizations concern on soil fertility should concentrate on integrated soil fertility management practices.
- According to the study, households with educated heads in the study area adopt and employ vermicomposting technology better than households with non-educated heads. So, it is suggested that farmers have access to education through Walmara Woreda Education Office. The Farmers' Training Centre (FTC) should be strengthened with agricultural supplies so that it can better serve all farmers in the study area by demonstrating vermicomposting technologies.
- In order for farmers to easily adopt vermicomposting technology, agricultural extension wings, research organizations, and universities should provide effective, focused, and soil fertility-oriented trainings concerning production, management, and usage activities.
- Vermicomposting production and application experience should be strengthened among farmers. Different soil fertility management practices with recommended package should be available for farmer in Walmara woreda. It is necessary to encourage and guide farmers to use improved agricultural technologies package such as vermicomposting technology to increase production and productivity by improving soil fertility status.
- Researchers should focus on increasing soil fertility because it is the foundation for increasing productivity and production. Policies should focus on increasing farmers' access to knowledge about the production and usage of vermicomposting technology.

This would make it easier for smallholder farmers in rural households to accept and disseminate vermicomposting technology.

- Vermicomposting technology adoption is becoming more challenging, and this requires for the intensive efforts of farmers, researchers, extension workers, and other stakeholders. This necessitates collaborations for the implementation of such programmes.
- Walmara Woreda Agricultural Office and other interested parties should cooperate closely with small-scale farmers to prevent vermin worm disease, insects and solve other challenges of vermicomposting technology adoption in the study area.
- Strong regulatory mechanism should be designed to overcome problems related to adoption of vermicomposting technology by providing incentives to committed and disciplined farmers in the study area.
- Finally, Ministry of Agriculture should establish policies, strategies, and proclamations around vermicomposting technology and forward the controlling mechanisms to Oromia Region Agricultural Office. Similarly, Oromia Regional Agricultural Office should support Walmara Woreda Agricultural Office in different ways, like training, material and financial support. Also, Walmara Woreda Agricultural Office and NGO should be engaged in providing training, materials, and financial support for rural farmers. Lastly, the farmers should apply training, struggle with the challenges, and use any opportunity and use vermicomposting technology to increase soil fertility, production and productivity.

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APPENDIXES

Appendix 1: Questionnaire for household survey

Dear Respondent,

This is data for MA Thesis research in Development Studies (Environmental and Sustainable Development) at Addis Ababa University. The research is to understand "Determinants of Adoption of Vermicomposting Technology Among Smallholder Farmers: The Case of Walmara Woreda, Oromia Region, Ethiopia". The purpose of this survey is to interview the head of household to generate primary data. The survey questionnaire will also contain questions about your' socio-economic status including levels of education, occupations, asset holding and source of income.

Informed Consent: Your participation in the survey is voluntary. Your response is confidential. All data will be reported in the aggregate only. Please be assured that any personal identifier information including your name will not be part of any report. Data will only be maintained by unique code number, not by name, and you will not be identified in the results. All data will be used for research purposes only. Your response will be greatly appreciated.

The interview will take about 45 minutes, thus do you have any question and are you willing to take part in the discussion? Yes = 1 No = 0

For further information kindly contact Getachew Alemu via mobile 0913213957. I kindly request we start the interview. Thanks, you.

General information

Date of interview (dd/mm/yy) ____________ / __________ / _____________

Name of Kebele ______________________

Name of village (Zone) ______________________

Name of respondent _____________________

Name of interviewer ____________________Signature ______________

1. Household demographic characteristics

1.1. Sex of the household head 1= Male 0= Female

1.2. Age of the household head__________________________ (in years).

1.3. What is your level of education? 1= No formal schooling 2=Grade 1-4 3=Grade 5-8

4= Grade 9-10 5= Grade 11-12 and above

1.4. What is your religion? 1= Orthodox 2= Protestant 3= Catholic 4=Muslim

5. Others (Specify) _________________________

1.5. Marital status? 1=Single 2= Married 3= Divorce 4=Widowed 5= Separated

1.6. How many people are living in the house? Specify the No ____________

1.7. How many of your household members fall in the following age group?

Age(years)	Number of males	Number of females
Below 15		
16-64		
Above 65		

1.8. How many years of farming experience do you have? _____________________

1.9. What is your major source of income for your means of living)?

No	Income Sources	Annual income
1	Crop production	
2	Livestock Rearing	
3	Mixed farming	

2. Livestock

2.1. Do you have livestock? 1=Yes 0= No

2.2. If yes for Q#2.1, indicate the number of livestock in the following table?

No	Types of Livestock	Number Sold in 2014	Income obtained in 2014
1	Oxen		
2	Cows		
3	Horses		
4	mule		
5	Donkey		
6	Chicken		
7	sheep		
8	Goat		
9	other		

2.3. Income from sales of livestock products in 2021/22 (2014 EC)

	Sales of livestock products in 2014 EC	Price per unit (average in Birr)
Meat		
Milk		
Butter		
Hides		
Eggs		
Cow dugs		
Others (specify)		

2.4. Income from apiculture in 2021/22 (2014 EC)

	Sale of products of beekeeping in 2014 EC	Price per unit (average in Birr)
Honey		
Bee wax		
Others (specify)		

2.5. Income from other sources in 2021/22 (2014 E.C)

Sources of income	Average annual income from sales in 2014 EC (*in Birr)*	Estimated total value of amount produced in 2014 EC (*in Birr)*
Tree, forest and tree/forest products		
Forage and crop residue		
Off-farm income (income from petty trade, pottery, local foods and drinks, weaving, from sale of firewood, wage, salary, etc.)		
Remittance/Compensation		
Other sources(specify)________		

3. Land holding and land use

3.1. Do you have your own land? 1. Yes 0. No

3.2. If yes for Q#3.1, total land size _____________in hectare.

3.3. If Yes for Q#3.1, list total area holding under different land use and property right 2021/22 (2014/15 EC)

	Area (In ha)	You have used Vermicompost to? (Tick as appropriate)
Area of annual crop cultivated land _Own plot(s)_Own managed (in Ha)		
Area of annual crop cultivated land _ Own plot(s)_Leased Out (in Ha)		
Area of annual crop cultivated land _ Own plot(s)_ Shared out (in Ha)		
Area of annual crop cultivated land _ Other farmers plot(s)_ Leased in (in Ha)		
Area of annual crop cultivated land _ Other farmers plot(s) _Shared in (in Ha)		
Area of perennial crop cultivated land _ Own plot(s)_Own managed (in Ha)		
Area of perennial crop cultivated land _ Own plot(s)_Leased out (in Ha)		
Area of perennial crop cultivated land _ Own plot(s)_ Shared out (in Ha)		
Area of perennial crop cultivated land _ Other farmers plot(s)_ Leased in (in Ha)		

Area of perennial crop cultivated land _ Other farmers plot(s) _Shared in (in Ha)		
Forest land _Own (in Ha)		
Pasture/fallowed land _Own (Ha)		
Other land use (specify)_Own (in Ha)		

3.4. Do you think that your piece of land is enough to support your family? 1=Yes 0=No

3.5. If no to 3.4, what are the reasons? 1= Low soil fertility 2= Small land size 3= Insufficient application of inputs 4= Large family size 5=others (specify) _______________

3.6. For whom do you think farm land belongs for natural conservation practices?

1= Government 2= my own 3= I am not sure

3.7. Do you expect that you will use the land throughout your life time?

1= I doubt 2= No, I may loss it 3= Yes, I am sure

3.8. Have you rented- in land at this moment? 1= Yes 0=No

3.9. If your answer is 'yes', who takes the responsibility of keeping the land quality?

1= me 2= the owner 3= both of us 4= none of us

4. Farming experience (crop type, land size, 2022(2014/15 E.C) production in quintal, type of seed used and type of fertilizer used)

4.1. Did you produce crop under rain fed during 2022(2014/15E.C)? 1= Yes 0=No

4.2. If yes to Q#4.1, what were the crops and inputs used by household? Use the following table.

No.	Crop type	Land size in Timad	2022(2014/15 E.C.) production in quintal	Type of seed used (Local, improved)	Type of fertilizer used (Tick as appropriate)	
					vermicompost	Chemical fertilizer
1	Teff					
2	Barley					
3	Wheat					
4	Maize					
5	Chickpea					

6	Lentil					
7	Pea					
8	Potato					
9	Onion					
10	Garlic					
11	Others					

5. Physical, institutional and environmental factors

5.1. Is there any government assigned agricultural DA in your 'kebele'? 1= Yes 0= No

5.2. Do you have contacts with DA? 1= Yes 0=No

5.3. If yes, how many times do you contact with them per month? ___________________

5.4. Do you get different advices/supports from DAs? 1= Yes 0=No

5.5. If yes to Q5.4, do you practically use their advices accordingly? 1= Yes 0= No

5.6. If no to Q5.4, why? 1. is irrelevant 2. Not timely, 3. Not affordable, 4. Other _______

5.7. If yes in (5.4), did he/she inform you about the existence of vermicomposting?

1= Yes 0=No

5.8. What was his/her main contribution for your a as a DA on vermicomposting?

1= s/he tells us the importance of composting 2=s/he tells us how to prepare composting 3=s/he tells us how to use composting 4=s/he tells us from what it can be prepared 5= s/he has no contribution in all these cases

5.9. Have you taken training on vermicompost in the last 12 months? 1= Yes 0=No

5.10. How many times do they take training on vermicompost in the last 12 months?

1= One time 2= Two times 3=Three times 4=Four times 5=Others (Specify) _______

5.11. If yes in (5.10) what was the agenda of the training? Possible to choose more than one answer. 1= How to prepare vermicomposting 2= How to use vermicomposting

3= the importance of vermicomposting

5.12. So, how did you feel about the importance of the training?

1= Unimportant at all 2=A little bit good 3=I don't know 4=Very important

5.13. Which institution provides you the extension service?

1= Government 2= NGOs/development agencies 3= Other___________________

5.14. Have you visited any field demonstration about vermicomposting? 1=Yes 0=No

5.15. If yes in (5.14), what is the frequency of the visit? 1. Very frequently in major cropping seasons 2= Once per months 3= Twice a year 4= Once a year

5.16. Do you have radio/television in your home? 1= Yes 0=No

5.17. How do you get information on vermicomposting technology?

1= Television 2= Radio 3=DA 4= Neighbors/Friends

5.18. What is the distance between your home and farm land in km? ___________________

6. Access to credit services

6.1. Do you have access to credit for your agricultural activities? 1= Yes 0=No

6.2. If yes for Q#6.1, did you used credit services during 2014 E.C? 1= Yes 0=No

6.3. If yes for Q#6.2, the source? 1= Commercial banks 2= Cooperative unions

3= Neighbors and relatives 4= Micro finance institutions 5=other ________________

6.4. If yes for Q#6.2, what was the amount of credit that you have received? _______Birr.

6.5. If yes for Q#6.2, for what purpose? 1=Purchase of seeds 2. Purchase of fertilizer

3=Purchase of oxen 4= for family consumption 5= others (specify) __________________

6.6. If no to Q#6.2, what are the reasons? 1= Collateral problem 2= No need of credit

3= High interest rate 4= No access 5=others _________________

7. Perception of farmers towards vermicomposting technology

7.1. To what extent soil fertility on your farm land is considered as a problem?

1=slight 2=moderate 3= high 4=severe 5=very severe

7.2. In case you thought it as a problem in (7.1), what do you think would be a solution?

1= Practicing SWC 2= Use chemical fertilizers

3= Use organic fertilizers (vermicomposting, compost, FYM 4=others (specify) ___________

7.3. Have you heard of vermicomposting technology? 1=Yes 0=No

7.4. Are the vermicomposting services affordable to you? 1=Yes 0= No

7.5. Do you adopt and start to use vermicompost on your farm land? 1=Yes, if yes since when? _________________________EC. 0= No

7.6. If yes in (7.5), what attracted you to adopt and use vermicompost on your farm land?

1=to increase productivity 2= to improve soil fertility

3= to income generation 4=other (specify) _________________

7.7. How do you think about beneficial aspect of composting before adopting it?

1= Unimportant at all 2=A little bit good 3=I don’t know 4= Very important

7.8. What was the source of vermicompost? 1= Own 2=purchase 3=Agricultural office 4. NGO 5. Other (specify) ___________________________________

7.9. What is the main source of material that you have used as an input for the preparation of compost? 1= Livestock's waste material 2= Crop residue 3= Leaf of a tree

4= Human waste material 5=Others________________

7.10. What factors prevent you from adopting and use vermicompost on your farm land?

1= Lack of land 2= Lack of awareness about the vermicompost technology

3=Lack of access to radio/mobile 4= Lack of labor 5= Cost of the service

6=others (specify) ________________

7.11. To what extent is vermicompost important in your farming activities?

1=not at all 2= Small extent 3= Medium extent 4= Very Large extent

7.12. If yes in (7.5) how useful do you find vermicompost to increase soil fertility and production? 1= Very useful 2=somewhat useful 3= Note very useful 4= Not at all

7.13. How would you see the relative advantage of vermicompost over chemical fertilizer in terms of quantity requirement per hectare? 1=Very few quantities 2=Few quantity

3= No difference 4=Large quantity 5=Very large quantity

7.14. How long it takes you on foot from your home to the plot you have applied /could apply composting? ________________

7.15. How do you feel your accessibility to water in your village in terms of distance you walk?

1=Very close 2=Close 3=Far 4=Very far

7.16. Do you think land ownership title motivate farmers to adopt vermicomposting technology, soil management, watermanagemen, and agroforestry practices? 1= Yes 0=No

7.17. What type of support would you need to better access and use of vermicomposting technology? 1= Theoretical training should be given 2= Practical training should be given

7.18. Do you think that vermicomposting preparation harms the health status of the one who prepares it? 1= Yes 0= No

7.19. If your answer for # 7.13 above is 'Yes', to what extent it is dangerous?

1= A little bit bad 2= Bad 3= Very bad

7.20. What type of health problem it will cause? ____

3= Creating awareness about the technology 4= other (specify) ____________________

8. Level of vermicomposting adoption

8.1. Last year (year 2014 EC) on what size of farm plot did you apply vermicomposting? _________________ (in 'Timad' to mean 'Oolchaa sangaa' in local language)

8.2. Relative to the previous year, what is the farm size under vermicompost?

1= Larger than last year's 2= Smaller than last years

3. The same 4=other (specify) ______________________________

8.3. If Smaller in (8.3), why? 1= Vermicompost preparation takes time 2=Vermicompost preparation is costly 3= Vermicompost preparation is labor intensive 4= Lack of space for v ermicompost preparation 5=Lack of waste material 6=other (specify) ___________________

8.4. Do you produce vermiworm and vermicompost to sell and generate income? 1=Yes 0=No

8.5. If no in (8.5), Why? 1= Lack of income 2= Lack of labor 3= Lack of time

4= Lack of waste material 5=lack of preparation area 6= Other________________________

8.6. What type of support would you need to better adoption of vermicomposting technology?

1= Give theoretical and practical training on the vermicomposting technology

2= Create awareness about the vermicomposting technology 3=other (specify) _____________

9. Factors constraining vermicomposting technology use?

9.1. What are the major problems/factors constraining vermin composting technology adoption and use in your kebele?

1= Lack of capital 2= Lack of access of technology 3= Lack of information

4= Lack of land 5= Lack of government support 6= Others_________________

THANK YOU FOR YOUR COOPERATION.

I. Questions used to key informants' interview (KII) guidelines

1. How do you explain the soil fertility problem in your woreda/kebele?

2. How do you explain the farmer's awareness and attitude on vermicompost technology?

3. What are the impacts of vermicompost technology to increase soil fertility and productivity in the context of your woreda/ kebele?

4. Is there any difference on soil fertility status between vermicompost users and non-users? If yes, what are the main differences between these two groups?

5. Is there any support from NGOs on adoption and expansion of vermicompost technology in your woreda/kebele?

6. What is level of adoption of vermicomposting technology in your woreda/kebele?

7. What are the major factors constraining adoption and expansion of vermicomposting technology in your woreda/kebele?

8. What solutions do you suggest to address the challenges face in adoption and expansion of vermicomposting technology in your woreda/kebele?

II. Checklist for focus group discussion

1. What is the severity of soil fertility problem in your land?

2. What is the causes of soil fertility problem in your land?

3. What advantages do you get from practicing vermicomposting technology in your land?

4. What are the major factors constraining to adopt vermicompost technology in your kebele?

5. What solutions do you suggest to address the challenges face in adoption and expansion of vermicomposting technology in your kebele?

6. Which do you prefer to use for your farm organic or inorganic fertilizer? Why?

7. What type of support would you need to better adoption of vermicomposting technology?

8. What is level of adoption of vermicomposting technology in your kebele/woreda?

THANK YOU FOR YOUR COOPERATION.

Appendix 2: Stata result of binary logit regression model

```
  ___  ____  ____  ____  ____ ©
 /__    /   ____/   /   ____/      17.0
___/   /   /___/   /   /___/       MP—Parallel Edition

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Notes:
      1. Unicode is supported; see help unicode_advice.
      2. More than 2 billion observations are allowed; see help obs_advice.
      3. Maximum number of variables is set to 5,000; see help set_maxvar.

. import excel "C:\Users\MOA\Desktop\Edited Regression Variables3.xlsx", sheet("variables") firstrow
(16 vars, 282 obs)

. logistic Vermicompostingadoptionstatus SexofHH1Male0Female AgeofHH EducationlevelofHH1Nofor FamilysizeofHH DependencyratioofHH Farmi
> ncomeofHH NonfarmIncomeofHH1yes0 Numberoflivestock Totallandsizeinha Accesstoextension1yes0no Fielddemonstration1Yes0 Distancetonear
> estfarmland Accesstocredit1Yes Extentofsoilfertilityproblem

Logistic regression                                     Number of obs =    184
                                                        LR chi2(14)   = 216.23
                                                        Prob > chi2   = 0.0000
Log likelihood = -16.629354                             Pseudo R2     = 0.8667
```

Vermicompostingadoptionstatus	Odds ratio	Std. err.	z	P>|z|	[95% conf.	interval]
SexofHH1Male0Female	.182841	.3198157	-0.97	0.331	.005932	5.635721
AgeofHH	1.192909	.1273576	1.65	0.098	.9676788	1.470563
EducationlevelofHH1Nofor	29129.72	81898.4	3.66	0.000	117.8087	7202699
FamilysizeofHH	.7111328	.2712166	-0.89	0.371	.3367548	1.501716
DependencyratioofHH	.8189098	.3516698	-0.47	0.642	.3529385	1.900085
FarmincomeofHH	.9999875	.0022492	-0.01	0.996	.9955889	1.004406
NonfarmIncomeofHH1yes0	4.503257	5.814225	1.17	0.244	.3585312	56.56221
Numberoflivestock	1.280791	.2500838	1.27	0.205	.8735241	1.877939
Totallandsizeinha	.1448221	.1918497	-1.46	0.145	.0107951	1.942872
Accesstoextension1yes0no	.5181505	4.822629	-0.07	0.944	6.19e-09	4.33e+07
Fielddemonstration1Yes0	1903.209	5470.852	2.63	0.009	6.802557	532476.7
Distancetonearestfarmland	261.2769	866.581	1.68	0.093	.3925619	173897.7
Accesstocredit1Yes	12.94629	18.65573	1.78	0.076	.768343	218.14
Extentofsoilfertilityproblem	.3374456	.219897	-1.67	0.095	.0940842	1.210293
_cons	2.40e-15	6.46e-13	-0.12	0.901	7.1e-245	8.1e+214

```
Note: _cons estimates baseline odds.
Note: 18 failures and 1 success completely determined.

.
```

Appendix 3: Variance inflation factors (VIF) (collinearity statistics) of the explanatory variables used in logit model

Variables	VIF	1/VIF
Field demonstration	1.91	0.524591
Total land size	1.72	0.582051
Education level of HH	1.78	0.589100
Age of HH	1.69	0.598652
Extent of soil fertility problem	1.67	0.599021
Distance to nearest farm land	1.56	0.640780
Family size of HH	1.43	0.697821
Access to credits	1.41	0.709387
Sex of HH	1.40	0.715606
Non-farm income of HH	1.34	0.744176
Number of livestock	1.33	0.749578
Access to extension	1.18	0.846914
Farm income	1.18	0.849665
Dependency ratio	1.16	0.861233
Mean VIF	1.48	0.69346964

Source: Own survey result (2023)

```
. estat vif

    Variable |       VIF       1/VIF
-------------+----------------------
Fielddemon~0 |      1.91    0.524591
Totallands~a |      1.72    0.582051
Educationl~r |      1.70    0.589100
     AgeofHH |      1.69    0.590652
Extentofso~m |      1.67    0.599021
Distanceto~d |      1.56    0.640780
Familysize~H |      1.43    0.697821
Accesstocr~s |      1.41    0.709387
SexofHH1Ma~e |      1.40    0.715606
NonfarmInc~0 |      1.34    0.744176
Numberofli~k |      1.33    0.749578
Accesstoex~o |      1.18    0.846914
Farmincome~H |      1.18    0.849645
Dependency~H |      1.16    0.861233
-------------+----------------------
    Mean VIF |      1.48

.
```

Appendix 4: Adult equivalent (AE)

Conversion factor used to calculate Adult Equivalent Age (AE)	Male	Female
<10	0.60	0.60
10-13	0.90	0.80
14-16	1.00	0.75
17-50	1.00	0.75
>50	1.00	0.75

Source: Storck, et al. 1991 as cited in Tesfaye (2015)

Appendix 5: Conversion factor for tropical livestock unit (TLU)

Animal category	Tropical livelihood unit
Ox	1.10
Cow	1.00
Heifer	0.50
Bull	0.60
Calves	0.20
Sheep	0.01
Goat	0.09
Donkey	0.50
Horse	0.80
Mule	0.70
Poultry	0.01

Source: Storck, et al. 1991 as cited in Seble (2016)