Technical Efficiency and Commercialization of Moringa and its Impacts on Food and Nutrition Security in Southern Nations Nationalities and Peoples' Regional State of Ethiopia

PhD Dissertation Research

Alula Tafesse Shirko

February 2021

HARAMAYA UNIVERSITY, HARAMAYA

Technical Efficiency and Commercialization of Moringa and its Impacts on Food and Nutrition Security in Southern Nations Nationalities and Peoples' Regional State of Ethiopia

A Dissertation Submitted to Postgraduate Program Directorate (School of Agricultural Economics and Agribusiness)
HARAMAYA UNIVERSITY

In Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY IN AGRICULTURAL ECONOMICS

Alula Tafesse Shirko

February 2021
Haramaya University, Haramaya

HARAMAYA UNIVERSITY

POSTGRADUATE PROGRAMS DIRECTORATE

As Ph.D. research advisory committee members, we hereby certify that we have read and evaluated this dissertation, which has been prepared under our guidance by **Alula Tafesse Shirko,** entitled "**Technical Efficiency and Commercialization of Moringa and its Impacts on Food and Nutrition Security in Southern Nations Nationalities and Peoples' Regional State of Ethiopia".** We recommend that the dissertation be submitted as it fulfills the requirements.

1. Degye Goshu___	__________	18 Aug 2020______
Chairman, Advisory Committee	Signature	Date
2. Fekadu Gelaw_________	__________	21 Aug 2020_______
Member, Advisory Committee	Signature	Date
3. _Alelign Ademe_______	__________	20 Aug 2020
Member, Advisory Committee	Signature	Date

As members of the Board of Examiners of the PhD. Dissertation Open Defense Examination, we certify that we have read, evaluated the Dissertation prepared by **Alula Tafesse Shirko** and examined the candidate. We recommend that the Dissertation accepted as fulfilling the dissertation requirement for the Degree of **Doctor of Philosophy in Agricultural Economics.**

1.______________________	____________________	___________________
Chairperson	Signature	Date
2. ______________________	____________________	___________________
Internal Examiner	Signature	Date
3. ______________________	____________________	___________________
External Examiner	Signature	Date

Final approval and acceptance of the Dissertation is contingent upon the submission of the final copy to the Council of Graduate Studies through the School Graduate Committee of the candidate's major Department.

DEDICATION

This dissertation is dedicated to my beloved father, Tafesse Shirko Halala; who has passed away without seeing this achievement.

STATEMENT OF AUTHOR

By my signature below, I declare that this dissertation is the result of my work and that all sources of materials used for its preparation have been duly acknowledged. This dissertation has been submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy at Haramaya University and is deposited at the library of the University to be made available to borrowers under the rules and regulations of the library. I solemnly declare that this dissertation has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this dissertation are allowed without requiring special permission provided that an accurate acknowledgment of the source is made. Requests for permission for extended quotations from or reproduction of the manuscript in whole or in part may be granted by the Head of the Department of Agricultural Economics or the Postgraduate Programs Directorate when in his or her judgment the proposed use of the material is for scholarly interest. In all other instances, however, permission must be obtained from the author.

Name: Alula Tafesse Shirko Signature: 

Date: September 05 2020

School: Agricultural Economics and Agribusiness

BIOGRAPHICAL SKETCH

The author was born on February 04, 1988, in Woliata Zone, Southern Nations, Nationalities, and the Peoples Regional State of Ethiopia. He attended elementary education at Zaalla Shasha Elementary School from 1995 to 2000 and secondary education at Otona Junior Secondary School from 2001 to 2002. He attended senior education at Bogal Wolelu senior School from 2003 to 2004. He took the Ethiopian General School Leaving Certificate Examination in 2004 and joined Preparatory School education at Wolaita Sodo Preparatory and comprehensive High School from 2005 to 2006. Then, he took the Ethiopian Higher Education Entrance Examination in 2006 and joined Mekelle University, College of Dry Land Agriculture and Natural Resources to pursue his BSc study in Natural Resource Economics and Management in 2007. He received his BSc degree in Natural Resource Economics and Management in 2009. After his graduation, he recruited at Mekelle University as a Graduate Assistant in 2010 and served for one year. He then joined Hawassa University Wondo Genet College of Agriculture and Forestry for masters' education and graduated with an MSc degree in Natural Resource Economics and Policy in 2012.

He began his career after reinstating as a lecturer in July 2012 at Mekelle University, College of Agriculture and Natural Resources in the Department of Natural Resource Economics and Management. After serving for one year and 4 months as a lecturer, he was transferred to Wolaita Sodo University, College of Agriculture, and Department of Agricultural Economics. He served as the head department of Agricultural Economics for two years from October 2014 up to October 2016. Then, based on his experience and research publications he was promoted to an academic rank of Assistant Professor of Natural Resource Economics and Policy. He joined Haramaya University in 2016 to pursue his Doctor of Philosophy studies in Agricultural Economics.

ACKNOWLEDGMENTS

Above everything, thanks to Almighty God for all unconditional support from start to end of this dissertation.

My deepest gratitude then goes to Dr. Degye Goshu (chairperson of the advisory committee), for the meticulous academic and research guidance, for sharing his deepest knowledge and skills and providing valuable comments. Without his close and professional guidance, this work would not have been in its present shape. I will never forget his overall support and the vital contributions he made towards my success; working with him was a wonderful learning opportunity in many ways.

I would also like to express my special heartfelt thanks and appreciation to Dr. Fekadu Gelaw (a member of the advisory committee) for his close supervision, constructive ideas, valuable comments, and hospitality. His overall support and motivation from the beginning to the end of my dissertation sincerely much appreciated.

I would also like to express my special thanks and appreciation to Dr. Alelign Ademe (a member of the advisory committee) for his guidance and valuable comments, sustained interest, stimulating views and encouragement during the writing up of this dissertation.

I would like to convey my sincere gratitude, appreciation, and thanks to various institutions and individuals who assisted me and contributed to the successful completion of this study. Special gratitude goes to the Ministry of Education (MoE) now Ministry of Science and Higher Education (MoSHE) and Wolaita Sodo University for sponsoring the research work and for offering a scholarship opportunity, providing field facilities and technical support for my Ph.D. studies. The School of Agricultural Economics, Agribusiness, and Directorate of Graduate Studies of Haramaya University deserve a special appreciation for providing me with the necessary facilities at the campus and offering me the Ph.D. courses timely. I would like to thank Girma Gezmu, a Ph.D. candidate at Kyushu University: Fukuoka, Japan for his support in the process of publication of one manuscript from the dissertation part. I would also like to thank Dr. Dagne Mojo, the Ethiopian Institute of Agricultural Research for his support in some analysis part of the dissertation.

I would like to express my sincere gratitude to my colleagues Mulken Gebre, Yoseph Halala, Asrat Worku, Yohannes Shonde, Ermias Belete, Alemayehu Assale, and Paulos Lukas from Wolaita Sodo University and Tadesse Getachew and Theodros Girma from Debre Birehan and Wollo University, respectively for their moral and material support and friendly togetherness. I am also grateful to Moringa producers in Humbo and Mirab Abaya district, Southern Ethiopia who kindly provided me the necessary information and shared their invaluable knowledge and experience in Moringa production during the survey work. I also thank zonal and district agricultural officers for their help during the survey work.

I also would like to express my sincere gratitude to all my family members Aynalem Tafesse, Tereda Tafesse, Abezash Tafesse, Zinash Tafesse, Tesfanesh Tafesse, Helen Tafesse, Lulit Tafesse, Tenaye Tafesse, Elsaye Tafesse, and my lovely mom Alemitu Dea. Particularly, I would like to express my heartfelt gratitude to my darling wife Meron Ermias and my daughters Ephrata and Elhanan for their fondling love and affection, and staying patient in times of my absence. Finally, I would like to thank all not mentioned here but who has contributed to the success of my dissertation work.

ACRONYMS AND ABBREVIATIONS

CSA	Central Statistical Agency
ETB[1]	Ethiopian Birr
DEA	Data Envelopment Analysis
EPHI	Ethiopian Public Health Institute
FCS	Food Consumption Score
FNS	Food and Nutritional Security
FYM	Farm Yard Manure
HMADBARD	Humbo and Mirab Abaya District Bureau of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
OECD	Organization for Economic Co-operation and Development
PDF	Parametric Distance Functions
PSM	Propensity Score Matching
RUF	Ready-to-use Food
SFP	Stochastic Frontier Production
SNNPR	Southern Nations Nationalities and Peoples Region
TE	Technical Efficiency

[1] One USD proximately equals 35ETB at current exchange rate

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LISTS OF TABLES IN APPENDICES

LISTS OF PUBLISHED MANUSCRIPTS

Appendix Figure **Page**

Technical Efficiency and Commercialization of Moringa and its Impacts on Food and Nutrition Security in Southern Nations Nationalities and the Peoples Regional State of Ethiopia

ABSTRACT

This study aimed at Moringa production efficiency analysis, commercialization, and evaluation of its food and nutrition security impacts at smallholder farm household level. It aims to fill the missing knowledge gaps through a cross-sectional survey study on data collected from selected 232 Moringa producer and 232 non-producer smallholder farmers from Wolaita and Gamo zones, southern Ethiopia. Descriptive statistics and econometric models were used to analyze data. First, the study has analyzed the technical efficiency of Moringa production. The analysis was conducted on sampled 117 Moringa producer farmers having five-year homogeneous production periods in southern Ethiopia. The Stochastic Frontier Model was used to estimate the level of productivity and efficiency. The one limit Tobit model was used to find sources of technical inefficiency of Moringa producing farmers. The collected data fitted Cobb-Douglas production function and it considered labor, land, and fertilizer as input variables; from these only labor is positively and significantly determined the yield of Moringa. The mean technical efficiency of 48.78% shows that farmers can increase Moringa yield by 51.22% with existing inputs and technology. The off/non-farm participation, access to road, credit, and irrigation were significant factors affecting the technical efficiency of Moringa. Moreover, the research investigated factors determining the Moringa commercialization in southern Ethiopia on selected 232 Moringa producing farmers in research areas. Heckman's sample selection model was adopted to identify the determinants of the likelihood of Moringa commercialization and the intensity. The results of the model revealed that access to irrigation and distance to the market as main variables significantly influencing the ability of farmers to participate in the Moringa yield market. Moreover, variables such as family size, extension contact, access to irrigation access to credit, and distance to market are the factors significantly influencing the intensity of market participation. Lastly, Propensity to Score Matching (PSM) model was used to evaluate the impact of Moringa production on household food and nutrition security. The findings of the PSM model indicated positive and significant differences among Moringa producer and non-producer farmers in selected outcome variables, weekly calorie intake, and *food consumption scores (FCS). Farmers producing Moringa were found to be more food and nutritionally secure than non-producers. Based on the findings the research recommended policies and development actions to be taken to advance the production and intensification of Moringa production in dry parts of the country. Therefore, policymakers should mainly work on development activities in the area through strengthening existing extension services, it should also focus on strengthening formal and informal education, strengthening the existing rural markets and rural-urban road and other infrastructural development activities. Arranging experience-sharing program in Moringa production is also required. Particularly, offering immediate practical training on techniques of market-oriented and value-added Moringa production and marketing systems to increase commercialization of Moringa in the study area. To advance the productivity of Moringa, any development direction should consider households with limited access to irrigation.*

Keywords: Food security; Propensity Score Matching; commercialization; Heckman sample selection model; Stochastic Frontier Model; Moringa; Ethiopia.

1. INTRODUCTION

1.1 Background

There are about 13 species of Moringa trees in the family Moringaceae (Ebert, 2014). They are native to India, the Red Sea area, and/or parts of Africa including Madagascar. From these species, *Moringa oleifera* and *Moringa stenopetala* are the most commonly grown Moringa species in the tropics and subtropics (Melesse *et al.*, 2011).

Moringa oleifera is massively known and utilized in Asia. It has been accorded research and development attention. *Moringa oleifera* is native to sub-Himalayan tracts of northern India and is commonly referred to as "horseradish tree" or "drumstick tree"(Foidl *et al.*, 2001; Jahn, 1991). According to Melesse *et al.* (2011), this multipurpose tree has been introduced to Ethiopia over the last few years and is grown on nursery sites parallel to *Moringa stenopetala* in southern parts of the country. *Moringa stenopetala* on the other side is a multipurpose tree, native to the East African lowlands, that is an even more promising coagulant crop for water clarification in the tropics than the "pan-tropical" horseradish tree *Moringa oleifera*.

Historically, Moringa was highly valued in the ancient world. According to Fuglie (1999) the Romans, Greeks, and Egyptians extracted edible oil from the seeds and used it for perfume and skin lotion. In the 19^{th} century, plantations of Moringa in the West Indians exported the Moringa oil to Europe for perfumes and lubricants for machinery. People in the Indian sub-continent have long used Moringa pods for food. It is indicated that the edible leaves are eaten throughout West Africa and in parts of Asia. The studies in nutritional aspects indicated the exciting benefits of Moringa. Its fresh leaves have 4 times the vitamin A of Carrots, 7 times the vitamin C of Oranges, 4 times the Calcium of Milk, 3 times the Potassium of Bananas, 3/4 times the Iron of Spinach, and 2 times the protein of Yogurt (Gopalan *et al.*, 1989). Dried leaves contain 10 times the Vitamin A of Carrots, the 1/2 times Vitamin C of Oranges, 17 times the Calcium of Milk, 15 times the Potassium of Bananas, 25 times the Iron of Spinach, 9 times the Protein of Yogurt (Fuglie, 1999). In Ethiopia and other developing countries, with its rich essential nutrients, it is believed to play a vital role in curbing malnutrition problems persistent in many parts of the country (Desalegn *et al.*, 2012; Seifu, 2015).

In Ethiopia, it is mainly grown in the Southern part of the country. It has grown in Konso, Gamo Gofa, Wolaita, Sidamo, Kaffa administrative area, and other parts of southern Ethiopia. Moringa is the cultural food for 14 nationalities in the south region and constitutes 50% of their food intake (Seifu, 2015). It was indicated that about 50% of Konso people in southern Ethiopia obtain their food from *Moringa stenopetela* (Endeshaw, 2003). A common way of cultivating the *Moringa* trees, in both southern Ethiopia and Kenya was intercropping with other staple food crops, for example, cassava, maize, and sorghum (Kumssa *et al.*, 2017).

According to Bosch (2004) in Konso (Ethiopia) the first leaves are harvested after about 3 years. *Moringa stenopetala* grows at a wide range of altitudes that range from 500 to 1800m above sea level. However, its upper altitude range can also extend to 2100 m above sea level if trees are sheltered from the wind and heavy rain. Annual rainfall in the area where it is found in Ethiopia is 500–2400 mm. The tree can tolerate light frost, but severe frost may cause trees to die back to ground level. In the wild *Moringa*, *stenopetala* usually occurs on the rocky ground near permanent water. It prefers well-drained soils with a high groundwater table, yet it also withstands dry conditions well, and consequently, it is found in both wetlands and dry areas. Schwarz (2001) stated that the annual harvest of a single Moringa tree reaches 3 kg. Bosch (2004) notes an annual production of 2000 fruits or 6 kg of seed per tree under ideal conditions. Medium to high fruit and leaf outputs are reported for the plains of the Rift Valley at about 1200m altitudes (Bosch, 2004).

Moringa is an almost daily food for farmers in the research area, Wolaita and Gamo Gofa. It is consumed with other food items such as maize, wheat, sorghum, and other cereal crops (as *Kurkufa*[2] and with *Kita*[3]). Its leaf consumed self (simply boiled with other spices) and with mentioned crops. Abuye *et al.* (2003) and Seifu (2015) mentioned that the people in the Gamo Gofa, Konso, Wolaita, and other parts of southern Ethiopia have a long tradition of consuming *Moringa stenopetela* locally called Shiferaw/Aleko/Haleko/ Shelchada. In the lowland and mid

[2] A paste prepared for from Moringa stenopetela (sometimes with cabbage too) and cereals such as sorghum, maize, millet and barley (Abuye *et al*., 2003).

[3] It is relatively thin unleavened bread typical of Ethiopian cuisine. It is generally made with maize/wheat/other cereals flour, water, and sometimes salt. It is cooked in a hot pan free-form (covered with *inset* leaf) until two side is cooked.

altitudes of this region, it is hardly possible to find a household without a Haleko tree in his/her homestead. The leaf of the Haleko tree is eaten after cooking it like a cabbage. Haleko is particularly important as a human food because the leaves, which have high nutritional value, persist throughout the year, including the dry season when few other sources of green vegetables are available. Farmers in these areas have been growing for consuming Moringa for a long period. It is mainly grown for consumption as a staple diet in the area to support a large family for several years due to its drought, insect, and pest resistance (Abuye *et al.*, 2003). Moreover, in the research area and other parts of the world, the Moringa family is planted as an ornamental tree, the unripe and mature seeds are used as foodstuff and spices (in Asia and African countries) and consumed in drinks prepared in folk medicine (Abuye *et al.*, 2003; Jahn, 1979). Recently, it is used as a tea and soft drink in different parts of the country. In comparison to Cabbage, Moringa is available throughout the year even in drought time.

Kelemu *et al.* (2012) indicated that the Moringa has been produced and marketed for a long period but its productivity remained low. Its production remained non-modernized and only limited to smallholder farmers, and unscientific (Seifu, 2015). The Ethiopian public health institute additionally mentioned the various challenges persisting including its productivity issues (EPHI, 2014). The lack of coordination both vertically and horizontally, lack of market-technology linkage, and problems of competing farmers with investors, and lack of ownership of regulation are among the mentioned challenges. The Moringa marketing has accounted for a long time that traces back before 1938 (Nowack, 1954 as cited in Abuye *et al.*, 2003). Thus, the production, consumption, and marketing in southern Ethiopia have taken more than 80 years.

However, in general it is indicated that Moringa is one of the least traded commodities in Ethiopia and the level of consumption is restricted to a few areas of the Southern Region (World Agroforestry, 2014). Currently, in the research area, Moringa leaf is sold at a very cheap price of about 10-20 Ethiopian Birr (ETB) per kilogram (Kg) in the local market as a cabbage (personal observation). The commercialization of Moringa products in Ethiopia, in general, is very informal and makes it difficult to get reliable information on production and marketing volumes and prices.

Moringa also has a higher potential role incurving food insecurity where the developing countries are suffering the challenge which is amongst the great problems in the areas (Fuglie, 2005). Malnutrition causes a great deal of human suffering and is associated with more than half of all deaths of children worldwide. Additionally, Moringa has been perceived to provide a great role in food security and improve the malnutrition of smallholder farmers (Desalegn *et al.*, 2012; EPHI, 2014; Melesse *et al.*, 2011; Seifu, 2015). It is also perceived as a source of food, medicinal, nutritional, industrial, and environmental benefits in the country (Baba *et al*., 2015; EPHI, 2014; Melesse *et al*., 2011). FAO recently was promoting Moringa as a collaborative food and nutrition program in the Southern Nations, Nationalities, and Peoples' Region (SNNPR) region in Ethiopia (FAO Forestry, 2014). However, *Moringa* still has not been given due to research and development attention.

Nowadays, improving productivity and efficiency of agriculture through commercialization is an inevitable reality throughout the world. Similarly, Ethiopia has advocated a policy of commercializing smallholder agriculture as a strategy towards attaining economic transformation. The current study mainly focused on the production efficiency of this agroforestry commodity, Moringa as a single yield. The analysis of productivity and efficiency of existing unscientific and inefficient production techniques of Moringa will have a great implication to improve the sector. Furthermore, as to the knowledge of authors, there are very limited studies conducted in the analysis of Moringa commercialization in the country as well as in the world. There is also a great need to conduct an empirical study to confirm the significant socio-economic contributions of Moringa to the livelihood of millions of people in the country. More specifically, it requires scientific researches to evaluate its impact on food and nutrition security. Considering this fact the current study is perceived as a shred of good scientific evidence for communities and policymakers aiming to enhance the role of Moringa to the countries food sector.

Thus, with Moringa's significant economic contributions to the livelihood of millions of people in Ethiopia, it is very important to conduct researches that focused on the production efficiency of this agroforestry commodity, investigate its commercialization and evaluate its impact on food and nutrition security in the country.

1.2 Problem Statement

According to Fuglie (2005), food insecurity and malnutrition commonly related to micronutrient deficiencies are amongst the great problems of developing countries. An iodine deficiency during pregnancy and other nutrient deficiencies nowadays are important contributors to the global burden of disease. They are severely influencing the socio-economic development of a nation through their effect on the workforce that is stunted both mentally and physically may have a reduced work capacity. The interaction of poverty, poor health, and poor nutrition has a multiplier effect on the general welfare of the population and contributes significantly towards keeping a population in a downward trend of poverty and nutritional insecurity.

The recent study on the socio-economic contribution of the Moringa tree in northern Ethiopia showed that Moringa contributes to different income components and is perceived by communities as having multipurpose roles (Kelemu *et al.*, 2012). The various studies showed Moringa's role in improving the food security and livelihoods of smallholder farmers in Ethiopia through its contributions to food, nutrition, health, industry, and environment. It is a recognized as nutritious food source for food-insecure people in East Africa (Yisehak *et al.,* 2011).

However, empirical studies evaluating the food and nutrition security impact of Moringa at the household level are missing. Previous studies only conducted in the area of Moringa's contributions to food, nutritional, health, industrial, and environmental concerns, they dealt exclusively with experimental and qualitative studies (Yisehak *et al.,* 2011; Kelemu *et al.*, 2012; Melesse *et al.*, 2013; Seifu, 2015; Baba *et al.*, 2015; Geleta *et al.*, 2016; Kiros, 2018). Although such studies are found very important for Moringa farming, there are no empirical studies in the world as well as in Ethiopia, particularly on the evaluation of food and nutrition security impact of Moringa production in southern parts of Ethiopia.

Moreover, it is highly required to implement the theories and approaches of economics to the area of agroforestry commodities. However, there are limited numbers of economic studies in this area. The studies by Alene *et al.* (2006), Azeez *et al.* (2013), Binam *et al.* (2003), Getachew and Temesgen (2016); Lindara *et al.* (2006), Mercer *et al.* (2014), Ngango and Kim (2019), and Sekhar *et al.* (2018) are among the few empirical studies that tried to examine the efficiency of agroforestry commodities including Moringa, coffee, and others. Particularly only Azeez *et al.* (2013) and Sekhar *et al.* (2018) studied the profitability of Moringa production; the productivity factors involved in Moringa production and efficiency analysis in Nigeria and India, respectively. In Ethiopia, particularly in southern Ethiopia there are still no empirical studies on the estimation of technical efficiencies of Moringa production. An efficiency study may help in providing the evidence-based outcome to make decisions about the introduction of important interventions/activities and discourage the use of inefficient interventions/activities. However, it lacks in Ethiopia in general and the study area in particular.

Further, the proportion of households selling Moringa in Ethiopia in general and the study area in particular is not well known. Past studies in commercializing Moringa by EPHI (2014) , Hegde and Vijayalaxmi (2013) and Kelemu *et al.* (2012) are a few qualitative types of research concerning the commercialization of Moringa in Ethiopia. It is not only in Ethiopia, there is also a lack of studies on the commercialization of Moringa in different parts of the world. The study by Gonzalez and van der Maden (2015) in Bangladesh and other developing countries are some of the studies indicated Moringa trees have great potential in terms of nutrition security and income generation, but often seem to be underutilized. The commercialization of Moringa products in Ethiopia has a big implication to economic growth through its contribution to income of the households and then the welfare of the society; and its contribution to the improvement of health of community through accessing the medicinally and nutritionally valuable commodity to the society.

Therefore, there is a need for empirical studies to analyze the production efficiency of existing production techniques of Moringa, investigate its commercialization by smallholder producers, and evaluate the impact of Moringa production on household food and nutrition security in Ethiopia. The study tried to answer the following research questions; what is the existing level of technical efficiency of Moringa producing farmers? Is there any possibility of improvement in the level of technical efficiency? What are the main sources of the existing level of inefficiency? What are the main possible solutions to improve the existing level of inefficiency? What are the determinants of the commercialization of Moringa producing smallholder farmers? Moreover, does Moringa production improve the food and nutrition security of smallholder farmers?

1.3 Objectives of the Study

The overall objective of the study is to analyze the technical efficiency, commercialization, and food and nutrition security impacts of Moringa production in the SNNPR State of Ethiopia. Specific objectives of the study are to:

1. Analyze the technical efficiency of smallholder Moringa producers;
2. Investigate the commercialization of Moringa by smallholder producers; and
3. Evaluate the impacts of Moringa production on household food and nutrition security.

1.4 Significance of the Study

Moringa processing can be seen as one of the untapped potentials and highly valuable income-generating activities in developing countries, with its high rate of improvement and increasing local as well as international demand. Moringa production and marketing has become an expanding global business. Therefore, proper development, efficiency, and competitiveness of the sector, as well as the marketing of its products, could assist in the quest for accelerated industrial growth and poverty alleviation in the country.

This research, therefore, was of immense value as it can provide detailed information about the production and marketing of Moringa in Ethiopia. The study may provide information for any concerned body such as local and regional governments, policy designers, NGOs, researchers, extension workers and smallholder farmers that seeks to address the factors that are responsible for Moringa production and marketing thereby to a role in its contribution to food and nutrition security improvement activities. Additionally, it may help all other concerned bodies whose effects are direct or indirect towards minimizing the problems of Moringa production.

Finally, at the current time, there is a very limited empirical study on the production efficiency and food security impact of Moringa at smallholder farmers' level. Thus, the study was having theoretical contributions by providing foundational information for conceptualizing the link between production, commercialization, and food and nutrition security impact of agroforestry commodities. This can also help as a way to analyze the related concepts. It can also serve as reference material for future references on the area.

1.5 Scope and Limitation of the Study

In the current study, the researcher needs to investigate Moringa production. Despite the availability of many issues related to Moringa, this research limited itself only to investigate the productivity and commercialization of Moringa by smallholder producers and evaluate the impacts of Moringa production on household food and nutrition security.

It is only limited to the analysis of technical efficiency, commercialization, and food and nutrition security impact of Moringa, where other commodities are not included. However, the result could be used for other commodities with similar production activities. This is due to the limitation of time and budget constraints. On the other hand, this study is only based on the information generated from the sample household survey during a single cropping season using across-sectional data due to the limitation of time and logistics. Moreover, the study used a stochastic frontier model for technical efficiency analysis from other efficiency analysis models due to the model's suitability to production efficiency analysis of single agroforestry commodities. Similarly, the study used the Heckman two-stage model for the suitability to analyze commercialization due to the expected interrelation of the two concepts. Finally, PSM was used for impact analysis due to its contribution to the formulation of comparable groups in observational studies.

1.6 Organization of the Dissertation

The dissertation is organized into five parts. The introduction included background, statement of the problem, objectives, significance, and scope and limitations of the study. The literature presents the literature review on basic concepts of Production efficiency, commercialization, and food and nutrition security; analytical reviews of productivity and efficiency, commercialization and food and nutrition security impacts; and empirical reviews of Moringa production efficiency, food, and nutrition security impacts of Moringa and commercialization. The methodology presents area description, data sources and collection methods, sampling procedures, and methods of analysis and variables used in the study. Results and discussion present the findings and discussions of the results obtained based on the objectives of the study. Conclusions and policy implications present a summary of the core findings of the study and policy directions based on the findings of the study.

2. LITERATURE REVIEW

2.1 Definition of Basic Concepts

2.1.1. Concepts of productivity and efficiency

Agricultural productivity and efficiency are at the stand of numerous debates, policies, and measures concerning the farming sector. The word productivity and efficiency can be used interchangeably in most cases and are considered as the measure of performance of a given firm. However, these two interrelated terms are not precisely the same (Coelli *et al.*, 2005). The term productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use" (Schreyer and Pilat, 2001). It is the quantity of a given output of a firm (a farmer) per unit of input. At its most fundamental level, productivity measures the amount produced by a target group (country, industry, sector, farm, or almost any target group) given a set of resources and inputs (Mechri *et al.*, 2017). The technical and allocative efficiency (price efficiency) in production, which together comprise the economic/overall efficiency are distinguished by Farrel (1957) and Coelli *et al.* (2005) through the use of frontier production function. The technical efficiency relates the physical input with the maximum level of output that can be produced at a given level of technology. In farming, the technically efficient farmers are those farmers that are operating on the production frontier that represents the maximum output attainable from the given input level. An allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. Economic efficiency shows a firm's ability to maximize profits by equating the marginal revenue of product of the factors of production to their respective marginal costs (Asfaw and Admassie, 1996).

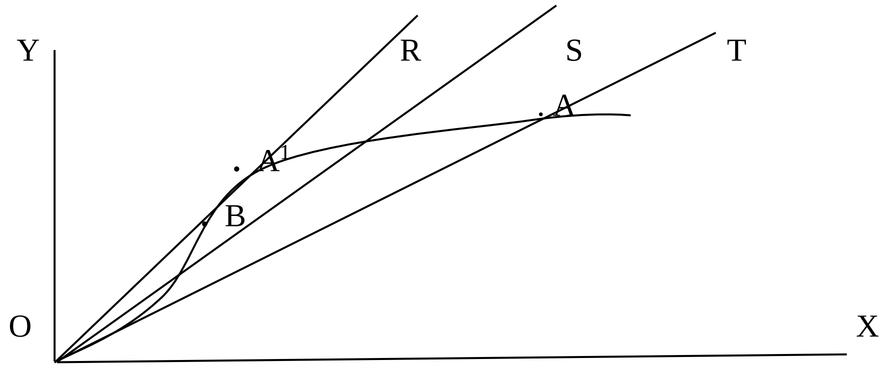


Figure 1: Productivity and Efficiency
Source: Coelli *et al.*, 2005.

The figure depicted above describes the variation between efficiency and productivity using input-output relationships. The curve OQ represents the production frontier. That shows a set of points of maximum levels of outputs that can be obtained when input X is used efficiently. Points below the curve are all inefficient points. The slopes of the line OR, OS, and OT represent the set of points of the ratio of output Y to input X and hence represent productivity level. Farmer A is more efficient than farmer B is yet farmer B is at a higher productivity level than farmer A is. In terms of productivity, farmer B is more productive than farmer A because he/she is getting higher output Y per unit of input X. However, if we evaluate from an efficiency point of view, farmer A is more efficient than farmer B is, as he/she is operating on the frontier. Yet, farmer A, who is efficient can still improve its productivity by moving to point A^1 using its economies of scale.

2.2.2. Concepts of Commercialization

Commercialization lacks clarity in its meaning and may result in misconception and a hindrance in the transformation of policy into practice. Commercialization can occur on either side; on the output side with increased market surplus or the input side with the increased use of inputs (Leavy and Poulton, 2007).

According to Gebremedhin and Jaleta (2010) commercialization involves market orientation which is production decisions destined for the market based on market signals and market participation which is all about products offered for sale and use of purchased inputs. However, the works of literature on the commercialization of smallholders make little distinction between market orientation and market participation of smallholders. Most of the pieces of literature consider market orientation and market participation as synonymous, and thus most of the analysis of the determinants of smallholder commercialization is based on the analysis of the determinants of output market participation (Jaleta *et al.*, 2009; Von Braun and Kennedy, 1994; Otieno *et al.,* 2009; Von Braun *et al.*, 1991). Nevertheless, policy implications to enhance the commercial transformation of subsistence agriculture drawn from the analysis of the determinants of household market participation alone could be inadequate if the determinants of market orientation and market participation are not the same.

The commonly accepted concept of commercialization is, therefore, that commercialized households are targeting markets in their production decisions, rather than being related simply to the amount of product they would likely sell due to surplus production (Pingali and Rosegrant, 1999 as cited in Jaleta *et al.,* 2009). In other words, production decisions of commercialized farmers are based on market signals and comparative advantages, whereas those of subsistence farmers are based on production feasibility and subsistence requirements, and selling only whatever surplus produce is left after household consumption requirements are met.

2.2.3. Concepts of Food and Nutritional Security

There is a difference but the close relation between Food and Nutritional Security (FNS). The massive number of definitions evolved from the point where the idea raised in 1943 has made food security complex issues. According to Weingärtner (2009), a global *Food* and Nutritional Security (FNS) has a history of more than 50 years and has evolved through a sequence of definitions and paradigms. The World Summit on Food Security in 2009 described the existence of Food security as "...when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 2012). Thus, "The four pillars of food security are availability, access, utilization, and stability". In another way, nutritional security is defined as an adequate nutritional status in terms of protein, energy, vitamins, and minerals for all household members at all times (Quisumbing *et al.*, 1996).

In general, according to Venugopal (1999), food security is considered as the availability and the access of food to all people; whereas nutrition security demands the intake of a wide range of food items that provide the essential needed nutrients. Siassi (2015) described that there is a consensus about food security (FS) definition but no such consensus about a definition for nutrition security (NS). However, he argued there is a need for a consensus on a definition for NS, and nutritionists should concentrate on NS and treat FS as an integral part of NS, one without the other was not achieve the goal of a healthy society.

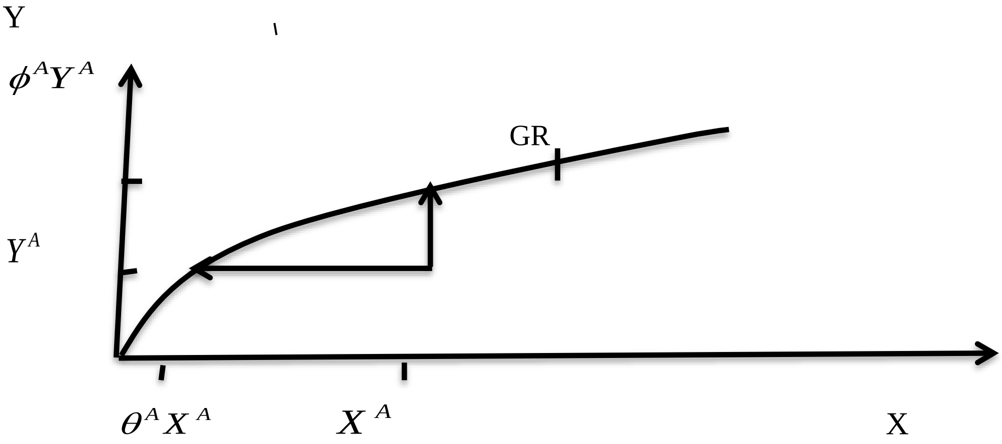
2.2 Theoretical Frameworks

2.2.1 Theoretical framework for production efficiency

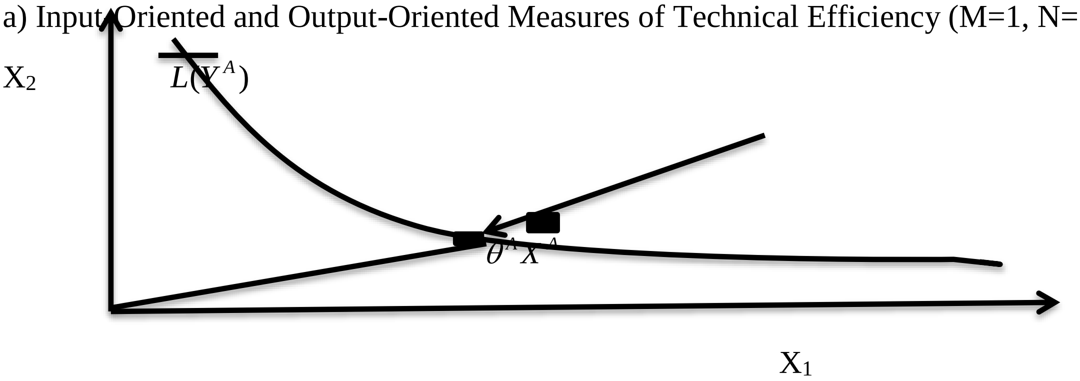
The microeconomics theory of production function that converts the input into output is a base for measurement of production efficiency. Production function describes the production performance of a firm using productivity that is defined as "the ratio of the value of total farm outputs to the value of total inputs used in farm production" (Coelli *et al*., 2005).

The view of measuring a firm's performance concerning a best practice frontier goes back at least to the 1950s. Koopmans (1951) conceptualizes technical efficiency as the capability of a firm to maximize output for given inputs. Later, in the late 1950s, Farrell addressed the issue concerning the degree of inefficiency. He suggested that inefficiency is the observed deviation from a frontier isoquant. Avoiding the problem associated with the traditional average productivity measure, he suggested a method, which consists of plotting inputs per unit output observations as points in space of a suitable dimension. It can be estimated by fitting an envelope to the scatter of points in the input plane from which other firms can be compared with those on the frontier (Farrel, 1957). From the work of Aigner *et al.* (1977) and Meeusen and van Den Broeck (1977), production frontier analysis has been widely used to estimate technical efficiency.

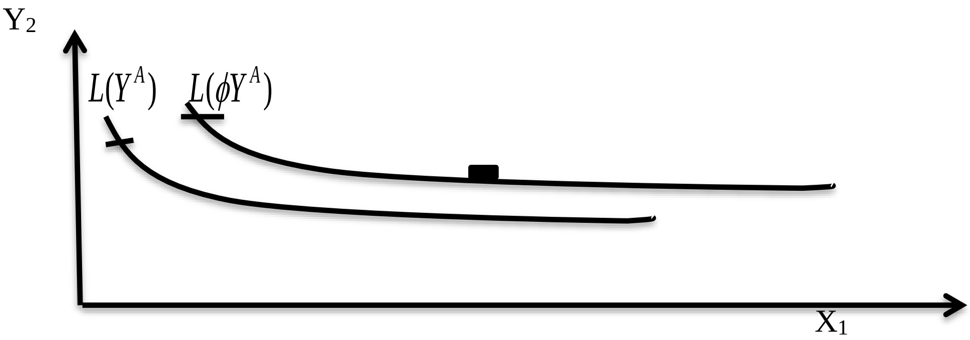
The several approaches that have been used to quantify technical efficiency that broadly follows the same logic: the measurement of the distance between observed productivity and theoretical, optimal, or average productivity. According to Kumbhakar and Lovell (2000), the single-output version of technical efficiency measures are defined as "…an input-oriented measure of technical efficiency is given by the function $TE_I(y,x) = \{\min\{\theta : y \le f(x\theta)\}$ and an output-oriented measure of technical efficiency is given by the function $TE_0(x, y) = [\max\{\phi : \phi y \leq f(x]^{-1}$. The figures below illustrate this concept in the case where producers use multiple inputs to produce a single output.



a) Input-Oriented and Output-Oriented Measures of Technical Efficiency (M=1, N=1))



b) An Input-Oriented Measures of Technical Efficiency (N=2)



c) An Output-Oriented Measures of Technical Efficiency (N=2)

Figure 2: Multiple inputs to produce single output measurements of technical efficiency

Source: Kumbhakar and Lovell, 2000

Figure 2 a) above uses the production frontier f(x) to illustrate both measures of technical efficiency. A producer using x^A to produce y^A is technically efficient since it operates beneath f(x). $TE_I(y^A X^A)$ measures the maximum contraction of x^A that enables continued production of y^A, and $TE_I(y^A, X^A) = \theta^A = 1$, since $y^A = f(\theta^A X^A)$. $TE_O(y^A, X^A)$ measures the reciprocal of the maximum expansion of y^A that is feasible with x^A, and $TE_O(X^A, Y^A = (\phi^A)^{-1} < 1)$ since $\phi^A y^A = F(X^A)$. Figure b) uses the input set L(y) and its isoquant Isoq L(y) to illustrate the input-oriented measures of technical efficiency. $TE_I(y^A, x^A)$ measures the maximum radial contraction in x^A that enables continued production of y^A, and $TE_I(y^A, x^A) = \theta^A < 1$, since $\theta^A x^A \varepsilon IsoqL(y^A)$. Figure c) uses the input set L(y) and its isoquant Isoq L(y) to illustrate the output-oriented measure of technical efficiency. The reciprocal of TE_0 (x^A, y^A) measures the maximum expansion of y^A that is feasible with inputs x^A, and $TE_O(X^A, Y^A = (\phi^A)^{-1} < 1)$, since x^A $Isoq \varepsilon L(\phi^A Y^A)$.

In general, it is possible to measure the efficiencies of production using output oriented and/or input oriented approaches. The current research, applied output-oriented approach as it indicates the magnitude of output of the i[th] Moringa producing farmer relative to the output that can be produced by fully efficient Moringa producing farmer using the existing level of inputs.

2.2.2 Theoretical framework for commercialization

The farm family units are controlled by the utility that they get because of settling on their own choice. In this investigation, it is accepted that the choice to partake in Moringa marketing is impacted by the anticipated utility, which will be higher if the advantages got from Moringa market participation is higher. The noticed result of Moringa participation choice can be displayed under the structure of the random utility function. The result of the choice to market Moringa will be reflected in the welfare of the household. Households are relied upon to showcase Moringa just when they see the net advantages from participating in the Moringa market to be more noteworthy than is the situation without it. Since utility can't be noticed straightforwardly, it very well may be found from the decisions economic agents make. For this situation, the choice will be to take an interest in the Moringa market or not. Consider the i[th] Household in Humbo and Mirab Abaya region confronting a choice on whether to market Moringa. Let C* signify the contrast between the advantage the smallholder farm household gets from marketing Moringa (EiA) and the advantage of not marketing Moringa (EiO).

Considering the axiom of judiciousness and benefit amplification, the smallholder farm household will partake in Moringa marketing if $C^* = E_{iA} - E_{iO} > 0$

The net benefit C is unobservable and can be expressed as a function of observed characteristics (Z_i) and error term (ε_i) as follows (Equation 1):

$$C_i^* = Z_{iA}\beta + \varepsilon_i;\ C_i = 1\ if\ C_i^* > 0\ and\ C_i^* = 0,\ otherwise \quad (1)$$

Where C is a dummy variable representing Moringa market participation decision; C = 1, if Moringa is marketed and C = 0, if otherwise. Z_i is a vector denoting household characteristic, farm-specific, and other institutional or policy variables, β is a vector of parameters to be estimated, and ε_i is an error term.

The Heckman sample selection model (two-step) was used to assess the determinants of farmers' decision to market Moringa outputs. The model helps to identify the factors that affect smallholder farmers' decision to commercialize Moringa and then to evaluate the factors that affect the intensity of commercialization (HCI). This model was adopted on the basis that it models the market participation decision as a two-step process that involves first the household deciding on whether or not to participate in the commercialization of Moringa and then the intensity of commercialization. The factors influencing the farmers' decision to commercialize Moringa was estimated by using the Probit model (selection equation) while the intensity was estimated by using the Ordinary Least Squares approach (Outcome equation). The model computes the inverse mills ratio from the probit regression and uses it as a regressor with other explanatory variables to explain the outcome of the dependent variable. The model was taking the following forms:

The outcome equation is given by:

$$yi = X_i\beta + \mu_1 \quad (2)$$

The selection equation:

$$Z_i\gamma + \mu_2 > 0$$

(3)

With the following holds:

$$\mu_1 \approx N(0,\sigma)$$

$$\mu_2 \approx N(0,1)$$

$$corr(\mu_1, \mu_2) = \rho$$

Where; Y_i = the dependent variables; X_i = the observable features of the independent variables such as demographic, socio-economic, farm specific, marketing and institutional attributes; β = the parameters to be estimated; μ_1 = a normally distributed error term with a mean of zero and a standard deviation σ to be estimated; Z_i = observable features including the overlapping variables with X_i; γ = the vectors of parameters to be estimated; μ_2 = a distributed error term with a mean of zero and a standard deviation equal to one; and ρ = the correlation between the two error terms to be estimated.

In instances where observed characteristics only occur in subsets, incidental truncation occurs (Greene, 2003). This study used this model as it corrects for sample selection bias and incidental truncation. The selection bias was arising due to the existence of sales from a subset of households who participated in the Moringa markets.

2.2.2 Theoretical framework for food and nutrition security

The framework used for this research draws upon from the utility maximizing theories of farm household production behavior. The fundamental assumption is that farmer's decision on whether to produce Moringa or not is based upon utility maximization theory. The farm households are determined by the utility that they get as a result of making their own decision. In this study it is assumed that the decision to produce Moringa is influenced by expected utility, which will be higher if the benefits (including food and nutritional security) obtained from Moringa production is higher. Thus, the observed outcome of Moringa production decision can be modeled under the framework of a random utility function. The outcome of the decision to produce Moringa can be reflected in the food and nutritional security benefits obtained. Households are expected to produce Moringa only when they perceive the net benefits from producing Moringa to be greater than is the case without it. Because utility cannot be observed directly, it can be deduced from the choices economic agents make. In this case the decision will be to produce Moringa or not. Consider the i^{th} Household in Humbo and Mirab Abaya district facing a decision on whether or not to produce Moringa. Let CD* denote the difference between the benefit the smallholder farm household derives from producing Moringa (D_{iA}) and the benefit from not producing Moringa (D_{iO}). Considering the axiom of rationality and profit maximization, the smallholder farm household will participate in Moringa production if $CD^* = D_{iA} - D_{iO} > 0$

The net benefit CD is unobservable and can be expressed as a function of observed characteristics (F_i), that is a vector of demographic, socio-economic, farm specific, marketing and institutional attributes of smallholder farmer and error term (ε_i) as follows (Equation (4)):

$$CD_i^* = F_{iA}\beta + \varepsilon_i; \text{CD}_i = 1 \; if \; \text{CD}_i^* > 0 \; and \; \text{CD}_i^* = 0, \; otherwise \quad (4)$$

Where CD is a dummy variable representing Moringa production decision; CD = 1, if Moringa is produced and CD = 0, if otherwise. F_i is a vector denoting household characteristic, farm-specific, and other institutional or policy variables, β is a vector of parameters to be estimated, and ε_i is an error term.

The functional form of F is specified with logit model. It is a vector denoting household characteristic, farm-specific, and other institutional or policy variables that determine the smallholder farmers' decision to produce or not produce Moringa. The model helps to predict the probabilities for the propensity scores matching model estimation.

Then the food and nutrition security difference between producers and non-producers is modeled with Propensity to Score Matching (PSM). It is used to evaluate food and nutrition security impact of Moringa production on smallholder farmers through balancing covariates determining Moringa production and non-production decision.

2.3 Analytical Frameworks

2.3.1 Analytical framework for production efficiency

There are two analytical measurement approaches that can be used to estimate production efficiency these are "parametric" and non-parametric.

Traditionally, these measurement methods are classified based on whether they rely on assumptions on the functional form of the production frontier: the ones that rely on those assumptions are considered to be "parametric" while the ones that do not rely on the assumptions are considered to be "non-parametric" (Mechri *et al.*, 2017).

Accordingly, the non-parametric methods are Malmquist productivity indices, Engineering approach, Superlative index numbers, and Data Envelopment Analysis. The parametric ones are like average production function and stochastic frontier analysis. The parametric frontier model can further be classified into deterministic (Average production function) and stochastic frontier methods. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise.

Although all methods rely on different computational methods and assumptions, it is interesting to note that the results are often not significantly different from each other. Mechri *et al.* (2017), Neff *et al.* (1993) and Sharma *et al.* (1999) described that estimates derived from DEA are not statistically different from other frontier estimation methods. The choice of specific frontier model depends on various considerations such as the type of data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data and the purpose of the research (Coelli *et al.*, 2005; Gelaw and Bezabih, 2004). Thus, considering such issues, the following parts explain Data Envelopment Analysis (DEA) from non-parametric and stochastic frontier methods from parametric methods that are widely used in empirical researches. Additionally, their advantages and disadvantages were also described.

Data Envelopment Analysis (DEA): It is the deterministic frontier, which is based upon Farrell's original approach of convex isoquant such that no observed points lay to the left or below it. This approach is later extended by Charnes, Cooper, and Rhodes (1978) and related work by Färe *et al.* (1985). The production frontier obtained is the boundary of the freely disposal convex cone of the data set. The first DEA model formulated by Charnes *et al.* (1978) well known as the CCR model was suggested by Boles and Afriat as Mathematical Programming methods to efficiency measurement in the mid 60's and early '70s. They proposed a method, which had an input orientation and assumed a constant return to scale. It is non-parametric, as it does not require an explicit functional form and constructs the frontier from the observed input-output ratios by linear programming techniques. Here technical efficiency is defined as minimum input for any particular combination of outputs. The production frontier obtained is the boundary of the freely disposal convex cone of the data set. DEA determines the frontier by constructing a virtual (or composite) producer with the highest possible efficiency, using farm-level data on outputs and inputs and without imposing any restrictions on production technology. The frontier "envelops" the observations when an average production function passes through the center of the data. This is illustrated in Figure 3 below:

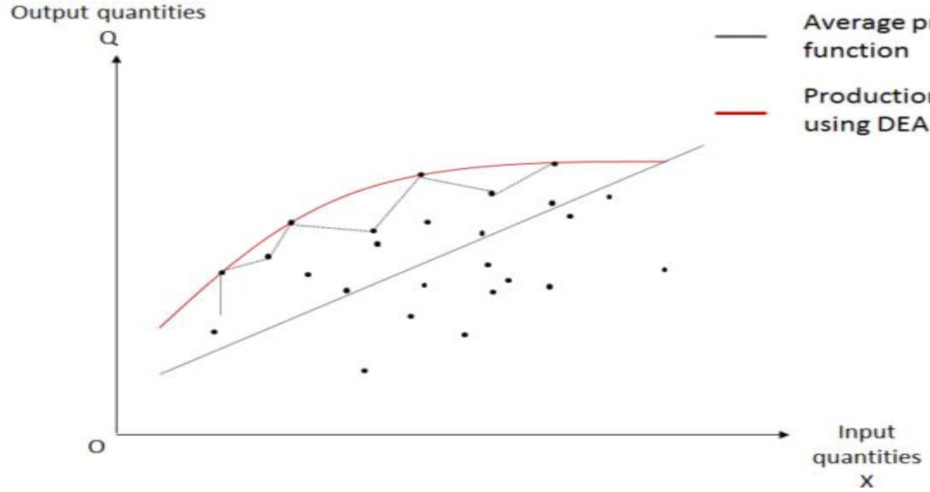


Figure 3: Construction of the production frontier using Data Envelopment Analysis.
Source: Arnade, 1994.

According to Coelli *et al.* (2005) and Llewelyn and Williams (1996), the advantages of DEA are it can handle multiple inputs and multiple outputs; it does not require an assumption of a functional form relating input to outputs; it does not require a priori assumption concerning the distribution of inefficiency parameter as in the case of parametric frontier models; and it is unit invariant.

On another side, the shortcoming of DEA is that it is not possible to test the hypotheses regarding the existence of inefficiency and the structure of the production technology that was possible in stochastic production frontier analysis (Chen *et al.*, 2015). Moreover, Neff *et al.* (1993) noted that many of the observations in the non-parametric frontier method are self-referencing and hence the method is unable to form a reference technology that includes other farms.

Mathematically, the equation of DEA is to find a set of weights that maximize the output expansion of the producer under consideration, under the constraint that the producer cannot be more efficient than the "best" producer can. This is an iterative process of construction of the production frontier with DEA that can be presented as a problem of linear optimization. The result is an optimal set of input-output combinations for each product, describing the production technology of a virtual or composite producer with the highest possible efficiency. The optimal weights are obtained by solving the mathematical programming problem (Coelli *et al.*, 2005).

$$\max_{u,v}(u'q_i / v'x_i),$$
$$st^1 \quad u'q_i/v'x_j \leq 1, \qquad j = 1,2,...I,$$
$$u,v \geq 0. \qquad (5)$$

Where: u is an Mx1 vector of output weight and v is an Nx1 vector of input weights. One problem with this ratio formulation is that it has an infinite number of solutions. Thus, one can introduce constraint, $uv'x_j = 1$ which provides the following multiplier form (equation 6):

$$\max_{\mu,v}(\mu' q_i),$$
$$st \quad v'x_i = 1,$$
$$\mu' q_j - v'x_j \leq 0, \qquad j = 1, 2...I,$$
$$\mu, v \geq 0. \qquad (6)$$

The duality in linear programming can derive an equivalent envelopment form of this problem (equation 7);

$$\min_{\theta,\lambda}\theta,$$
$$st^1 \quad -q_i + Q\lambda \geq 0,$$
$$\theta x_j - X\lambda \geq 0,$$
$$\lambda \geq 0, \qquad (7)$$

Where: θ a scalar and λ is an Ix1 vector of constants. The value of θ obtained is the efficiency score for the i^{th} firm, which satisfies θ≤1, with value 1 indicating a point on the frontier and technically efficient firm.

Several authors like Coelli *et al.* (2005), Thiam *et al.* (2001), Ajibefun (2002), and many others agree that stochastic frontiers are more likely to be appropriate than DEA in agricultural applications of efficiency analysis.

Stochastic Frontier Model: Based on the effort of Aigner and Chu (1968), many authors have contributed to the further development of the stochastic frontier model (Aigner *et al.*, 1977; Meeusen and van Den Broeck, 1977; Battese and Corra, 1977). It assumes that all firms share a common family of production, cost, and profit frontiers, and all variations in the firm's performance are attributed to variations in the firm's efficiency. Under this approach, different scholars apply different methods (Non-parametric, Parametric, Probabilistic, and Statistical methods) in the empirical studies of technical efficiency analysis. It takes into account the possible influence of measurement errors and other noise upon the frontier (Coelli *et al.*, 2005). These are random shocks especially in agriculture as well as measurement errors and misspecification of models.

Stochastic Frontier Model requires measuring efficiency based on the econometric estimation of a production function that explicitly includes an error component. It assumes a specific type of production function. However, its account of inefficiency is more explicit and general than other parametric methods, such as the average production method that compares technical efficiency only between predetermined groups of farms (Mechri *et al.*, 2017).

Adedeji *et al.* (2013), Azeez *et al.* (2013), Gelaw and Bezabih (2004), Alemu and Amare (2005), and many others used this methodology in different agricultural and related commodities in several regions and countries under different production systems and Agro-climatic regions.

The stochastic frontier analysis is based on the standard production function approach, which relates the quantity or value of output of a given farm, I (q_i) to the number of inputs used (x_i) through the production technology f (.) as:

$$qi = f(xi).\exp(vi - ui) \tag{8}$$

Where: v_i is a two-sided random error component beyond the control of the farmer; ui is a one-sided inefficiency component.

The inclusion of a random error term takes into account that, although the production function is assumed correctly on average, random shocks may lead to differences between the observed production and the theoretical output based on the production technology. It is generally assumed to be the realization of asymmetric random error with mean zero.

The existence of an inefficiency component is formalized by defining ui as a non-negative variable, implying that the observed output was always equal to or lower than the technically efficient output. In the case of the absence of inefficiencies ($u_i = 0$), the model becomes a simple production function that assumes technical efficiency. Technical inefficiency is the ratio between the output assuming technical efficiency and the technically inefficient output (equation 9):

$$IEi = f(xi).\exp(vi) / f(xi).\exp(vi - ui) = f(xi).\exp(ui) \qquad (9)$$

Afriat (1972) proposed a two-parameter beta distribution for e^{-u}, and proposed that the model be estimated by the maximum likelihood method. On the other hand, if u is exponential, then linear programming procedure is a maximum likelihood, while their quadratic programming procedure is a maximum likelihood if u is half-normal (Aigner and Chu, 1968).

In general, most empirical studies on technical efficiency analysis in agriculture used a stochastic frontier model that is due to the very nature of the agricultural output. It is affected by a natural hazard, climatic condition and measurement errors that could attribute to the presence of noise in the data (Alemu and Amare, 2005; Gelaw and Bezabih, 2004; Mango *et al.*, 2015; Azeez *et al.*, 2013; and many others). Hence, most recent studies on technical efficiencies in agriculture have used the stochastic frontier model to account for random noise. However, theoretical as well as empirical findings revealed that the smaller the random noise present on the data in question, the closer was inefficiency estimates between these two deterministic and stochastic frontier models.

Unlike that of the deterministic frontier approaches, the stochastic frontier approach measures productive efficiency by the ratio of observed output to the stochastic production frontier, $Yi / f(Xi, \beta) + Vi$ rather than by the ratio of observed output to the deterministic frontier, $Yi / f(Xi; \beta)$. The measuring of productive efficiency by the ratio of observed output to the stochastic production frontier simply distinguishes productive efficiency from another source of disturbance that is beyond the firm's control (Aigner *et al.*, 1977).

The primary advantage of the stochastic frontier production function is that it enables one to estimate farm-specific technical efficiencies with the inclusion of ui. However, the estimation of efficiency using the stochastic method requires a prior specification of functional form and needs distributional assumptions (half-normal, gamma, truncated, etc.) for the estimation of ui, which cannot be justified given the present state of knowledge (Coelli *et al.,* 2005). The issue of functional form and distributional assumptions for the estimation of ui is the main discussion points in the following paragraphs.

Coelli *et al.* (2005) discussed three common functional forms namely Cobb-Douglas, Translog, and Zellner-Revankar generalized production functions. Each functional form has its strengths and shortcomings. The Cobb-Douglas functional form has been commonly used in the empirical estimation of frontier models. Its simplicity is a very attractive feature. This simplicity, however, is associated with several restrictive features like constant elasticities, the constant return to scale for all firms and elasticities of substitution are equal to one. On the other hand, the translog functional form imposes no restrictions upon returns to scale or substitution possibilities and the Zellner-Revankar form removes the return to scale restriction. However, these functional forms are susceptible to Multicollinearity and degree of freedom problem (Coelli *et al.*, 2005). Battese and Broca (1997) pointed out that Cobb- Douglas and Trans log are the two most common functional forms that have been used in empirical studies on production, including frontier analysis. There is a debate on the selection of Cobb-Douglas functional form and translog specification on yielding lower average technical efficiency indices and Multicollinearity issues.

However, according to Gelaw and Bezabih (2004), most researchers compared the two and preferred Cobb-Douglas functional form. Kalirajan *et al.* (1996), Apezteguía and Gárate (1997), Bravo-Ureta and Pinheiro (1997), Yao and Liu (1998), Sharma *et al.* (1999), and many others were among them. The reasons are its simplicity; the possibility of decomposing efficiency estimates into technical and allocative efficiencies (since the function is self-dual); and the problem of Multicollinearity associated with trans-log. However, it is important to test the two functional forms based on actual data on the rising issues and decide them.

The other advantage of the model is that the ability of the model to separate the random error or noise, such as weather that is stochastic and not due to operator inefficiency, from deviations arising from technical inefficiency. Due to this, most empirical studies especially in agriculture where random errors due to random shock and measurement error are a high focus on the stochastic frontier model. Coelli *et al.* (2005) recommended that SPF is more appropriate than DEA and deterministic models in agricultural applications, especially in developing countries, where the data are heavily influenced by measurement errors, and the effect of weather, disease, etc. plays a significant role.

An additional attractive feature is that it permits the estimation of standard errors and tests of hypothesis using traditional maximum likelihood methods which were not possible with the deterministic model due to the violation of certain ML regularity conditions (Coelli *et al.*, 2005).

However, a serious shortcoming, in general, is that there is no prior justification for the selection of any particular functional form for the inefficiency term, ui. The parametric frontier methodology requires the selection of specific functional form, which may not hold.
In addition to this, the other main issue in efficiency analysis is a prediction of firm-level efficiencies that is related to ui's. The absence or the presence of technical inefficiency in a given data can easily be tested using the generalized- ratio test which requires the estimation of the model under both the null and alternative hypotheses. Under the null hypothesis, Ho: $\gamma = 0$, the model is equivalent to the traditional average response function, without the technical inefficiency effect, ui’s. The test is as follows (equation 10):

$$LR = \lambda = -2[L(Ho) / L(H_1)] \qquad (10)$$

$$\lambda = -2[L(Ho) - L(H_1)]$$

Where: $L(H_0)$ and $L(H_1)$ are the values of the log-likelihood function under the null and alternative hypotheses, H_0 and H_1, respectively. This generalized likelihood-ratio test, LR, has asymptotic distribution, which is a mixture of $\chi 2$ distribution, namely $1/2\ \chi_0^2 + 1/2\ \chi_i^2$ (Coelli, 1995).

The other characteristic of the stochastic frontier model associated with inefficiency effects is the type of distributional form for the ui's. This characteristic, specification of appropriate distributional form, is the main criticism of the stochastic frontier model for it has generally no prior justification for its selection. The half-normal distributional form is the most common and almost universally assumed in empirical studies of technical efficiency. There are also other general distributional forms such as truncated-normal and the two-parameter gamma distribution.
Though there are generally theoretical agreements among researchers that the arbitrary nature of the distributional assumption and the restrictive nature of specifying a given functional form as disadvantages, its consideration of noise on the data and the possibility of the testing

hypothesis are the most appealing characteristics of the stochastic frontier model (Gelaw and Bezabih, 2004).

Having said the above basic issues, the next point is types of modeling in identifying determinants of efficiency. Researchers mostly use two types of modeling. One way is the linear regression method in a second stage analysis after efficiency estimates are obtained for each decision-making in the first stage estimation. The other way of modeling determinants of inefficiency is by estimating these variables using a one-stage analysis with the production frontier. Regarding these two methodologies, there are debates whether the two-stage estimation procedures produce better estimates of efficiency as well as locate appropriate variable that determines the inefficiency level or not (Gelaw and Bezabih, 2004).

In the first stage estimation, the inefficiency effects are assumed to be independently and identically distributed to predict the value of technical inefficiency. However, in the second stage, the predicted inefficiency effects are assumed to be a function of several firm-specific factors, which implies that they are not identically distributed unless all the coefficients of all the factors are simultaneously equal to zero (Gelaw and Bezabih, 2004). To avoid inconsistency in a two-stage analysis Kumbhakar *et al.* (1991) and Reifschneider and Stevenson (1991) specified stochastic frontier models in which the inefficiency effects were defined to be an explicit function of some firm-specific factors, and all parameters were estimated in a single-stage ML procedure (Coelli *et al.*, 2005). However, the dependent variable for the inefficiency effects model here is the inefficiency scores which is censored from left, as the efficiency scores are censored from the right. Thus, we cannot employ a one-stage analysis using SPF because it is not a productivity model.

Therefore, a two-stage analysis is used in current research. Hence, the Tobit model is used in two-stage to identify sources of inefficiency variables.

Concerning appropriate distributional form for inefficiency effect, ui's is assumed mostly a truncated normal distribution N (μi, σi^2) (Gelaw and Bezabih, 2004). The kernel density graph that is mostly used to determine the nature of the distribution is used in this research.

2.3.2 Analytical framework for commercialization

There are different approaches used to measure household commercialization levels. According to Von Braun *et al.* (1991) and Von Braun and Kennedy (1994), there are three types of commercialization indices at the household level: which are output and input side commercialization, commercialization of the rural economy and degree of a household's integration into the cash economy. For each type, the authors formulated indices measuring the extent of household commercialization. The first index measures the proportion of agricultural output sold to the market and input acquired from the market to the total value of production. The latter defines the commercialization of the rural economy as the ratio of the value of goods and services acquired through market transactions to total household income. Here, there is an assumption that some transactions may take place in-kind such as payments with food commodities for land use. Thirdly, the degree of household integration to the cash economy is measured as the ratio of the value of goods and services acquired by cash transactions to the total household income.

Govereh *et al.* (1999) and Strasberg *et al.* (1999) used a household commercialization index (HCI), which is a ratio of the gross value of all crop sales per household per year to the gross value of all crop production. This ratio does not incorporate the livestock subsector, which could be more important than crops in some farming systems.

The other approaches to measure the level of household commercialization are sales-to-output and sales-to-income ratios, net and absolute market positions (either as a net buyer, net seller, or autarkic/self-sufficient household), and income diversification or level of specialization in agricultural production. The sales-to-output ratio measures the gross value of all agricultural sales by a household as a percentage of the total gross value of its agricultural production (Gabre-Madhin *et al.*, 2007 as cited in Jaleta *et al.*, 2009). The total sales-to-income ratio is the ratio of the gross value of total sales to total income from crop production. In this index, income from crop production is assumed as a proxy to total household income, ignoring income from livestock, and off-and non-farm sources. The market position of a household is evaluated using the ratio of the volume of sales and volume of purchases to the total volume of stock: the sum of storage from the previous production year and production in the current year. The specialization index tries to capture to what extent farm households are specialized in their production to capture the benefits from comparative advantages: producing what they can efficiently produce and buying what they cannot. This index measures the proportion of the value of purchased agricultural products not produced by households to the gross value of agricultural production (Jaleta *et al.*, 2009).

Additionally, using the marketable surplus of produce as a measure of commercialization is also another option. The term marketable surplus in the context of produce denotes the quantities of products available for consumption by the non-farming population and as raw materials for manufacturing and processing industries. This concept helps to measure the extent of the commercialization of the production activities of a particular crop. While high proportions of marketable surpluses indicate the greater market orientation of the producers, lesser proportions of surpluses mean that the producers are more subsistence-oriented.

As it is mentioned above, there are various ways to measure the level of commercialization for different commodities. According to Govereh *et al.* (1999), it can be measured in the range from zero to unity that is from complete subsistence-oriented production to a hundred percent commercialized productions. Von Braun *et al.* (1991) and Von Braun and Kennedy (1994) specified the forms of commercialization and integration into the cash economy from at least three different angles and measured the extent of their prevalence at various levels with the following ratios:

1. Commercialization of Agriculture (Output side)

$$= \frac{Gross \text{ value of Agricultural sales in markets}}{Gross \text{ value of Agricultural production}} \tag{11}$$

b) Commercialization of Agriculture (Input side)

$$= \frac{Gross \text{ value of inputs required from market}}{Gross \text{ value of Agricultural production}} \tag{12}$$

2. Commercialization of Rural Economy

$$= \frac{Gross \text{ value of goods and services aquired through market transaction}}{\text{Total Income}} \tag{13}$$

3.The degree of integration into the cash Economy

$$= \frac{\text{Gross value of goods and services aquired through cash transaction}}{\text{Total Income}} \quad (14)$$

Accordingly, equation (12) above was adopted for the current study considering an output as an agroforestry commodity.

Furthermore, the works of literature suggests two analytical approaches for analyzing the determinants of commercialization. The following are some of the analytical models, which can be applied in the analysis of determinants of commercialization.

The model, tobit (Table A 13) (Tobin, 1958) is among important models in the analysis of determinants of commercialization. It describes the relationship between a non-negative dependent variable and an independent variable. A special case of censored regression models used when the dependent variable is limited (or censored) from above and/or below. It can capture in cases where the Probit or Logit model cannot.

Heckman’s two-stage model that was developed by Heckman (1979) and has been used extensively to correct for bias arising from sample selection. The model assumes that the missing value of the dependent variable implies that the dependent variable is unobserved (not selected). Heckman's two-stage model models the participation decision as a two-step process that involves first the household deciding on whether or not to participate and compute the inverse mills ratio from the probit regression and use it as a regressor with other explanatory variables to explain the outcome of the dependent variable. The other important model is Double hurdle model. The Craggs' Double hurdle model (as estimated in Table A 12) was among the first introduced models by Cragg (1971). It assumes a two-step decision process. First, the individual determines whether he or she wants to participate in the market, which is the participation decision. Then the individual determines an optimal selling amount (which may be 0) given his or her circumstances, this is quantity decision. This is based on the assumption that the household makes two separate decisions; the first step involves the decision to participate in the market or not participate and secondly the level of participation. First, the model involves a probit regression to identify factors affecting the decision to participate, and then a truncated regression model on the participating households to analyze the extent of participation, in the second stage. The model considers error terms of the participation equation and the quantity equation are jointly normal and may be correlated. Its basic shortcoming is not capturing sample selection bias when an error of the selection and outcome equation is dependent or correlated.

However, in the current study, it is observed that there are sample selection bias and no need to make incidental truncation. Thus, the Heckman two-stage model was used to identify determinants of Moringa commercialization. The detail of the model is explained in methodology part.

2.2.3 Analytical framework for food and nutritional security impact

The complex issue in measuring food security is selecting the best indicator. The current study used one of the indicators mentioned in Lele *et al.* (2016) that grouped indicators into eight different categories based on the underlying data source, and each of them might be used in various ways. It provided 33 types of indicators, drawn from the growing universe of over 100 measures in current use.

The mentioned eight indicators based on sources of data are national observations, market observations, household or individual recall, anthropometric measures, prevalence and depth of undernourishment, biomarkers and clinical data, breastfeeding and sanitation, and composite indexes and multidimensional measures (Lele *et al.*, 2016).

The National observation indicators use data collected at the national scale. Market observations use price indicators of relevance to food security and nutrition that are intended to measure access and affordability by households and individuals. Household or individual recall uses household/individual consumption recall data. The Anthropometric measures in other forms measure the human body's physical dimensions, principally in terms of height, weight, and circumferences. The prevalence and depth of undernourishment use a combination of individual data on age, sex, and height, with household data from food consumption and expenditure surveys, plus country-level data from food balance sheets that are used to produce the UN system's headline measure of dietary deprivation, prevalence of undernourishment. Biomarkers and clinical data are used for data that require bodily samples (biomarkers) or records collected from health service provision (clinical data). Breastfeeding and sanitation are based on data from breastfeeding and sanitation patterns of the household. Lastly, the composite indexes and multidimensional measures combine different dimensions to rank or classify different factors in a standardized way, providing a summary statistic for overall performance over time. It has good implications in providing the multiple data into a single measure but suffers from the danger in a claim to have measured a phenomenon in a holistic manner, which can be misleading because the index components and weights measure different things. In addition to this rankings can lead to complacency among those at the top, or frustrations among those eat the bottom if they are unable to rise (Lele *et al.*, 2016).

Among the above-mentioned indicators household or individual, recall indicators considered the easiest way to get relevant data from households using a questionnaire. The number of total calories from each food item (see Appendix A) intake per household is among the most useful household-level indicators of food security. Additionally, the Food Consumption Score (FCS) of food groups or prevalence of low diversity is another important indicator to measure food and nutrition security (Berry *et al.*, 2015; Lele *et al.*, 2016).

In the current research, the difference in calorie intake between the treated and the control group was used to estimate the FS impact of Moringa production. Moreover, the difference in FCS of the treated and control households was used to evaluate the nutritional security impact of Moringa production which is based on the food groups proposed by Vhurumuku (2014). The dissertation has used these indicators for measuring food and nutrition security impact of Moringa production. The Food Consumption Score (FCS) of food groups or prevalence of low diversity is another important indicator to measure food and nutrition security (Berry *et al.*, 2015;Lele *et al.*, 2016) as listed in the appendix A (Table A 5). The Food Consumption Score (FCS) is calculated by summing the number of food groups consumed in the household or by the individual respondent over the 7 days recall period.

For the evaluation food and nutrition security impact, literatures suggest various approaches to analyze food and nutrition security impact of specific intervention/exposure. Traditionally, researchers have tried to address the issue of confounding using multivariate matching methods, regression adjustment, or stratification (Manca and Austin, 2008). These approaches though have limitations. Multivariate matching is impractical and often impossible when there are large numbers of covariates. Regression adjustment requires the joint distribution of the covariates to be approximately the same between treatment groups. Stratification has limitations in that as the number of covariates increases the number of subclasses increases exponentially, making it difficult to create strata that contain both treated and untreated subjects.

An approach found convincing to current research is the Propensity Score Matching (PSM) model. PSM model is an important model in an observational study to estimate the effect of treatment on outcomes (Rosenbaum and Rubin, 1983).

The problem of biases from simple regression or logistic models made PSM a good option to look at causal effects in observational studies. As mentioned in Abate *et al.* (2014) the PSM model used in this research has also the following three expected biases. The 'selection on observables' which may arise due to sampling bias, the selection of a comparison group in the presence of externalities, and lastly 'selection on unobservable arising due to differences between producers and non-producers in the distribution of their unobserved characteristics. The third bias will not be removed but the quality of the data collection method, identification of relevant variables, and the evaluation of matching quality used are expected to reduce it (Abate *et al.*, 2014).

Simple regression or logistic models also did not adjust for the distribution between the treated and control groups, the models suffer the problems of endogeneity and used to adjust for confounding covariates, but such models rely on assumptions regarding functional form.

PSM model is advantageous in the computation of the causal effect because it is less susceptible to the violation of model assumptions; it eliminates two sources of bias (Heckman *et al.*, 1998), the bias from non-over-lapping supports and different density weighting. Further, if treatment assignment is strongly ignorable in observational studies, it estimates an Average Treatment Effect on Treated (ATT) close to the ATT calculated from experiments. The matching technique in PSM is nonparametric (did not suffer from problems that are prevalent in most parametric models); it is much easier to understand than the interpretation using ''control all other variables at mean'' or ''ceteris paribus.'' in regression models (Li, 2013).

Despite many advantages, PSM faces limitations on drawing statistical inferences, it has no established procedures to investigate whether treatment assignment is strongly ignorable, it cannot deal with unobservable variables, it depends on the quality of the observational data and little guidance in selected propensity score matching techniques (Li, 2013).
There is almost no technique perfect in drawing an unbiased causal inference. The research has tried to minimize limitations through quality data collection, the inclusion of most relevant variables, and using recommended matching techniques.

In this study, PSM was used to evaluate the causal effect of Moringa production on food and nutrition security of smallholder farmers. The detail of empirical model is explained in methodology part.

2.3 Review of Empirical Studies

2.3.1 Empirical studies on production efficiency analysis

It is highly important to implement the theories and approaches of economics to the area of agroforestry. However, there are limited numbers of economic studies in this area. Mercer *et al.* (2014) tried to examine necessary conditions for achieving efficiency in agroforestry system design and economic analysis tools for assessing efficiency and adaptability in agroforestry. The study presented capital budgeting, linear programming, production frontier analysis, and risk analysis as a tool that can help to determine when agroforestry is a feasible option and provide arguments for cases when agroforestry systems are economical, socially and environmentally appropriate, fostering improved sustainable development for landowners, farmers, and communities. The following are some of the recent empirical studies on productivity and efficiency analysis of different agroforestry commodities around the world that are found relevant for the current study.

The stochastic frontier analysis is most preferred in the analysis of single-output. The study by Alene *et al.* (2006) measured the efficiency of intercropping systems of annual and perennial crops production in southern Ethiopia using the stochastic frontier production function (SFP), parametric distance functions (PDF), and data envelopment analysis (DEA) and compared the empirical performances of these methods. The study indicated the PDF and DEA approach provided higher efficiency of the systems than the single output SFP approach in case of multi-output agriculture involving intercropping of annual and perennial crops, Maize, and coffee. Single-output measures of productivity and efficiency may thus underestimate resource use efficiency of intercropping systems. Based on the geometric mean technical efficiency predictions for each data point using the preferred approaches, the sample farmers in southern Ethiopia have an average technical efficiency of 91% (Alene *et al.*, 2006).

Lindara *et al.* (2006) applied a stochastic frontier analysis using a Cobb-Douglas production function to evaluate factors affecting the TE of spice-based agroforestry systems in Sri Lanka. The study found that hired labor, organic fertilizer, inorganic fertilizer, land size, and soil fertility maintenance cost showed significant and positive effects on agroforestry production. The mean technical efficiency of the spice-based agroforestry systems was 84.32 percent. The inefficiency model indicated that the efficiency increased because of farm visits by extension officers, participation in farmer training, less sloping lands, more experienced, and higher diversity of the agroforestry system. Technical efficiency decreased, however, with the higher education level of the farmer and with higher non-farm income.

Moreover, Luangmany (2014) analyzed the technical efficiency of rubber tree cultivation at the productive stage to observe the actual efficiency level and the potential efficiency of smallholder rubber tree cultivation across the sample villages in Northern Laos. Results indicated that the actual level of efficiency of rubber tree cultivation among smallholder remained to be low on average. Moreover, it implied that in the future the large potential efficiency could be further improved. The study found that technical efficiency in rubber tree cultivation negatively influenced by females and positively influenced by age below 50 years old.

Frey *et al.* (2012) investigated whether Silvopasture, a combination of planted trees and pasture, is a more efficient use of resources for farmers than conventional systems such as pasture and plantation forestry in Argentina. A non-parametric technique based on linear programming called data envelopment analysis is used to estimate the relative technical efficiencies of the different systems. The study used non-parametric statistics to compare the systems within farms. Thus, Silvopasture found to be a more efficient use of resources than conventional cattle ranching, but its result indicated inconclusive concerning conventional forestry.

Azeez *et al.* (2013) studied the profitability of Moringa production; the productivity of the factors involved in Moringa production as well as the technical efficiency (TE) of Moringa production in Nigeria by using descriptive and stochastic frontier analysis. The study result indicated that cooperative membership and farming experience have a significant and positive effect on the farmer's technical efficiency of Moringa production.

In India Sekhar *et al.* (2018) implemented resource use efficiency analysis by using a Cobb-Douglas production function to find factors affecting Moringa cultivation. The study indicated four principal variables such as several limb cuttings used for planting, the quantity of Farm yard Manure (FYM), the quantity of fertilizer applied (kg), and the number of human labor used (man-days) per ha per annum were found to significantly influence the yields of Moringa.

The current study mainly also focuses on the output of this agroforestry commodity, Moringa as a single output. In general, it is likely to conclude that household demographic and socio-economic, farm and farmer specific characteristics, marketing and institutional factors are among the various determinants of Moringa production efficiency and would be the focus of current research.

2.3.2 Empirical studies on commercialization of agroforestry commodities

The new initiatives in agroforestry are seeking to integrate into tropical farming systems indigenous trees whose products have traditionally been gathered from natural forests. This is being done to provide marketable products from farms that generated cash for resource-poor rural and peri-urban households. This poverty-alleviating agroforestry strategy is at the same time linked to one in which perennial, biologically diverse, and complex mature stage agro-ecosystems are developed as sustainable alternatives to slash-and-burn agriculture. One important component of this approach is the domestication of the local tree species that have commercial potential in local, regional, or even international markets (Leakey and Simons, 1998).

The study by Gibreel (2013) evaluated the shift in the farming system from a traditional sustainable system to a more commercialized one, which has resulted in a drastic decline in soil fertility, decreased crop productivity, and low gum Arabic production. The research empirically investigated the factors influencing the decision to adopt agroforestry using a binary probit model. The results showed that farmers with less commercialization, access to credit, less fragmented land, more education, high gum Arabic gate price, located away from the markets, and with more years of experience in farming are more likely to practice the traditional gum Arabic agroforestry system. In contrast, the allocation of more working days for commercial sole crop production, more fragmented land, and higher commercialization index reduce the probability of gum Arabic agroforestry adoption. The study recommended a traditional intercropping system with a gum tree (*Acacia Senegal*) to promote the sustainable farming system in the area to promote soil fertility and to improve the effect of sole crop commercialization on traditional gum Arabic agroforestry system.

Additionally, the research by Kelemu *et al.* (2012) presented the experience gained from the project intervention aimed at the commercialization of Moringa production conducted at Shoarobit, North Shoa zone of the Amhara national regional state. The project implemented a value chain approach through creating awareness and building the capacity for different actors involved. Documentation of available technologies and knowledge, promotion of production, the creation of enabling environment and aligning public and non-public support, demand, and market creation was also the major strategic intervention elements that contributed to the success of the project. The research mentioned Moringa as a processed and traded commodity in the local and Addis Ababa markets.

Apart from the above-mentioned points, there are no empirical studies conducted in the commercialization of Moringa in different parts of the world. However, the study by Gonzalez and van der Maden (2015) indicated that Moringa trees in Bangladesh and other developing countries have great potential in terms of nutrition security and income generation, but often seem to be underutilized.

In general, the recent government of Ethiopia attempts to promote the production and marketing of high-value products, which is intending to increase competitiveness in domestic, regional, and international markets. Besides, the shift in the paradigm of strategy for food security from food production-oriented to improving food access through improving household income and promoting market-oriented production has opened the window for engagement of smallholder farmers in market-oriented production (MoFED, 2010).

However, smallholder commercialization is still determined by institutional factors, infrastructural and market-related factors, household resource endowments, and household-specific characteristics (Abera, 2009; Bekele *et al.*, 2010; Gebremedhin and Jaleta, 2010; Gebremedhin *et al.*, 2009; Pender and Alemu, 2007). These factors are broadly categorized as external and internal factors.

In general, from the above reviewed literatures, it is possible to conclude that household demographic, socioeconomic, farm and farmer specific attributes, marketing and institutional factors are among the most essential determinants of Moringa commercialization that are the main focuses of this study.

2.3.3 Empirical studies on impacts of Moringa on food and nutrition security

Among different food items, Moringa is perceived as a good potential in the fight against hunger and malnutrition in the developing world (Ebert, 2014). *Moringa oleifera*, an edible tree found worldwide in the dry tropics, is increasingly being used for nutritional supplementation. Its nutrient-dense leaves are high in protein quality, leading to its widespread use by doctors, healers, nutritionists, and community leaders, to treat under-nutrition and a variety of illnesses (Thurber and Fahey, 2009).

Most parts of the tree are edible. According to Ebert (2014), the leaves and flowers of *Moringa oleifera* are eaten as a salad, like cooked vegetables, or added to soups and sauces or used to make tea. The young, tender pods "known as drumsticks" are highly valued as a vegetable in Asia and are pickled. Fried seeds taste like groundnuts. The root bark has a pungent taste similar to horseradish (*Armoracia rusticana*) and is used as a condiment. Dried leaf powder is a good option to supplement the diets of children and pregnant and lactating women. For example, Moringa leaf powder is added to a soybean and groundnut/peanut paste to form an energy-dense supplemental food known as ready-to-use food (RUF) for the treatment of severe acute malnutrition.

The studies by Agbogidi and Ilondu (2013) and James and Zikankuba (2017) indicated every part of the tree (leaves, stem, bark, root, pod, flower, seeds, and gum, oil (from seed)) is beneficial in some way hence regarded as the tree with greatest benefits on planet earth. The tree is rich in proteins, vitamins, minerals. All *Moringa oleifera* food products have a very high nutritional value. They are eaten directly as food, as supplements, and as seasonings as well as fodder for animal supplements, and as seasonings as well as fodder for animals.

In Ethiopia according to Abuye *et al.* (2003) in the Arba Minch and Wolaita areas, the local people cook the leaves of the *Moringa stenopetala* tree and eat them with their traditional *kurkufa* (a cereal dish made with maize and sorghum). In contrast, the people of Konso use the tree not only for food but also as a medicine and they cultivate it in large areas around their villages. There are claims that the leaves, boiled in water, can cure malaria, hypertension, and stomach pain, whereas the roots, chopped and mixed with water, are also used for treating severe cases of malaria. It is used as herbal medicine in areas where visceral leishmaniasis or kala-azar (caused by the *Leishmania* parasite) prevails (Mekonnen, 2003).

Moringa has a higher contribution to the countries suffering the problem of food security. The studies conducted by Melesse *et al.* (2009) described that the plant yields at least five different edibles: leaves, pods, seeds, flowers, and roots. The protein content of the leaf, pod, flower, seed, and root was 28.36, 25.19, 29.93, 40.46, and 4.79% on a dry weight basis, respectively. In crude fat content, the seed was found to be superior while the root was the lowest. In the crude fiber content, the pod was the highest while the seed kernel was the lowest. Ash contents also vary greatly from 4.54% for seed kernel to 18.41% for the leaf. In mineral contents, the leaf was found to be better than other parts with 2869, 54.62, 1.22, and 0.72 mg/100 g, dw, for Ca, Fe, Zn, and Cu respectively. The pod and the seed contained 10.64 and 5.64 mg/100 g dw of Fe respectively. The pod and the leaf contained comparable amounts of Zn and Cu to that of the leaf. The essential amino acids of the leaf and the seed were also found in appreciable quantities. The leaf contained from the lowest (17 mg/g protein) sulfur-containing amino acids to the highest (80.48 mg/g protein) aromatic amino acids. While the seed contained 14.48 mg/g protein lysine to 60.96 mg/g protein leucine. As the nutrient composition of Moringa edible parts is higher than other leafy vegetables, they can be good sources of nutrients in dry seasons when other vegetables are scarce.

There are also other studies in various parts of Ethiopia on the nutritional aspect of Moringa species. Tekle *et al.* (2015) found that there has been a statistically significant difference in the mean values of all nutrition composition parameters between study regions such as Tigray, Amhara, Oromia, SNNPR, and Dire Dawa except for tannin content of the samples. These findings revealed that *Moringa stenopetala* species of Moringa tree in Ethiopia has an appreciable nutritional profile that can be of great input to fight the long-overdue malnutrition problem in Ethiopia. The consumption of seeds by animals and humans has confirmed to have no toxic effect. The levels of anti-nutritional contents of Moringa seeds consumption may have no significant toxic effect on humans or animals (Ndamitso *et al.*, 2014). With these nutritional values combined with countries suitable agro-climatic conditions, Moringa production can be a good alternative means to curve the countries food insecurity problem.

According to Ebert (2014), the greater use of Moringa has good potential in the fight against hunger and malnutrition in the developing world by improving nutrition and health of the rural and urban poor, increasing incomes of smallholder farmers, and enhancing environmental services by controlling soil and wind erosion, and providing shade and clean water. Given its multiple uses and a wide range of adaptability, Moringa is an ideal crop for sustainable food production that would thrive as the climate changes. Table A. 7 describes the various kinds of nutritional sources from Moringa.

As it has been described above even if it has a great contribution to food and nutritional security there are very limited studies conducted to evaluate its impact on households' food and nutritional security. Therefore, this research is mainly focused on evaluation impact of Moringa production on smallholder farmer's food and nutritional security

2.4 Conceptual Framework

The production, commercialization and food and nutrition security (FNS) impact of Moringa are assumed to be interdependent. As illustrated in Figure 4 the major factors influencing the production and commercialization of Moringa and its economic, food, and nutrition security (FNS) impact interrelations are explored in this study.

The production of Moringa could be increased in various ways. The new technology, increased use of inputs and improving efficiency of resource use are the main ones. The new technology and increased use of production inputs to enhance productivity is difficult due to capital constraints and resource shortage. Thus, the third method that is found best to country like Ethiopia having limited access to technologies, is improving the production efficiency of farmers using the current amounts, quality of inputs and existing technology.

Improving agricultural productivity, particularly Moringa's has a number of benefits. It facilitates the flow of resources from one sector to other, it lower prices of food for consumers and increases income of households and competiveness of the sector.

Commercialization of more specifically commercialization of Moriga in turn provides benefits such as income to the households from selling Moringa yield that increases the welfare of the society and it improves health of community through accessing the medicinally and nutritionally valuable commodity to the society.

The production and commercialization of Moringa are influenced by so many factors. The factors include the socio-economic characteristics; the attributes of Moringa; institutional factors; natural factors; and awareness of the benefits of Moringa affect the production and commercialization of Moringa. The socio-economic characteristics factors include age, sex, family size and household size, livestock holding, off/non-farm income, education level, family education, land size, number of plots, and experience of farming. The institutional factors include use of credit, extension service, and membership of cooperatives, accessibility of development centers. The factors related to the marketing characteristics include distance to market and all-weather road, etc.

The production and commercialization of Moringa may affect the economic, financial, food, and nutrition security of smallholder producers that, in turn, affect the amount of its production and commercialization. The focus of current research laid on socio-economic characteristics, institutional factors, production input-out factors, marketing characteristics and food and nutrition security concerns.

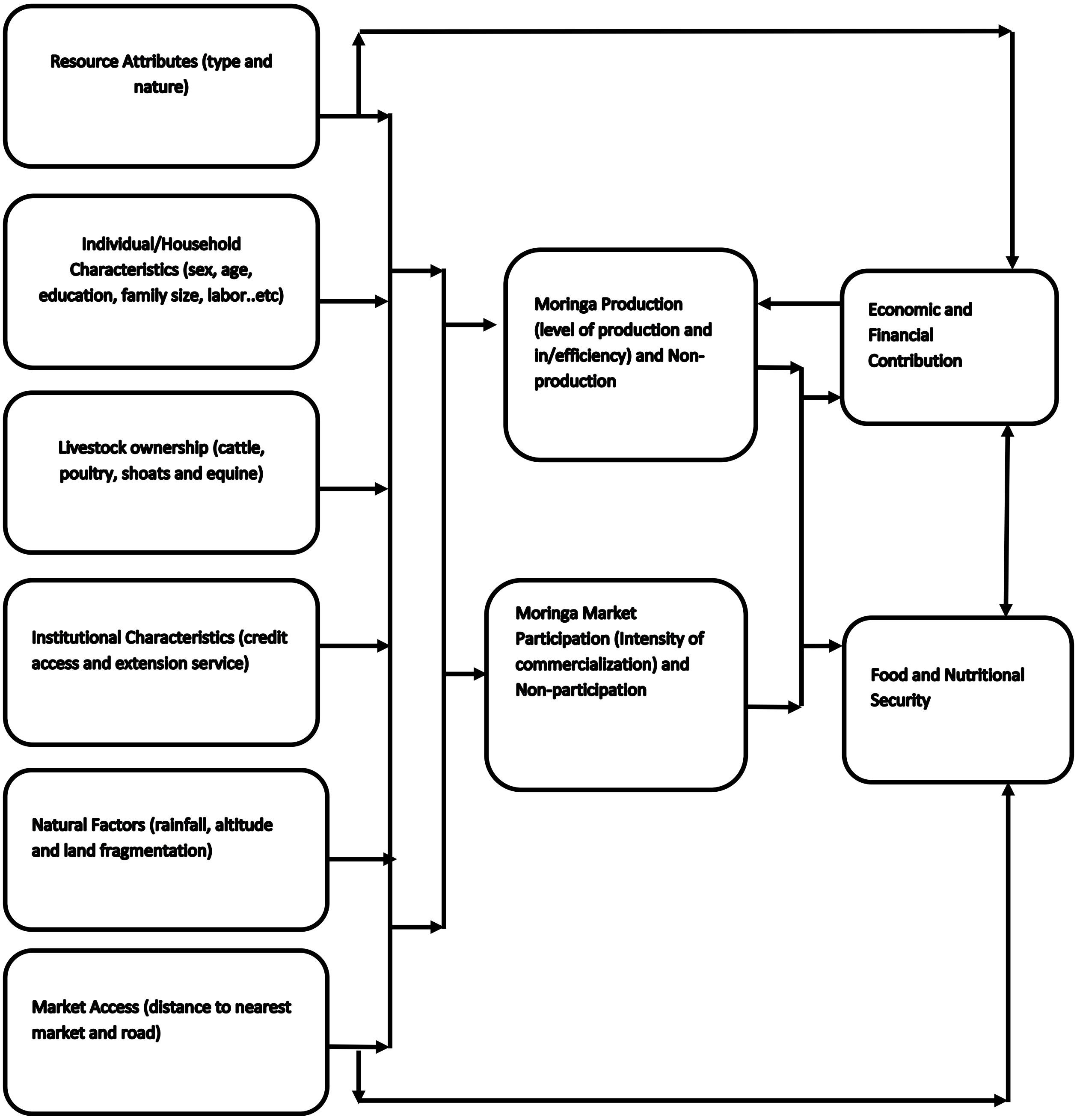


Figure 4: Conceptual framework

Source: Own sketch based on literature review

3. METHODOLOGY

3.1 Description of the Study Area

Wolaita and Gamo Gofa zones are two adjacent zones among the 13 zones in the Southern Nations Nationalities and Peoples Regional State (SNNPR) of Ethiopia where Moringa is extensively produced. Wolaita Sodo is the administrative center of the Wolaita zone. The administrative center of Gamo Gofa is Arba Minch. Wolaita and Gamo Gofa zones are located in between 350 - 500 km south of Addis Ababa on the Sodo Gamo Gofa main road. Wolaita zone is subdivided into 16 districts. The zone has a total area of 4512 square kilometers, administratively divided into 16 districts (locally termed *woredas*). According to the Central Statistical Agency (CSA) (2013) of Ethiopia projection for 2017, the total population of the Wolita zone is 1,948,139. Gamo Gofa zone has a total area of 18,010.99 square kilometers, administratively divided into 18 districts (locally termed *woredas*). Based on the similar CSA (2013) projection for 2017, the zone has a total population of 2,043,668. Figure 5 below demonstrates the study area setting.

According to the CSA (2013) projection report for 2017, from the total population of Wolaita zone, 366,567, or 11.49% are urban inhabitants. Previously, CSA (2007) census reported as 1,196 or 0.08% pastoralists. The number of total households was 310,454, which results in an average of 4.84 persons to a household, and 297,981 housing units. The main economic activity in the area is Agriculture, accounting for more than 90% of the population in rural areas. Animal husbandry is complementary to crop production, and the livestock population of Wolaita with estimated standing livestock populations of 685,886 cattle, 87,525 sheep, 90,215 goats, 1951 horses, 669,822 poultry and 38,564 beehives. Mixed farming involving the production of cereals, root crops, *Ensete*, Moringa, and coffee is practiced.

From the CSA (2013) projected for 2017 for the total population of Gamo Gofa zone, 334,639 or 16.37% were urban inhabitants. Moreover, the last CSA (2007) census reported as 480 or 0.03% pastoralists. The number of total households was 337,199, which results in an average of 4.72 persons to a household, and 324,919 housing units. The main economic activity in Gamo Gofa is Agriculture, accounting for more than 85% of the population in the rural areas.

Animal husbandry is also complementary to crop production The estimated livestock population and beehives of Gamo Goffa zone were; 1,301,056 cattle; 476,329 sheep; 392,380 goats; 50,296 horses; 15,244 mules; 65,441 donkeys; 1,029,170 poultry and 63,479 beehives. The main crops grown in the area are maize, Enset, Moringa, common bean, groundnut, sweet potato, and potato.

As mentioned above Wolaita and Gamo Gofa are among the main growing zones of Moringa. Edwards *et al.* (2000) mentioned South Omo, Gamo Gofa, Kaffa, Sheka, Bench Maji, Wolaita, Dawro, Bale, Borena, Sidama, Burji, Amaro, Konso and Darashe as the main Moringa cultivating zones and special districts of Ethiopia.

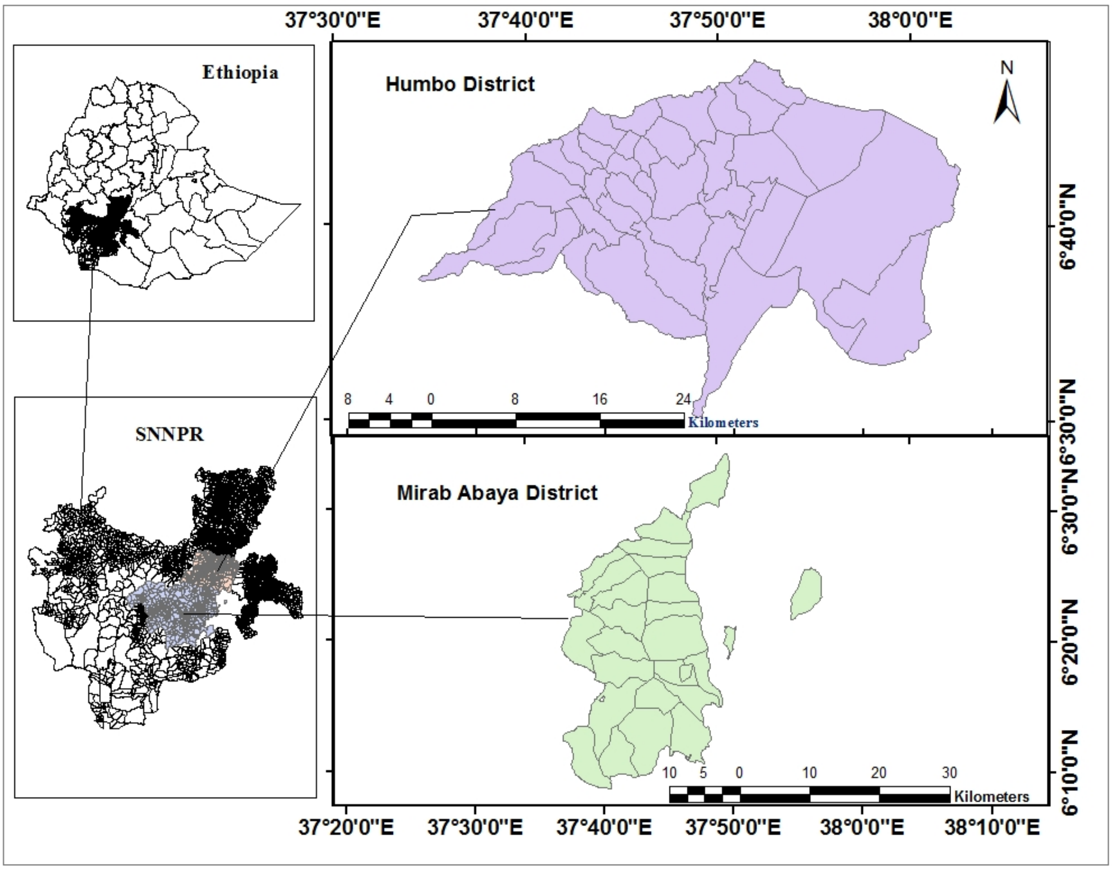


Figure 5: Map of the study areas

Source: Own design using ArcMap 10.7

This study was conducted in Humbo and Mirab Abaya districts of Wolaita and Gamo zones, respectively. The description of location, farming systems and agro-ecology of the two districts are given below:

3.1.1 Humbo District

Humbo District is one of the 16 districts in Wolaita Zone of Southern Nations, Nationalities, and Peoples Regional State (SNNPR). It is bordered by Soddo Zuria District in the north, Ofa district in the west, Abala Hobicha District in the northeast, Abala Abaya District in the southeast, and Boroda District of Gamo Gofa Zone in the south. The District located 397 km south-west of the capital city Addis Ababa and 18 kilometers from Sodo, which is the administrative seat of Wolaita Zone. The District is composed of 20 Kebele administrations, from 20 rural kebeles, 9 have participated in Moringa production agriculture. The district is located between 6.50 to 6.81º N Latitude and 37.57 to 38.04º E Longitude. When considered in terms of agro-climatic zones, 11.11% of the District falls under highland *(Dega)*, 27.77% falls under mid-highland (*Woina-Dega*) and the remaining 61.12 % falls under lowland (*Kolla).*The mean annual temperature of the District is 22.0ºC and the mean annual rainfall is 1123.15 mm (Wolaita Zone Finance and Economic Development Department (WZFEDD), 2018). According to Humbo District Finance and Economic Development Office (HDFEDO) (2018), the district has a total population of 86246 of which the males and females are 41142 and 45104, respectively.

3.1.2 Mirab Abaya District

Mirab Abaya district is one of the 18 Districts in Gamo Zone of Southern Nations, Nationalities, and Peoples Regional State (SNNPR). It is bordered on the east and south by Lake Abaya, which separates it from the Oromia Region on the east and Arba Minch Zuria on the south, on the west by Chencha, on the northwest by Borena, and on the north by the Wolayita Zone. Towns in Mirab Abaya include Birbir. Mirab Abaya was part of former Boreda Abaya woreda. The District located 417 km south-west of the capital city Addis Ababa and 18 kilometers north from Arbaminch, which is the administrative seat of Gamo Zone. It has three major agro-ecologies: dega (high land), woina dega (mid-altitude) and kolla (low land). The District is composed of 24 *kebele* administrations, from these rural kebeles, 16 kola *kebeles* have participated in Moringa production agriculture. The district is located between 6.3418° N Latitude and 37.7663° E Longitude. According to Gamo Zone Finance and Economic Development Department (GZFEDD) (2018) more than 90% of the population of the Woreda depends on agriculture. The total area is 107,971ha, out of which 40,200ha are covered by water, 4,262ha are woodland and 2,462ha are non-arable land. According to Mirab Abaya District Finance and Economic Development Office (MADFED) (2018), the District has a total population of 104,967, of whom 52,472 are men and 52,495 women, respectively (Mirab Abaya District Finance and Economic Development Office (MADFED), 2018).

3.2 Data Types and Sources

The study used both primary and secondary data. The primary data were collected from sample respondents and key informants using an interview schedule and checklists, respectively.

The collected data were technical input-output production data such as the amount of Moringa yearly output, amount of labor utilized for Moringa production, a hectare of land available for the household including Moringa production, and quantity of organic fertilizer added in Moringa.

Market and marketing data such as market prices of Moringa yield from different market agents (producer, broker, retailer, and consumer), amount of Moringa sold per household per year in market and pattern of Moringa selling, places, and challenges in selling Moringa yield.

Data on household and community characteristics such as age, income, marital status, sex, livestock and asset holdings, family size, land size, credit access, irrigation access, education, distance from infrastructural and social services and amount, diversity and frequency of weekly consumption of Moringa and other food items of sampled households.

In addition to primary data on the above issues, secondary data on Moringa production at zonal and district levels, and price of Moringa yield from different market agents (producers, brokers, retailers, and consumers), etc. were collected from different sources, such as government institutions, the *kebele* administrations, trade offices and websites. Published and unpublished documents were also extensively consulted to secure relevant secondary information.

3.3 Methods of Data Collection

Primary data were collected through an interview schedule, focus group discussion, and direct observation. In the course of interviewing, all the respondents were asked a basic set of questions that can help to get the right response to achieve each objective of the study.

Before the data collection task, the data collectors were trained for two days (one day for each district) on how to collect the necessary data using a questionnaire and a pre-testing survey was carried out for one day in each district. Then, the necessary improvements were made on the previous version of the questionnaire (Appendix E). The total number of enumerators used for data collection was 16 (8 from Humbo and 8 from Mirab Abaya districts). The enumerators having a minimum of BSc degree in areas of different agricultural fields were involved in data collection. The overall data collection process was made in three months from December 2018 to February 2019. Besides, the researchers were supervising the data collectors.

3.4 Sampling Design

To choose an appropriate sample size mainly four factors need to be taken into considerations: the desired level of confidence (Z), the margin of error (E), the variability of the population(s), the number of total population (N), and the number of groups within the samples. In addition to this, the degree of precision desired (95% confidence interval), the method of analysis, the objective of the research, cost, and time determine the type and size of the sample. The data were collected from purposively selected zones, Wolaita and Gamo. These two zones were among 14 Moringa growing zones in the region. From these two zones, according to information from the zones, Humbo district (from Wolaita zone) and Mirab Abaya district (from Gamo zone) have a relatively higher potential of Moringa growing than other districts in these zones. Thus, these districts were selected purposively. The total number of sample respondents selected from each district was determined by using the probability proportional to household size method. For determination of the total sample size the Kothari (2004) formula was used as described in the equation (15) below:

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq} \quad (15)$$

$$n = \frac{(1.96)^2(0.5)(0.5)5372}{(0.05)^2(5372-1)+(1.96)^2(0.5)(0.5)} \approx 359$$

Where; n is the sample size; Z is the standard cumulative distribution that corresponds to the level of confidence with the value of 1.96; e is desired level of precision; p is the estimated proportion of an attribute present in the population with the value of 0.5 as suggested by Israel (1992) to get the desired minimum sample size of q=1-p; N is the size of the total population from which the sample is drawn.

Based on the above total sample size determination formula the minimum sample size is 359. However, considering the non-response rate of 29% and aiming to make the dissertation more reliable the total sample size was 464. To make a control group compared to the treatment group 232Moringa producers (treated households) and 232 non-producer (control households) were selected. The same sizes of the samples were selected from the two groups.

To select the above sample size, the study used a multistage sampling technique. That is first, two Moringa growing zones from 13 zones in SNNPR were identified. Then, two Moringa growing districts from two zones were identified based on their actual Moringa production, one from each zone. Then based on potential production, four Moringa growing *kebeles* from each district were selected randomly among the Moringa growing *kebeles*. In the third stage, respondents were selected from respective *kebeles* randomly from Moringa producing and non-producing households in each *kebele*[4] as listed in Table 1 below. The total amount of sample respondents selected from each *kebele* was determined by using the probability proportional to household size method. Finally, sample respondents were selected from the list of *kebele* residents using a simple random sampling technique. In general, 232 from treated and 232 from the control group were selected using probability proportional to household size method.

The sizes of Moringa producing (treated) and non-producing (control) household on districts and *kebeles* are described in Table 1 below.

[4] The smallest administrative unit of Ethiopia, similar to a ward, a neighbourhood or a localized and delimited group of people

Table 1: Sampled households based on districts and *Kebele* administrations

Sampled Districts	Sampled Kebeles	Total Households			Sampled Households		
		Producers	Non-Producers	Total	Producers	Non-Producers	Total
Mirab Abaya	Wanke Wajifo	397	377	774	38	36	74
	Kola Barana	222	188	410	20	17	37
	Yayike	229	204	433	18	16	34
	Delbo	247	223	470	20	18	38
Humbo	Abala Faracho	350	514	864	32	47	79
	Abala Kolshobo	412	318	730	35	27	62
	Buke Dongola	391	502	893	35	45	80
	Abala Longena	394	301	695	34	26	60
Total		2642	2627	5272	232	232	464

Thus, the research used 232 sampled Moringa producer households to identify determinants of Moringa commercialization.

Finally, form 232 Moringa producer households selected above, only 117 respondents having five years of Moringa production experience were used for the analysis of the technical efficiency of Moringa production.

3.5 Methods of Data Analysis

Descriptive statistics and econometric methods of data analysis were used. The descriptive and inferential analysis used for quantitative data collected on Household and community characteristics data; and Quantity of Moringa produced and marketed. It used T-test and chi-square tests, means, percentages, and graphs. The econometric models were used to analyze the efficiency and productivity of Moringa producers, to identify the determinants of farmers' decision to market Moringa yields, level of commercialization and to evaluate the impact of Moringa production on food and nutrition security of smallholder farmers. The details of the mentioned analysis are described below.

3.5.1. Efficiency and productivity analysis

The efficiency and productivity analysis were conducted using a stochastic frontier model. As described in the literature part the stochastic frontier production function was first proposed by Aigner *et al.* (1977) and then Meeusen and van Den Broeck (1977) and then Kumbhakar *et al.* (1991) and others extended the stochastic frontier methodology by explicitly introducing the determinants of technical efficiency into the model. In the agricultural productivity studies, the model has gained popularity as opposed to the Data Envelopment Analysis (DEA). The assumption that all deviations from the frontier arise from inefficiency as assumed in the data envelopment analysis approach is considered difficult to accept, given the natural variability of agricultural production; and the rareness of farm record data availability. Thus, the available data on production is likely to contain measurement errors.

Most commonly, the Cobb–Douglas and Trans-log functional forms of the stochastic frontier production models were used depending on the nature of data. According to Kopp and Smith (1980), functional forms have minimum effect on efficiency measurement, even if it requires specification of the model first. However, the study tested the two functional forms (Appendix C) and observed that the data fitted Cobb-Douglas form. The study used the production data of Moringa in the 2018/19 production season. The stochastic frontier methodology later developed by Battese and Coelli (1995) and Meeusen and van Den Broeck (1977). It is specified as (equation 16):

$$Y_i = f(X_i;\beta) + \varepsilon_i(V_i - U_i) \tag{16}$$

Where: Y_i is the amount of the Moringa yield produced by i^{th} household in the 2018/19 production year that is expressed in kg; $f(X;\beta)$ is a production function; β are the parameters to be estimated; X's are exogenous input factors (labour, land and organic fertilizer) affecting the amount of yield; εi is the error term, equal to ($V_i - U_i$); v_i is a two-sided random error component beyond the control of the farmer, and U_i is one-sided inefficiency component.

The above equation (116) estimated using maximum likelihood estimation yields estimators for β and γ;

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \text{ and } \gamma = \sigma_u^2 / \sigma^2 = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2) \qquad (17)$$

Where: γ parameter has a value between zero and one. A value of γ of zero indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency. According to Battese and Coelli (1995) σ_u^2 is the variance parameter that denotes deviation from the frontier due to inefficiency; σ_v^2 is the variance parameter that denotes deviation from the frontier due to noise, and σ^2 is the variance parameter that denotes the total deviation from the frontier.

Definition of variables used in production efficiency analysis

Dependent variables

The dependent (yield of the Moringa) and independent (input) variables are:

Amount of Moringa produced: A dependent/yield variable measured in the natural logarithm of the yield of Moringa produced by households in the 2018/19 production year expressed in kg.

Independent variables

Labor: A continuous input variable measured in the natural logarithm of the amount of pre-harvest, harvest, and post-harvest family labor input used by Moringa producing households in 2018/19 measured in adult-equivalent.

Land: It is a continuous independent (input) variable measured in terms of the natural logarithm of a hectare of land available for the household including Moringa production.

Application of fertilizer: A continuous independent (input) variable measured in the natural logarithm of the total quantity of an average organic fertilizer added in Moringa plant by households in the 2018/19 production year expressed in kg.

3.5.2 Sources of inefficiency

After computation of the technical efficiency estimates for each smallholder Moringa producer, by using the equation (12) above, a kernel graph (Figure 6) was produced for the distribution of technical efficiency in the sample. The technical inefficiency determinants (sources of inefficiency) are explained as in equation (18):

$TE_i = Exp(-U_i)$, So that $0 < TE_i \leq 1$

$U_i = \delta_0 + \delta_1 C_i + Z_i$

(18)

Where: U_i is technical inefficiency of Moringa producers in 2018/19 production year, expressed in value between zero and one; $\delta_0, \delta_1 \ldots \delta_n$ are the parameters to be estimated; C_i is a vector of a farmer and household socio-economic characteristics; Z_i *is* a random error. The technical inefficiency model, defined by equation (14), was estimated by using the Tobit model.

The stata version 14 was used to run Tobit regression. The model checked for problems of multicollinearity and heteroscedasticity and found no serious problem (Appendix C). The Variance Inflation Factor (VIF) is less than 10 for continuous explanatory variables (Mean 1.245) and Contingency Coefficient (CC) for dummy variables found below 1 and the Breusch-Pagan test result shows a chi-square value of 0.02 (Prob > chi2 = 0.8831), respectively. According to Greene (2008), the Tobit regression model is referred to as the censored regression model or the Tobit model by Tobin (1958) where the model was first proposed. The general formulation is usually given in terms of an index function. The inefficiency scores which is censored from left by considering the technical inefficiency score that lies in ranges of zero and one. The model is in detail specified in the following equation 19 below:

$$y^* = x'\beta + \mu_i, \qquad (19)$$

$$y = 0 \; if \; y^* \leq 0,$$

$$y = y^* \; if \; y^* > 0$$

Where,

Y* = technical inefficiency of individual Moringa producers in 2018/19 production year, expressed in value between 0 and 1

β = vector of parameters to be estimated

X’ = set of explanatory variables defined below in Table 2 and

μ_i = the disturbance term with $\mu \sim N(0,\sigma^2)$.

Below are descriptions of the dependent variable (technical inefficiency) and the sources of technical inefficiency (TE) determining variables and hypothesis of their expected effects (Table 2).

Dependent variable

Technical inefficiency score: It is a limited dependent variable expressed in value between 0 and 1 that measures the technical inefficiency score of Moringa producers in the 2018/19 production year.

Source of inefficiency (independent variables)

Based on review of literature the following variables are hypothesized to affect technical inefficiency of Moringa production.

Gender (female): Is a dummy variable taking a value of one if the household head is female and 0 otherwise. According to Mango *et al.* (2015), the gender of the household head was among the significant determinants of technical efficiency of Maize production. Moreover, Addison *et al.* (2016) indicated male households are more efficient in rice production than their female counterparts. It is related due to the attributed higher labor participation of males in rice production. In the current research case, the sex of the household head is expected to affect Moringa’s production technical inefficiency positively.

Age of the household: Is a continuous variable that measures the number of years of the household head. According to Saiyut *et al.* (2018) that the labor force aged 60 years and over increased the technical inefficiency, while the labor force aged 15–59 years reduced the technical inefficiency in Thai agricultural production. However, it contradicts with the result obtained by Dessale (2019). It is perceived that older farmers were more efficient than their young counterparts this might be probably that the farmers become more skillful as they get older due to cumulative farming experiences (Liu and Zhuang, 2000). Hence, in the current study case, the age of the household head is expected to affect the amount of Moringa technical inefficiency positively.

Education level of the household: A continuous variable that measures the number of years the household head attended formal education. The study by Beyan *et al.* (2013) on the technical efficiency of farm production of smallholder farmers found education level statistically significant and positive relationship between the efficiency level of the sampled household. A similar finding was obtained by Dessale (2019). It might be due to the skill to use obtained information from different sources and can apply that new information and technologies on their farm that would increase outputs (Dessale, 2019). Therefore, education is expected to negatively influence technical inefficiency of Moringa production.

Distance to all-weather roads: It is a continuous variable and measured distance in km for farmers to reach to the nearest all-weather road. Rabirou *et al.* (2012) showed the positive effect of distance on farmer's inefficiency. This contradicts Tiruneh and Geta (2016). They related this with the availability of more off-farm activities nearby to all-weather roads and farmers more likely spent more time outside their farm. However, in the current case, it is hypothesized to affect the technical inefficiency of Moringa production positively.

Access to credit: It is a dummy variable that takes a value of 1 if a household head has accessed credit service from formal sources and 0 otherwise. According to von Cramon-Taubadel and Saldias (2014) the amount of credit had a significant impact by increasing and decreasing efficiency in crop and livestock production, respectively. Moreover, the study by Dessale (2019) indicated an increase in credit increases farmers' efficiency due to it solves temporarily the shortage of liquidity/working capital. Therefore, credit expected to affect the technical inefficiency of Moringa production negatively.

Access to irrigation: It is a dummy variable taking a value of one if a household head has access to Irrigation and zero otherwise. Access to irrigation technology has higher technically efficient agricultural production than those without access to technology (Gebrekidan, 2012). Moreover, according to Beyan *et al.* (2013), it also showed a positive relationship with farm household technical efficiency. It is used to escape from the risk of crop failure and diversify their source of income. It is also due to household with access to irrigation can use their land properly throughout the year by producing short-term vegetable and chat to obtain cash needed.

Thus, it is hypothesized to have a negative influence on the technical inefficiency of Moringa production.

Cooperative membership: This is a dummy variable that taking a value of 1 if a household head is a member of agricultural cooperatives and 0 otherwise. Abate *et al.* (2014) indicated that agricultural cooperatives are effective in condition to support services that significantly contribute to members' technical efficiency. According to Tipi *et al.* (2009), the expected result could be due to the technical assistance to the farmers, information sharing, and training courses by cooperatives. Thus, membership in cooperative is hypothesized to affect the technical inefficiency of Moringa production negatively.

Participation in off/non-farm activity: A dummy variable that taking a value of 1 if a household head has participated in non-farm activities and 0 otherwise. Abebe (2014) described the non-farm income on farm output and technical efficiency is positive showing the spillover effects of income from non-farm activities on farm productions. Thus, participation in off/non-farm activities is hypothesized to affect the technical inefficiency of producing Moringa negatively.

Table 2: Description of the sources of technical inefficiency variables and hypothesis

Variables Name	Description	Type	Expected Effect
Dependent variable			
Inefficiency score	Technical inefficiency score of Moringa producers (expressed in value between 0 and 1)		Inefficiency score
Independent variables			
Gender	Gender of the household head (1 if female and 0 otherwise)	Dummy	+
Age	Age of household head	Continuous	+
Education	Years of formal education of the household head	Continuous	-
Distance to all-weather road	Km to reach the nearest all-weather road	Continuous	+
Access to credit	1 if a household has accessed credit service and 0 otherwise	Dummy	-
Irrigation	1 if a household head has access to irrigation and 0 otherwise	Dummy	-
Cooperative membership	1 if a household is a member of cooperatives and 0 otherwise	Dummy	-
Non-farm participation	1 if household participated in off/non-farm activities and 0 otherwise	Dummy	-

3.5.3. Analysis of commercialization of Moringa

The Heckman sample selection (two-step) model was used to examine factors affecting the probability of Moringa producer farm households' participation in the Moringa commercialization and degree. The model helps to identify the factors that affect smallholder farmer's decision to participate in the Moringa commercialization and evaluate the factors that affect the intensity of commercialization (HCI). This model adopted on the basis that it models the market participation decision as a two-step process that involves first the household deciding on whether or not to participate in the Moringa market and then the extent of commercialization. The household commercialization index (HCI) of Moringa is implemented to capture the household intensity of Moringa commercialization. It is computed as the ratio of the gross value of Moringa sold to the gross value of Moringa produced that is taken by expecting to better explain Moringa commercialization than the commonly used gross amount sold. Here, the intensity of Moringa commercialization of Moringa producers was analyzed from the output side. Precisely, the HCI formula implemented here by following Von Braun *et al.* (1991) and Von Braun and Kennedy (1994) as expressed in equation (20) below:

Household commercialization index (HCIi) =

$$\frac{Gross\ \text{Value of Moringa Sales by i}^{\text{th}}\ \text{Household in year j}}{Gross\ \text{Value of Moringa Production by i}^{\text{th}}\ \text{Household in year j}} * 100 \qquad (20)$$

Where: HCIi = Commercialization index of i^{th} household in Moringa sales expressed in percentage.

As it is indicated in literature review part the observed outcome of Moringa commercialization can be modeled under the framework of a random utility function. Consider the i^{th} Moringa producing household facing a decision on whether or not to commercialize Moringa yield. Let C* denote the difference between the benefit the smallholder farm household derives from commercializing Moringa (E_{iA}) and the benefit from non-commercialization (E_{iO}). Considering the axiom of rationality and profit maximization, the smallholder farm household will participate in Moringa commercialization if $C^* = E_{iA} - E_{iO} > 0$

The net benefit C is unobservable and can be expressed as a function of observed characteristics (Z_i) and error term (ε_i) as follows (equation 21):

$$C_i^* = Z_{iA}\beta + \varepsilon_i;\ C_i = 1\ if\ C_i^* > 0\ and\ C_i^* = 0,\ otherwise \qquad (21)$$

Where C is a dummy variable representing Moringa commercialization decision; C = 1, if Moringa is marketed and C = 0, if otherwise. Z_i is a vector denoting household characteristic, farm-specific, and other institutional or policy variables, β is a vector of parameters to be estimated, and ε_i is an error term. It is expected that not all Moringa producing households will participate in the Moringa market. In such a situation, the fundamental econometric problem that is most likely to arise is the sample selection bias. The selection bias has aroused due to the existence of sales from a subset of households who participated in the Moringa markets. This is very necessary for the market participation variable but it is not observed for the sample as a whole. By excluding individuals who are non-market participants means the dependent variable is censored and the residuals may not satisfy the condition that the sum of residuals must be equal to zero (Maddala, 1977; Maddala, 1986). In this study, the problem of sample selection bias was resolved by the use of the Heckman two-step sample selection estimation procedure (Heckman, 1976).

Thus, Moringa commercialization involves a two-stage process: the first stage has to do with the probability of participating in Moringa marketing using the Probit maximum likelihood function. The second stage takes into consideration the extent (intensity) to which a Moringa farmer participates in Moringa marketing (intensity of Moringa commercialization) and this is done through Ordinary Least Squares (OLS) estimator. Because the later decision largely depends on that taken in the former, likely, the procedure in the second stage is not random thereby creating selectivity bias. This is due to only those who are positively affected by the determinants of market participation will more participate in Moringa marketing. Thus, Heckman’s two-stage sample selection model used to correct for the sample selection bias (Heckman, 1976). The first step of Heckman’s model (selection equation) is given by:

$$F_i^* = \beta_0 + \beta_1 X_i + \varepsilon_i \qquad (22)$$

Where F* is an unobserved latent variable representing household market participation decision, X_i is a vector of explanatory variables, β is a vector of parameters to be estimated, and ε_i is an error term distributed with mean 0 and variance 1. The observed dummy variable can be expressed as:

$$F = 1 \; if \; F_i^* > 0 \; (For \; market \; participants) \tag{23}$$

$$F = 0 \; if \; F_i^* < 0 \; (For \; non\text{-}market \; participants) \tag{24}$$

The substantive equation (the second step) which is usually estimated by an Ordinary Least Square (OLS) estimator is given as:

$$Y_i = \alpha_0 + \alpha_1 Z_i + \mu_i \tag{25}$$

It should be noted that equation (23) is a sub-sample of equation (21) and is only estimated for Moringa market participants. For the correction for self-selection biases in the substantive equation (27), and Inverse Mills Ratio (IMR) represented by the symbol λ as an extra explanatory variable is added. The computed IMR provides OLS selection corrected estimates (Greene, 2003). The IMR is estimated as the ratio of the ordinate of a standard normal to the tail area of the distribution (Greene, 2003).

Declining to add the IMR will reduce the results from equation (25) bias Heckman (1976). Adding IMR translates Equation (23) into Equation (24) as:

$$Y_i = \alpha_0 + \alpha_i X_i + \delta_i \lambda_i + \mu_i \tag{26}$$

Where; δ_i is the coefficient of the IMR (λ_i). If lambda (λ) is statistically significant, sample selection bias is a problem and, therefore, Heckman's two-stage sample selection model is appropriate for the estimation (Marchenko and Genton, 2012). The formulation process of IMR is given by:

$$\lambda_i = \frac{\varphi(X_i \alpha)}{\phi(X_i \alpha)} \tag{27}$$

Where; φ and ϕ are normal probability density function and cumulative density function, respectively of the standard normal distribution, and $\phi \equiv (\omega_i \chi)$. μ_i is a two-sided error term with $N(0,\sigma^2_v)$:

Equation (27) is obtained by an extrapolation process of Probit equation (22) with the substantive equation defined by OLS equation (18) and then integrate it into the equation defined by equation (26). In general, the model computes the inverse mills ratio from the Probit regression and uses it as a regressor with other explanatory variables to explain the outcome of the dependent variable.

Table 3 explains and hypothesizes the relations of the dependent, outcome, and explanatory variables used to analyze the Moringa commercialization.

Definition of variables

The descriptions below explain and hypothesize dependent, outcome, and explanatory variables that were used in the investigation of Moringa commercialization.

Dependent variables

Market participation: A dichotomous dependent variable measured the market participation decision of Moringa producing households in 2018/19 and measured as a binary outcome. If the household participates in Moringa marketing, it received a value of 1, otherwise 0.

Outcome variable

Intensity of commercialization: It is an outcome variable measured as the ratio of the total value of Moringa sales to the total value of Moringa produced by the household in the 2018/19 production year, expressed in percentage as shown in equation (20) above.

Explanatory variables

Gender (female): It is a dummy variable taking a value of one if the household head is female and zero otherwise. The study result by Rabbi *et al.* (2019) indicated that the gender of the household head is among the major determinants of market participation. Moreover, Djurfeldt (2018) described that in Mozambique, Malawi, and to a lesser extent Tanzania stands out in terms of non-grain food crops, where market participation by male farm managers had increased relative to female-headed households. Thus, the sex of the household head is expected to affect Moringa commercialization negatively.

Age: Is a continuous variable that measures the age of the household head in years. Age is attributed to farming experience and expected that older farmers have more experience in farming and well aware of changes in weather, pesticide use and production. Besides, the young generation does not like farming and they want to find employment in the urban area especially in the service sector. The study result by Rabbi *et al.* (2019) indicated that household head age is among the major determinants of market participation affecting positively. On the contrary, younger farmers are innovative and they understand the need of the day and are aware of the benefits which commercialization provides. Thus, the age of the household head is expected to affect the amount of Moringa commercialization positively or negatively.

Education: A continuous variable measures the number of years the household head attended formal education. The study result by Rabbi *et al.* (2019) indicated vocational training, is among major factors determining market participation positively. Thus, the education of household head is expected to have a positive effect on Moringa production and marketing because it is perceived to bring better skill and access to information and make households better use of their available resources. It is expected that education positively influences Moringa commercialization.

Family size: It is the amount of the total number of family members, which is measured in terms of adult equivalent (Appendix D). The study result by Rabbi *et al.* (2019) indicated that the number of family members who assist in farming, and household size were the major determinants of market participation. In other way having more household members reduces the amount of output that goes to the market due to households with large members tend to consume more of what they have produced and less is available for sales (Tura *et al.*, 2016). This is because a greater number of the family tends to share from existing production and yield (Astemir, 2014). Thus, household size is expected to affect the Moringa commercialization negatively or positively.

Land size: It is a continuous variable measured in terms of a hectare of land available for the household. The study result by Rabbi *et al.* (2019) indicated that the farmer being landlord and farm size were the major determinants of market participation. Ele *et al.* (2013) also found that the size of land used for cultivation is important factors determining the level of commercialization of smallholder farms. This implies that households with a higher size of cultivated land had a higher amount of marketable surplus. Access to greater farm size and better land quality tends to result in better productivity (Astemir, 2014). Thus, it is hypothesized to have a positive effect on the Moringa commercialization.

Distance to the nearest market: It is a continuous variable and measured distance of km for farmers to travel to sell their Moringa product to the nearest market. It is hypothesized to affect the amount sold negatively. This is because of the increased transaction costs associated with the marketing of the farmers' product (Bekele *et al.*, 2010). However, it contradicts with Sebatta *et al.* (2014) and Dube and Guveya (2016) findings, which are conducted in Zimbabwe. Their possible explanation was that although towns offer markets for agricultural produce, on the other hand, the nearer the farm is to a town, the higher the chances of a farmer getting non-farm employment and taking farming as a part-time weekend affair.

Distance to an all-weather road: It is a continuous variable and measured in distance km for farmers to reach to the nearest all-weather road. Fredriksson *et al.* (2017) indicated inadequate market and transport infrastructure affects negatively the share of output sold. This implies that a typical farmer was commercialized his/her output if it is not difficult to get transport. This is due to higher/lower transaction costs and deterioration in the road condition reduces the number of animals offered for sale. Moreover, one of the deteriorating situations of food security in Ethiopia is poor social and infrastructural facilities (Endalew *et al.*, 2015). Thus, it is hypothesized to affect the Moringa commercialization negatively.

Access to credit: It is a dummy variable that taking a value of 1 if a household head has access to credit service and 0 otherwise. A study by Hussain and Thapa (2012) revealed that credit caused the transformation of a significant proportion of smallholders from conventional agricultural systems to commercial practices. The amount of credit taken increases the probability of a household's market participation. This might be due to the higher amount of credit eases liquidity constraints of households that contribute to market orientation. Additionally, it means higher capital to invest in livestock, in higher-yielding crops, in seasonal inputs that boost yields, in the purchase of fertilizer and improved seeds, and invest in improved technologies.

Extension contact: A continuous variable measured in several days that development agents give households technical advice on Moringa and other Agricultural production and marketing in a particular year. Agricultural services (extension, credit) are expected to enhance farmer skills and knowledge, link farmers with modern technology and markets, and ease liquidity and input supply constraints (Lerman, 2004), thus are expected to induce market orientation and market participation. Thus, the frequency of extension contact is hypothesized to have a positive influence on the commercialization of Moringa.

Table 3: Description and hypothesis of the variables used in the analysis of determinants of Moringa commercialization

Variables Name	Description	Type	Expected effect on	
Dependent variable			Dependent variable	Outcome variable
Moringa market Participation	The household decision to market Moringa (1= yes, 0= no)	Dummy		
Outcome variable				
Intensity of commercialization	The ratio of the gross value of *Moringa* sold to the gross value of *Moringa* produced	Continuous		
Gender	Gender of the household head 1 if female 0 otherwise	Dummy	-	-
Age	Age of Household head	Continuous	+/-	+/-
Education	Years of formal education of the household head	Continuous	+	+
Family Size	Amount of household in adult equivalence	Continuous	- /+	- /+
Land Size	Amount of hectare of land available	Continuous	+	+

Distance to nearest Market	The average distance of household to reach the nearest all-weather road (km)	Continuous	-	-
Distance to all-Weather Road	The average distance of household to reach the nearest all-weather road (km)	Continuous	-	-
Irrigation Access	1 if a household has access to irrigation and 0 otherwise	Dummy	+	+
Access to Credit	1 if a household has access to credit service and 0 otherwise	Dummy	+	+
Extension Contact	The number of days advice on *Moringa* production and marketing	Continuous	+	+
Cooperative Membership	1 if a household is a member of cooperatives and 0 otherwise	Dummy	+	
Zone	1 if a household is located in Wolaita zone and 0 if in Gamo Zone	Dummy	-	-

Access to irrigation: It is a dummy variable that taking a value of 1 if a household head has access to Irrigation and 0 otherwise. It is perceived that households engaged in irrigation activity had more involvement in the production of cash crops, which is resulting in a higher marketed surplus when compared to farmers who depend on rain-fed agriculture. The study by Parvin and Rahman (2009) indicated that the expansion of irrigated areas increased the production of various crops in Bangladesh. Thus, it is hypothesized to have a positive influence on the Moringa commercialization.

Zone: This is a dummy variable that takes a value of 1 if a household head is located in Wolaita Zone and 0 if located in Gamo Zone. It is hypothesized to affect the Moringa commercialization negatively.

Cooperative membership: This is a dummy variable that taking a value of 1 if a household head is a member of agricultural cooperatives and 0 otherwise. Ele *et al.* (2013) found that membership in cooperatives is an important factor determining the level of commercialization of smallholder farms. Hence, membership in cooperative is hypothesized to affect the Moringa commercialization positively.

3.5.4 Analysis of the impact of Moringa production on food and nutritional security

To evaluate the impact of Moringa on food and nutritional security Propensity Score Matching Method (PSM) was used. The method, propensity score (Rosenbaum and Rubin, 1983), or propensity score matching (PSM), is the most developed and popular strategy for causal analysis in observational studies. Propensity score analysis minimizes the effects of confounding and provides some of the advantages of a randomized study. The theoretical foundation for propensity score methods is based on the causal effect model introduced by Rubin (1974). Many non-experimental studies used propensity-score methods to estimate causal effects by balancing treatment and control groups on a set of observed baseline covariates. Full matching on the propensity score has emerged as a particularly effective and flexible method for utilizing all available data and creating well-balanced treatment and comparison groups (Austin and Stuart, 2017). It attempts to simulate the conditions of an experiment in which recipients and non-recipients are randomly assigned, allowing for the identification of a causal link between treatment (producer) and outcome variables (food and nutritional security proxy variables). For outcome variables, this study used household calorie intake per week for food security and Food Consumption Score (FCS) per week including Moringa leaf intake per household for nutrition security.

The propensity score is the probability of receiving the treatment of interest conditional on measured baseline covariates: $e = \Pr(Z = 1)X$ where X denotes the vector of measured control covariates and Z denotes treatment status (Z= one for treated and Z= 0 for control). Let us say $P(Z) = \Pr(D = 1/Z)$ be the probability of producing Moringa where Z is a vector of observed control variables (socioeconomic/demographic). Propensity score matching constructs a statistical comparison group by matching individual treatment households with control households based on similarities in P (Z). There are two fundamental assumptions of these models that pertain to the estimation of the propensity model. Rosenbaum and Rubin (1983) defined treatment assignment to be strongly ignorable if the following two conditions hold: (I) $(Y(1), Y(0) \perp Z/X)$ and (II) $0 < P(Z = 1/X) < 1$, the first condition says that treatment assignment is independent of the potential outcomes (food and nutritional security) conditional on the observed baseline covariates (demographic and other variables). The second condition says that every subject has a non-zero probability to receive either treatment (common support). This demonstrated that if treatment assignment is strongly ignorable, conditioning on the propensity score allows one to obtain unbiased estimates of average treatment effects. Assuming that both the conditional independence and common support conditions hold, the propensity score-matching estimator for ATT can be expressed as follows (equation 28):

$$\tau_{ATT}^{PSM} = E_{P(x)/T=1}\{E[Y(1)/T = 1, P(X)] - E[Y(0)/T = 0, P(X)]\} \quad (28)$$

This equation (28) depicts that the propensity score matching estimator, which is simply the mean food and nutritional security difference between producers and non-producers of Moringa over the common support area.

The four major steps in propensity score analysis in observational studies are propensity score estimation, propensity score matching, matching quality evaluation, and outcome analysis after matching.

For estimation of propensity scores, Logit and Probit are standard approaches mostly used with limited dependent variables (producer or non-producer). Even if they provide almost similar output, the current study estimated the propensity score by using a Logit regression model, with the propensity scores being the predicted probabilities generated by that model.

For propensity score matching several matching algorithms, such as nearest-neighbor matching (NNM), caliper matching, and kernel matching as Heckman *et al.* (1998) and Smith and Todd (2005) have been suggested by different authors. In theory, all approaches should yield the same results when applied to large datasets. However, it is reassuring that in practice; the choice of matching method often appears to make little difference (Smith, 2000). Pragmatically, it seems sensible to try several approaches because; the performance of different matching estimators varies case-by-case and depends largely on the data structure at hand (Zhao, 2003). Thus, the current dissertation was used all three of the above approaches to evaluate the food and nutritional security impact of Moring production.

For matching quality evaluation, because the matching procedure conditions on the propensity score does not condition on individual covariates, one must check that the distribution of variables is 'balanced' across the producer and non-producer groups (Wu *et al.*, 2010). As recommended by Rosenbaum and Rubin (1985) t-test for differences of the matching used to check matching quality. Besides, Sianesi (2004) also suggested re-estimating the propensity scores.

For outcome analysis after matching there are four ways to conduct it which are outcome analysis on the matched data after propensity score matching, outcome analysis on the entire original data after subclassification, outcome analysis on the entire original data with propensity score weighting and outcome analysis on the entire original data with propensity score adjustment (Wei, 2015). There are some variations in outcome analysis after matching, depending on the appropriateness of propensity score methods. The current dissertation used outcome analysis on the matched data after propensity score matching.

Regarding the choice of variables, statistical significance was used which relies on statistical significance and is very common in textbooks of econometrics. To do so, one starts with a parsimonious specification of the model, e.g. a constant, the age and some regional information, and then `test up' by iteratively adding variables to the specification. A newly added variable is kept if it is statistically significant at conventional levels (Heckman *et al.,* 1998).

Lastly, for sensitivity analysis was made to check the quality of comparison matching between Moringa producer and a non-produce group with observed covariates and chiefly to check robustness for unobserved covariates and the outcome. It has showed the ATT estimate result is insensitive.

Definition of variables

The descriptions below explained and hypothesized dependent, outcome, and explanatory variables that were used in the evaluation of the food and nutrition security impact of Moringa.

Dependent variable

Household participation in Moringa production: It is a dichotomous dependent variable measured as whether the household is a Moringa producer (treated) or non-producer (control) in 2018/19 and measured as a binary outcome. If the household participated in Moringa production it was 1, otherwise 0.

Outcome variables

Household Calorie Intake: It is a continuous outcome variable measured by the amount of calorie intake from different food items consumed per 7 days/week, expressed in calorie per gram. It was based on the calorie value depicted in Appendix A.

Food Consumption Score (FCS): It is a continuous outcome variable that was measured by the weight of food group scores obtained by calculating the frequency of consumption of different food groups consumed by a household during the 7 days before the survey. It was based on procedures depicted in Appendix A.

Explanatory variables

Sex (female): Is a dummy explanatory variable taking a value of 1 if the household head is female and 0 otherwise. The study by Mohammed and Abdulquadri (2012) in Nigeria revealed that the involvement of women in Agricultural production increased the production, while that of men declined relatively. Agidew and Singh (2018) indicated that on average, male-headed households were more food secure than female-headed households do. Moreover, the study by Kebede (2009) indicated that female-headed households compared to male-headed households are found at a low level of food security and are not- self-sufficient in terms of the food requirement of their households. Thus, the sex of the household head is expected to affect Moringa's production positively and food security negatively.

Age: Is a continuous explanatory variable that measures the number of years of the household head. The study by Agidew and Singh (2018) in the South Wollo Zone of Ethiopia showed that the majority of the food insecure households were younger household heads, who own less than 1 ha of farmlands. It is related to farm experience and expected that elder farmers have more experience in farming and are well aware of changes in weather, pesticide use, and production. Tauer (1984) described in the study on six age groups of farmers that the greater the age differential the greater is the difference in production functions. It indicated that middle-aged farmers appear to be the most productive. Thus, the age of the household head is expected to affect the amount of Moringa production positively or negatively and it is hypothesized to affect food security negatively.

Education: A continuous explanatory variable measures the number of years the household head attended formal education. The education of household head is expected to have a positive effect on Moringa production and marketing because it is perceived to bring better skill and access to information and make households better use of their available resources. Empirical analyses by Weir (1999) revealed substantial internal (private) benefits of schooling for farmer productivity, particularly in terms of efficiency gains. Thus, education positively influences food security (Abafita and Kim, 2014).

Family size: It is the amount of the total number of family members, which is measured in terms of adult equivalent. There is a negative correlation between household size and food security. This is because a greater number of the family tends to share from existing production and yield (Astemir, 2014). Thus, household size is expected to affect food security negatively and Moringa production positively.

Farm experience: A continuous explanatory variable measured by several years the households stayed in farming. It is perceived that farmers who have stayed more in a certain production have more experience in farming and are well aware of changes in weather, pesticide use, and production. Moreover, the higher the years of farming experience by the head of the household the higher the likelihood of a household being food secured (Mohammed *et al.*, 2016). Thus, the farming experience is expected to affect the amount of Moringa production and food security positively.

Livestock: It is a continuous explanatory variable measured in the amount of Tropical Livestock Unit (TLU) of livestock owned by the household including equines. According to Endalew *et al.* (2015) lack of oxen mentioned as one of the deteriorating situations of food security in Ethiopia. Thus, livestock ownership is hypothesized to affect Moringa production and food security positively.

Land size: It is a continuous explanatory variable measured in terms of a hectare of land available for the household. Access to greater farm size and better land quality tends to result in better productivity (Astemir, 2014). Thus, it is hypothesized to have a positive effect on Moringa production and food security.

Distance to the nearest market: It is a continuous explanatory variable and measured in Km of travel to sell their Moringa product to the nearest market. Endalew *et al.* (2015) mentioned poor social and infrastructural facilities as one of the deteriorating situations of food security in Ethiopia. Moreover, according to Feleke *et al.* (2003) the farther the household is away from the marketplace and information about market prices, the less likely the family is food secure. Thus, farmers who are far from their own tend to take farming as an alternative form of employment. It is hypothesized to affect Moringa production positively and food security negatively.

Distance to an all-weather road: It is a continuous explanatory variable and measured in km for farmers to travel to sell their Moringa product to the nearest all-weather road. It is also indicated that is poor social and infrastructural facilities are deteriorating situations of food security in Ethiopia (Endalew *et al.*, 2015). Moreover, the distance to the nearest all-weather roads and distance to a zonal headquarter harms agricultural productivity in Abe Dongoro, Hababo Guduru, and Amuru districts (Tamene and Megento, 2017). Thus, it is hypothesized to affect Moringa production and food security negatively.

Access to credit: It is a dummy explanatory variable that taking a value of one if a household head has access to credit service and zero otherwise. It is indicated that alleviating credit constraints would generate substantial productivity gains in Ethiopia of around 60% (Mukasa *et al.*, 2017). It means higher capital to invest in livestock, in higher-yielding crops, in seasonal inputs that boost yields, in the purchase of fertilizer and improved seeds, and invest in improved technologies. It is perceived that credit access, determining food security positively. Households with access to credit are capable enough to diversify their income that can contribute to ensuring food security (Astemir, 2014). It is perceived to affect Moringa production and food security positively.

Extension contact: A continuous explanatory variable measured in a number of days that different agents give households technical advice on Moringa and other agricultural production and marketing in a particular year. Agricultural services (extension, credit) are expected to enhance farmer skills and knowledge, link farmers with modern technology and markets, and ease liquidity and input supply constraints Lerman (2004), thus are expected to induce market orientation and market participation. Furthermore, Endalew *et al.* (2015) described that one of the deteriorating situations of food security in Ethiopia is weak extension services. Thus, the frequency of extension contact is hypothesized to have a positive influence on Moringa production and food security.

Application of irrigation: It is a dummy explanatory variable that taking a value of 1 if a household head has access to irrigation and 0 otherwise. It is perceived that households engaged in irrigation activity have more involvement in the production of cash crops that are resulting in a higher marketed surplus when compared to farmers who depend on rain-fed agriculture. The study by Parvin and Rahman (2009) indicated that the expansion of irrigated areas increased the production of various crops in Bangladesh. Thus, it is hypothesized to have a positive influence on Moringa production and food security.

Off/Non-farm participation: This is a dummy explanatory variable that takes a value of one if a household head participated in off-farm activities and zero otherwise. It is a hypothesis that off/non-farm income promotes smallholder commercialization by relaxing liquidity constraint to invest and raise productivity and marketable surplus. According to Astemir (2014) and Abafita and Kim (2014), off/non-farm income significantly and positively determines food security. This is due to its effect on diversifying income. Thus, the amount of income obtained from on/non-farm activities is hypothesized to affect the production of Moringa and food security positively.

Zone: It is a dummy explanatory variable that taking a value of 1 if a household head is located in Wolaita Zone and 0 if it is located in the Gamo zone.

Table 4: Description and hypothesis of the variables used in the analysis of the impact of Moringa production on food and nutritional security

Variables	Description	Type	Expected effect	
Dependent and outcome variables				
Moringa Production	Household decision to produce Moringa (1 = yes, 0 = no)	Dummy	Dependent variable	Outcome variable
Calorie	Weekly food intake (Calorie)	Continuous		
FCS	Food Consumption Score	Continuous		
Independent variables				
Age	Age of household head (years)	Continues	-	-
Age square	Age of household head squared (years)	Continues	-	-
Sex(female)	Sex of household head(1 = female, 0= male)	Dummy	+	-
Family size	Number of family members (in adult equivalent)	Continues	-	+
Education	The education level of household head (years of formal education)	Continues	+	+
Livestock (TLU)	Livestock holding (TLU)	Continues	+	+
Land size	Total land size household-owned(ha)	Continues	+	+
Farm experience	Number of years the household staid in the farming	Continues	+	+
Zone	Household location (Wolaita zone = 1, 0= Gamo zone)	Dummy		
Distance to the main road	The average distance of household to reach the nearest all-weather road (km)	Continues	-	+

Distance to market	The average distance of household to reach the nearest market (km)	Continues	+	-
Irrigation	Access of household to irrigation (1 = yes, 0 otherwise)	Dummy	+	
Credit access	Access of household to credit (1 = yes, 0 otherwise)	Continues	+	+
Participation in the non-farm activity	Experience of household participation in non-farm activities (1 = yes, 0 otherwise)	Dummy	+	+
Extension contact	Average Agricultural extension advice received (number of days)	Continues	+	+

4. RESULTS AND DISCUSSION

This chapter presents the results and discussions of the core findings of the study. Thus, it is organized in the following order. The first part presents findings and discussions on the analysis of the technical efficiency of Moringa production. It follows with the findings and discussions of the determinants of the commercialization of Moringa. Lastly, the findings and discussions about evaluating the food and nutrition security impacts of Moringa presented.

4.1 Descriptive Statistics of Socio-Economic and Institutional Characteristics of Moringa Producers

The statistical report of socio-economic and institutional characteristics of Moringa producers is depicted in the summary Table 5 provided below. Accordingly, the mean average age of sample households was found around 49 years with the youngest being 25 and the oldest are 90 years. This implies that most of the household heads were within their productive age group. Moreover, the mean typical household attended 3 years and 8 months of formal education with a minimum of zero years and a maximum of 13 years of schooling. The selected households owned two livestock in TLU with a minimum of none and a maximum of twelve. The mean land holding of sampled households was about 1.57ha with a minimum of 0.1 and a maximum of 5.5 hector. The mean distance of households from the all-weather road was 0.06 with a minimum of 0.01 and 0.4 km. This indicates that road infrastructure access in the research area is not bad. In addition to this, the distance of households from the market is 0.62km with a minimum of 0.01 and a maximum of 0.4km. Finally, on average the households made 13-day annual contact with extension agents with a minimum of zero and a maximum of 60 days. This indicates that most of the household made less contact with extension agents.

Table 5: Statistical summary of household and demographic characteristics

Continuous Variables (n=232)	**Mean**	**Std. Dev.**	**Min**	**Max**
Age	48.77	13.51	25	90
Family size	6.18	2.01	2	12
Education	3.83	3.87	0	13
Livestock (TLU)	2.54	1.89	0	12.2
Land size	1.57	1.041	0.1	5.5
Distance to the main road (km)	0.06	0.05	0.01	0.4
Distance to market (km)	0.62	0.63	0	2
Extension contact frequency	19.50	12.99	0	60

Source: Survey result, 2018/19.

As indicated in Table 6 below from the sampled Moringa producing households, 47% accessed credit from different credit institutions in the area. This shows credit facility in the area is insufficient. On another hand, 40% of households have access to irrigation in the area. About 53% of households have participated in off/non-farm activities in the area. Furthermore, it has indicated that the proportion of female-headed households was only about 7% that is they are quite fewer than male-headed households are. At the end, proximately about 48% from sampled households were members of different cooperative groups in the research area.

Table 6: Statistical summary of dichotomous independent variables

Dummy Variables (n=232)		**No.**	**%**
Gender	Male	218	93.97
Off/non-farm participation	Yes	124	53.45
Credit access	Yes	74	31.9
Irrigation access	Yes	93	40.09
Cooperative membership	Yes	111	47.84

Source: Survey result, 2018/19

Descriptive statistics of Moringa utilization

The descriptive statistical summary of Moringa utilization by sampled households is provided in Table 7 below. It shows quantity sold, price and income, consumption of Moringa by the sampled household. In the mean sampled households owned 18 Moringa trees in their farmyard with a minimum of six trees and a maximum of 85 trees. Moreover, the mean yearly yield of Moringa production of the sampled household is 128.40kg with a minimum of 18kg and a maximum of 500kg. From the total yield of Moringa produced households in the research area consumed in a mean of 95.76kg with a minimum of 18 kg and a maximum of 500kg. The households sold 32.64kg in average per household. Furthermore, on average the households received 391.70ETB from selling Moringa yield with a minimum of zero and a maximum of 3600ETB.

Table 7: Descriptive statistics of Moringa utilization

Variables (n=232)	**Mean**	**Std. Dev.**	**Min**	**Max**
Total Moringa production	128.40	83.54	18	500
Number of the Moringa tree	18.04	13.01	6	85
Quantity of Moringa sold (ETB)	32.64	46.67	0	300
Moringa leaf price (per kg)	11.95	1.96	6	16
Income from selling Moringa (ETB)	391.70	560.15	0	3600
Quantity of Moringa consumed (kg)	95.76	56.41	18	297

Source: Survey result, 2018/19

4.2 Technical Efficiency of Moringa Production

4.2.1 Descriptive statistics of Moringa Production inputs and yields

The summary Table 8 provided below shows Moringa yield and inputs used for Moringa production for sampled for production efficiency analysis that are having homogenous five-year Moringa production period. The mean yearly levels of Moringa production of the sampled household is 103.11kg. In the mean sampled households used 40.83 labors (a.e) to produce a specified amount of Moringa. On another hand, on average the respondents have owned 1.15 hectares of land. Further, in the mean respondents have used 13.06kg of organic fertilizer for Moringa production.

Table 8: Descriptive statistics of Moringa production inputs and output

Output and input variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Total Moringa production	117	103.11	41.30	20	196
Organic fertilizer	117	13.06	5.70	5	30
Land	117	1.16	0.84	0.1	5.5
Labor	117	40.83	16.87	8	80

Source: Survey result, 2018/19

4.2.1 Parameter estimates of the SF Model

In this sub-section input variables used in the production of Moringa and TE estimation using the SPF model was discussed. The study used three inputs mainly labor, land, and fertilizer for the production of Moringa. As displayed in Table 9 below in the SPF model only labor was found to be positively and significantly affecting Moringa yield. However, the land and fertilizer were found to be insignificant.

Table 9: Parameter estimates of the OLS and SF model

Variables	OLS Estimates		Maximum likelihood SF estimates	
	Coef.	Std. Err.	Coef.	Std. Err.
Ln labor	1.203***	0.062	1.232***	0.106
Ln land	0.014	0.062	0.017	0.063
Ln fertilizer	0.127	0.122	0.130	0.117
Constant	-0.631	0.462	0.033	0.480
			Sigma-squared (δ^2)	0.45
			Gama (γ)	0.79
			Return to scale	1.23
			Mean Technical efficiency	48.78%
Log likelihood	-110.35		-107.85	

Note: "***" represent statistical significance at 1 % levels respectively

Source: Survey result, 2018/19

The level of labor coefficient in the above SFP model implies that by maintaining other factors constant a percentage increase in labor increases the amount of Moringa production by 120.3%. This result is similar to Sekhar *et al.* (2018) who indicated the number of human labor used (man-days) per ha per annum was found to influence the yield of Moringa in India. The estimated value of gamma is 0.79, which implies that 79% of the total variation in Moringa production is due to the technical inefficiency effect.

4.2.2 Tests of hypotheses

This study used the LR test, which is among the most important test used to check the fitness of parametric models. This subsection thus discusses the different tests used in this study using LR as it is specified by the equation (10) in the literature review part.

Before taking tests for the SPF model, the test for multicollinearity and heteroscedasticity was made. The VIF test for the independent variables was conducted as indicated in Appendix C. The average value of VIF of 1.001 indicates the existence of no severe multicollinearity problem among the independent variables. Moreover, the heteroscedasticity test has been made using the Breusch-Pagan /Cook-Weisberg test for heteroscedasticity. The test result indicated a small chi-square (2.09 with Prob > chi2 of 0.148) which indicates that there is no heteroscedasticity problem in the data.

The other important test is checking the presence of inefficiency in the production of Moringa. The test was made by comparing the OLS and SPF results presented in Table 9 above to fit the data. It was conducted using the likelihood ratio formula displayed in equation (10). As it is indicated in Table 10 the critical value of five at $\chi 2$ at 1 degree of freedom at a 5% significance level is greater than 3.84, which leads to reject H_o. Thus, there is technical inefficiency, which shows there is a statistically significant inefficiency in the observed data. This implies that the stochastic frontier production function is an appropriate functional form for the current data.

It is also required to test the relevant functional form best to fit the data. The most common functional forms are Cobb-Douglas production and Tran-slog production functions. The log-likelihood ratio (LR) test was made for these two functional forms (Appendix C). As indicated in Table 10, the LR value of -86.96, this is less than the critical value of $\chi 2$ at 7 degrees of freedom at a 5% significance of 14.07. Hence, this implies that the null hypothesis that dictates all coefficients of the Trans-log functional form is equal to zero is accepted. Thus, this implies the Cobb-Douglas functional form best fits the current data.

Moreover, the null hypothesis stating the independent variables related to the technical inefficiency effect are zero tested against the alternative hypothesis of these variables related to the technical inefficiency effects are different from zero. The computed LR value of 24.16 is greater than the critical value of χ^2 at 5 degrees of freedom at a 5% significance level of 11.07. Thus, this implies that the inefficiency effect variables considered are simultaneously affecting the efficiency disparity observed between the selected respondents.

Lastly, as is indicated in Table 9 above the estimated value of sigma-squared is 0.45 and the gamma value is 0.79, which implies 79% of the total variation in Moringa yield is coming from technical inefficiency. The return to scale value of 1.23 in Table 9 showed the production structure with given inputs is characterized by increasing returns to scale form. This means that a percentage increase in all inputs proportionally would bring the total production by more than a percent increase. This finding is similar to a result by Sekhar *et al.* (2018) that indicated the increasing return to scale with 1.48 value in their study of the economic efficiency of Moringa in India.

Table 10: Tests of hypotheses

Hypothesis	Degree of freedom	LR	Critical value	Decision
H_O:γ_1=0	1	5	3.84	Reject H_O
H_O:= β_1= β_2= β_3… β_{10}=0	7	-85.96	14.07	Accept H_O
H_O: δ_1= δ_2= δ_3 = δ_4… δ_{13}=0	5	24.16	11.07	Reject H_O

Source: Survey result, 2018/19

4.2.3 Technical efficiency scores and Moringa yield gap due to inefficiency

The estimation of results obtained from the SFP model displayed in Table 11 shows the average level of Technical Efficiency (TE) of 48.78%, which is obtained by dividing actual yield by potential yield as described by Coelli *et al.* (1998). This implies the possibility that with existing levels of inputs and technology, in the short run the Moringa yield level could be increased by 51.22%, or to obtain a given level of yield it is possible to decrease the level of inputs by 51.21%. However, this could be possible only if the existing level of inefficiency was removed or if Moringa producing farmers operate at a fully efficient level. It should be also remarked that this analysis is made in the relative sense meaning that Moringa producer farmers fall at the inefficient level relative to those efficient farmers in the area who set the frontier.

Furthermore, the kernel distribution of TE displayed in Figure 6 below shows the distribution of the efficiency level of farmers.

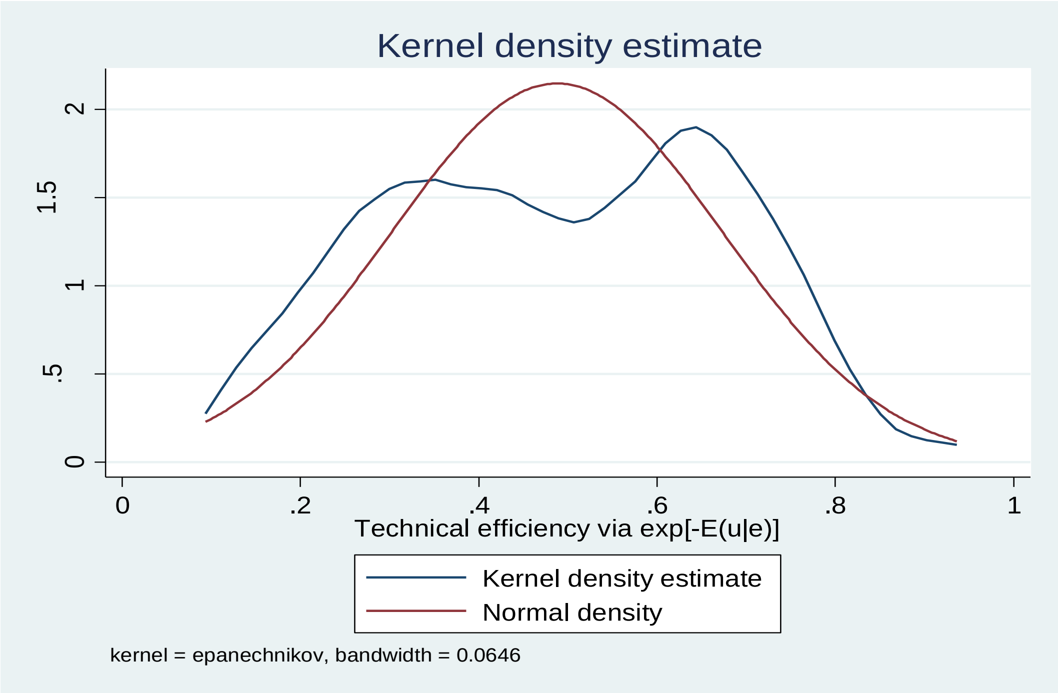
Table 11: Efficiency scores and Moringa yield gaps

Variable	Mean	Std. Err.
Actual production (kg)	103.11	3.81
Potential production (kg)	260.75	18.37
Yield mean difference (kg)	157.63***	18.77
Technical efficiency (%)	48.78	0.017

Note: *** represent statistical significance at 1%.

Source: Survey result, 2018/19

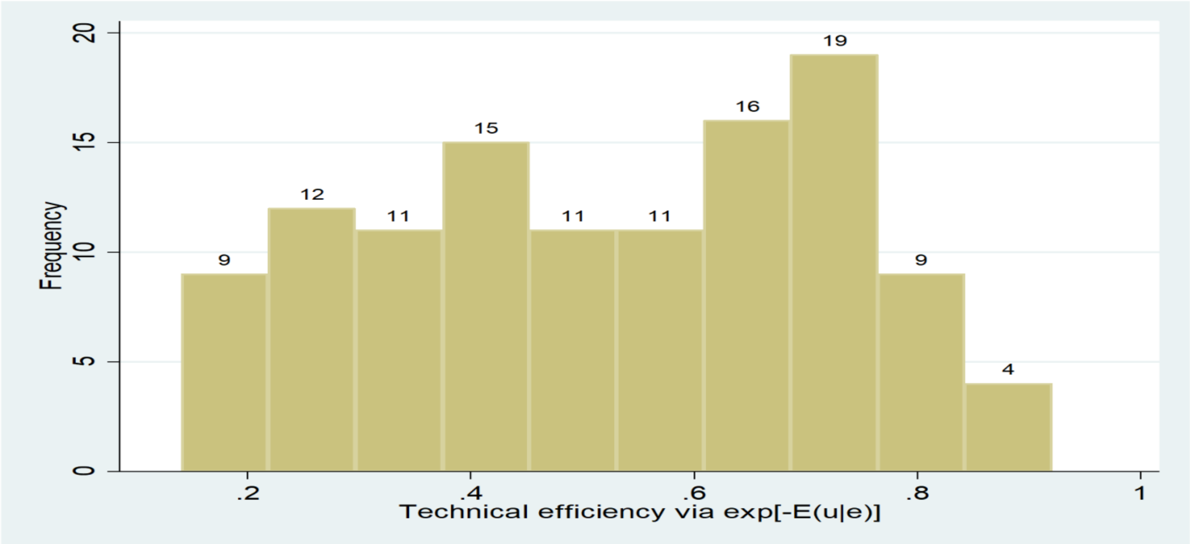
Table 11 above also shows the yield difference due to the presence of inefficiency. The mean actual, potential, and yield differences of Moringa producing sampled households were 103.11, 260.75, and 157.63kg per household, respectively. The potential yield is obtained by dividing the actual yield by individual farmers technical efficiency (Coelli *et al.*, 1998). This implies that if the farmers eliminate inefficiency or operate at full efficiency level through experiencing good internal management practice and learning from the efficient Moringa producing farmers from their locality, they can increase their current production by 157.63kg with the existing level of inputs and technology. Even if the commodity is different this study is in line with Ateka *et al.* (2018) on the technical efficiency study of tea production in Kenya.



Source: Survey result, 2019

Figure 6: Technical efficiency distribution of Moringa

Moreover, the frequency distribution of TE displayed in Figure 7 below shows that more than 89% of Moringa producing farmers fall below the 80% level of technical efficiency. It also shows a big disparity between the efficiency level of farmers with a minimum level of 14% and a maximum of 92%.



Source: Survey result, 2019.

Figure 7: Technical efficiency distribution of Moringa

4.2.4 Sources of technical inefficiency

The results presented above showed the level of efficiency, the presence of the inefficiency, and distribution of inefficiency levels among Moring producing farmers. The estimated yields were made using the SFP model. This part thus discussed the estimated results of the Tobit model to identify the determinants of the technical inefficiency of Moringa producers.

The Ramsey RESET test using powers of the independent variables test by estate ovtest, rhs Stata command was used to test whether the model does suffer from omitted variable bias. The significance p-value of 0.05 of the RESET test is not significant (F (9, 99=0.76 and p-value of 0.6517) (Appendix Table A. 18), indicating there are no omitted variables in the model.

Thus, the Tobit estimated results of the model displayed in Table 12 below. It is, indicated that from among 8 demographic and socio-economic explanatory variables used in the analysis to identify sources of the inefficiency of Moringa production the distance to the main road, irrigation access, non-farm participation, and access to credit service were found to be statistically and significantly determining the level of technical inefficiency of Moringa producing smallholder farmers.

Table 12: Sources of technical inefficiency

Variables	Coefficients	Std. Err	Marginal effect
Age	0.001	0.002	0.001
Gender	-0.090	0.080	-0.089
Education	0.005	0.005	0.005
Cooperative membership	-0.050	0.036	-0.050
Distance to the main road	0.568*	0.319	0.563*
Irrigation	0.119***	0.037	0.118***
Off/non-farm Participation	0.154***	0.040	0.153***
Credit Access	-0.071**	0.036	-0.070**
Constant	0.335***	0.096	-

Note: *, and *** represent statistical significance at 10, 5, and 1%, respectively.

Source: Survey result, 2018/19

The distance of the house of the household from the main road had a statistically significant and positive relationship with the technical inefficiency of Moringa production at a 10% level of significance. The finding indicates that in Moringa production households living far away from the main road are less efficient than their counterparts are. This might be due to farmers' proximity to main roads encourage market participation due to it makes it easy to transport farm yields to the market, thus it helps in improving productivity. This result is similar to Tefera *et al.* (2018). However, it is not similar to Tiruneh and Geta (2016).

Household participation in off/non-farm activities had a statistically significant and positive effect on the technical inefficiency of Moringa production at a 1% level of significance. The finding indicates that households who participate in off/non-farm activities are less efficient than households not participated in non-farm activities in the production of Moringa. This might be due to the farmer's provision of attention to off/non-farm activities than the production of Moringa. The result is in line with Abebe (2014). However, it is in contrast with Teferra *et al.* (2018) and Ahmed and Melesse (2018).

Household access to credit had a statistically significant and negative relationship with the technical inefficiency of Moringa production at a 5% level of significance. The finding indicates that households that received credits from financial institutions are more efficient than household households not received credit in Moringa production. Boucher and Guirkinger (2007) indicated that credit constraints have lowered the value of agricultural output in Peru by 26%. In the current case, it might not be due to the farmer’s cash requirement from credit institutions to cover inputs costs for Moringa production that lead to an increase in the productivity of Moringa. However, the positive relation of credit with technical efficiency of Moring might be due to farmers' capability to meet the liquidity need to discharge their formal credit responsibility through Moringa selling. This finding is similar to the TE study of Coffee by Ngango and Kim (2019) in Rwanda and the TE study of smallholder wheat growers in Ethiopia by Dessale (2019). However, it is in contrast with Abate *et al.* (2019).

The household’s access to irrigation is statistically significant and positively related to the technical inefficiency of Moringa production at a 5% level of significance. This finding indicates that households who have access to irrigation are less efficient than households are with no access to irrigation in the production of Moringa. It is known that irrigation is most commonly used for the production of cash crops. Thus, an implication of this result is households with better irrigation access might be less concerned with the production of Moringa rather they might prefer to produce other annual or biannual crops. The result is similar to the TE study of sorghum by Weldegebriel (2014) but not similar in TE of maize and Teff of by similar study. It is also not similar to the result by Anang (2017) of rice farming in Ghana.

4.3 Commercialization of Moringa

4.3.1 Statistical summary of Moringa commercialization of sampled households

This sub-section briefly discusses and explains the results of the statistical summary that shows the difference between market participants and non-participants in selected variables of demographic and socio-economic characteristics (Table 13). The overall level of Moringa market participation in the research area is at the subsistence level with an average level of commercialization of 19.73% (see Table A. 11).

The age of the household head, family size, household head level of education, livestock holding, farm experience, and land size of the selected Moringa producers are not significantly different. Moreover, the frequency of extension contact and access to irrigation there is no significant difference among market participants and non-participants. The numbers of market participants and non-participants living in Wolaita and Gamo zones are also not significantly different.

However, in some other variables, Moringa market participants and non-participants are significantly different. The socio-economic variables such as cooperative membership, access to credit, distance to the main road, and distance to the market, the participants and non-participants are significantly different.

The percent of cooperative members who participated in the Moringa leaf market (38%) is lower than that of non–participants (60%). Furthermore, from non-participants (38%), market participants in the mean accessed less credit (26%). In contrast, Moringa market participants live in the nearest distance in km (0.48) to the main road than non-participants (0.76). Similarly, non-market participants are living in a long-distance in km (0.05) to the local market than market participants (0.04).

Nevertheless, due to the expected selection bias in the sample, the results discussed above should not be used for inferring the determinants of Moringa market participation and non-participation. Therefore, as discussed in the latter part the Heckman two-stage sample selection model that introduces Lambda (IMR) or selectivity bias correction factor in such a case was implemented here to identify determinants of Moringa commercialization.

Table 13: Statistical summary of sampled Moringa market participants and non-participants

Continuous variables	Market Participants (n=131)		Non-market Participants (n=101)		Mean differences
	Mean	Std. Dev.	Mean	Std. Dev.	
Age	49.02	13.67	48.44	13.37	0.57
Family size	4.07	1.52	3.78	3.73	0.28
Education	3.77	3.87	3.91	3.73	-0.13
Livestock (TLU)	2.50	2.03	2.59	1.70	0.08
Per capita income	4077	3183	3888	3271	189
Land size	1.62	1.06	1.50	1.01	0.11
Farm experience	24.98	11.43	25.92	13.40	-0.93
Distance to the main road	0.05	0.05	0.08	0.04	-0.02***
Distance to market	0.48	0.50	0.79	0.74	-0.31***
Extension contact	20.45	12.97	18.26	12.96	2.19

Dummy variables						
	Category	No.	%	No.	%	χ^2 value
Gender	Male=0	122	93.12	96	95.04	0.37
Zone	Wolaita=1	71	54.19	45	44.55	2.12
Credit access	Yes	35	26.71	39	38.61	3.71*
Irrigation access	Yes	48	36.64	45	44.55	1.48
Cooperative membership	Yes	50	38.16	61	60.39	11.29 ***

Note: “*” and “***” represent statistical significance at 10, 5, and 1 % levels respectively

Source: Field Survey, 2018/19

4.3.2 Determinants of Moringa commercialization

Literature indicated that there are macro-level and micro-level factors determining the decision or willingness of smallholder farmers to participate (or not) in the output market. In this study, the whole focus is on identifying only some of the specific factors determining Moringa market participation of Moringa producing smallholder farmers.

Therefore, the Heckman two-step sample selection model is adopted here to identify determinants of Moringa market participation and the intensity of participation, level of commercialization. The model is considered on the basis that it models the market participation decision as a two-step process that involves first the household decision whether or not to participate in the Moringa market and then the level of commercialization. The model computes the inverse mills ratio from the Probit regression and uses it as a regressor with other explanatory variables to explain the outcome of the dependent variable. The Lambda is used to capture/for the correction factor of sample selectivity biases. The estimated result of the Heckman two-stage selection econometric model (Table 14) used in the current research also shows the existence of sample selectivity bias. This is indicated in the statistically significant inverse mills ratio (IMR) in Table 14 below. The positive sign of the correction factor also shows that the unobserved factors are positively affecting both Moringa market participation decisions and the level of Moringa commercialization. Moreover, positive rho also indicates that unobservable factors positively correlated with one another.

According to the first stage analysis, the Probit (selection) model that showed the determinants market participation variables such as family size, age, level of education, land size, the frequency of extension contact, gender (female), access to credit and cooperative membership are significantly not different.

However, the location of the sampled householders is negative and significantly different. When comparing the market participation of Moringa producers living in the Gamo and Wolaita zone, Moringa producers in Gamo are better participants in the Moringa market.

Moreover, Moringa market participants have less irrigation access than non-market participants do. This implies households with better access to irrigation are more concerned about the production and marketing of other seasonal cash crops than perennial crop, Moringa.
Moringa market participants are more likely to live at a shorter distance from the market than non-market participants are. This finding is similar to Akinlade *et al.* (2016), Alemu (2007), Gani and Adeoti (2011), Gebremedhin and Jaleta (2010), Yisehak *et al.* (2011), and others who indicated that households closer to market outlets were more likely to participate in marketing activities than households living farther to market outlets. This is because of the increased transaction costs associated with the marketing of the farmers' agricultural produce. It is also that the location of farmers in respect of potential markets is an important factor in encouraging farmers to increase their sales (Tufa *et al.*, 2014). However, these researches are concerned about the general farm commercialization than single commodities. In contrast, Sebatta *et al.* (2014) and Dube and Guveya (2016) statement although towns offer markets for agricultural products, on the other hand, the nearer the farm is to a town, the higher the chances of a farmer getting non-farm employment and taking farming as a part-time weekend affair. Thus, farmers who are far from town tend to take farming as an alternative form of employment and less market Moringa yield. However, the plausible explanation for the current study is household's marketed Moringa yield due to better access to market information and lesser transaction cost related to the nearness of the market than non-market participants did.
In the second stage analysis, OLS (outcome equation) considered factors affecting the intensity of Moringa commercialization. The variables are the age of household head, land size, access to irrigation, gender (being female), family size, level of education, zone, distance to the main road, distance to market, access to irrigation, access to credit and frequency of extension contact.

Land size has a positive and statistically significant effect on the intensity of Moringa commercialization at 5% significance levels. This indicates households with a higher size of land have a higher land resource available to produce Moringa and then higher amount provided to the market. The result of this study is consistent with the findings of Ele *et al.* (2013), and Astemir (2014).

However, the distance of households from the market has a negative and statistically significant effect on the intensity of Moringa commercialization at 1% significance levels. It shows that while maintaining other variables constant when the number of a kilometer to the market increases by one unit the level of commercializing Moringa yield decreased by 2.7kg. This finding is consistent with Gebremedhin and Jaleta (2010), Leta (2018), and Tufa *et al.* (2014) that distance to the nearest market and all-weather road detracts from crop input market participation due to its effect on increasing the marketing costs of both inputs and yields. On another side, this finding contradicts the finding of Fredriksson *et al.* (2017), in which the distance to sales point affects positively the proportion of yield sold. The possible reason for the current side is similar to the explanation of the market participation case above, it is due to better access to market information and lesser transaction cost.

Similarly, the distance of households from the main road has a negative and statistically significant effect on the intensity of Moringa commercialization at 10% significance levels. Even if the commodity is different this finding is consistent with Kyaw *et al.* (2018) study that indicated access to the better road has resulted in higher participation of Rice farmers in the Rice market. It shows that better access to the road from rural areas to urban areas makes it easy to transport agricultural commodities to the market. Thus, it enables the transportation of more agricultural goods from farms to markets.

Access to irrigation has also a negative and statistically significant effect on the level of Moringa commercialization at 1% significance levels. This implies that households with better access to irrigation are more concerned about the production and marketing of cash crops. This finding contradicts the finding of Tufa *et al.* (2014) on the commercialization of Horticultural crops.

Credit access was also a statistically significant and negative effect on the intensity of Moringa commercialization at 1% significance levels. This implies households with better access to credit are more interested to allocate their financial resources from the credit to other household activities example for consumption purposes or use it for the production and marketing of cash crops. The result of this study is similar to Hussain and Thapa (2012).

However, the frequency of extension contact positively and significantly affects the intensity of Moringa commercialization at 1% significance levels. This implies households with higher contact with extension agents have better information about to make informed decisions on the production and marketing of Moringa yields than their counterparts are. Apart from the commodity difference, the result of this study is similar to Kyaw *et al.* (2018) and Leta (2018).

Table 14: Heckman selection two-stage model estimates result of commercialization

Factors	Market Participation				Level of Participation	
	Coe.	St. Err.	dy/dx	Std. Err.	Coe.	St. Err.
Age	0.0009	0.001	0.0007	0.00072	-0.01	0.008
Gender	0.008	0.041	0.0066	0.0313	0.225	0.383
Family size (AE)	-0.003	0.007	0.0025	0.0054	0.082	0.063
Education	0.001	0.003	0.0012	0.0022	-0.015	0.029
Land size	0.014	0.013	0.0107	0.0116	0.209**	0.106
Zone	-0.22***	0.064	-0.1661**	0.0691	-0.582	0.392
Cooperative membership	0.003	0.018	0.0022	0.0140	-	-
Distance to the main road	-	-			-3.898*	2.179
Distance to market	-0.209***	0.066	-0.1575**	0.0746	-0.989***	0.236
Irrigation	-0.276***	0.073	-0.2081**	0.0843	-0.953***	0.385
Credit access	-0.027	0.038	-0.0205	0.0315	-0.621***	0.210
Extension contact	0.0006	0.001	0.0004	0.0013	0.032***	0.009
Constant	1.174 ***	0.081			1.191*	0.677
Mills| lambda					0.124*	0.092
Rho					1.00	
Sigma					0.124	

Note: "*" and "***" represent statistical significance at 10 and 1% levels respectively; Wald $\chi 2$ (14) = 34.47; Censored observations = 103; Uncensored observations = 129; Probability > $\chi 2$ = 0.0003.

Source: Survey result, 2018/19

4.4 Food and Nutrition Security Impacts of Moringa

4.4.1 Statistical summary of Moringa producer and non-producer households

In this part, the results of the demographic and socio-economic characteristics of sampled households were presented and discussed. As it is displayed in the statistical summary provided in Table 15 below, the equal proportion of Moringa producing 232 (50%) and non-producing 232 (50%) households were selected.

In some specified covariates, Moringa producer and non-producer households are not different. The level of education, distance to the main road, access to irrigation, and credit in the two groups are not significantly different. Moreover, the number of off/non-farm participants and non-participants are not significantly different between Moring producers and non-producer groups.

However, there is a significant mean difference in other variables. The outcome variables such as weekly calorie intake and FCS; and in the covariates like age, family size, numbers of livestock holding, land size, farming experience, and distance to market there is a significant mean difference between Moringa producers and non-producers.

The two outcome variables, weekly food calorie intake and FCS of Moringa producers are higher than non-producer households are. The mean weekly calorie intake of producers (74114.96) is greater than that of non-producers (68619.3). Additionally, the FCS of producers (49.73) is greater than non-producers (43.87).

Similarly, the covariate such as the mean age of Moringa producers (48.77) is greater than the non-producers (44.28). Moreover, the producer's mean amount of family size (3.94 adult equivalent) is also higher than non-producing (3.50 adult equivalent) households. Producers own more livestock (2.54 TLU) than none producers (1.93TLU). Additionally, The landholding of producers (1.56 ha) is also higher than non-producers (1.25ha). On average, producers (25.39) stayed more years in farming than non-producers (21.72). When comparing the distance of producers (0.62 km) from the nearest market with non-producers (0.37 km) producers live longer distances from the market.

However, to control for the confounding factors, the above results should not be used for inferring the impact of Moring production on household food and nutrition security. Thus, there is a need to conduct PSM for results that are more reliable.

Table 15: Statistical summary of sampled Moringa producer and non-producer households

Variables	Producers (N= 232)		Non-producers (N= 232)		Mean differences
	Mean	Std.dev.	Mean	Std.dev.	(t-test)
Dependent and outcome variables					
Sample households	232		232		
Calorie	74115	6600	68619	14625	5496***
FCS	49.79	17.22	43.87	14.11	5.92***
Independent variables					
Age	48.77	13.51	44.28	12.44	4.48***
Gender	0.06	0.23	0.09	0.29	0.03
Family size (a.e)	3.94	1.47	3.50	1.38	0.44***
Education	3.83	3.87	3.73	3.83	0.09
Livestock (TLU)	2.54	1.89	1.93	1.55	0.61***
Land size	1.56	1.02	1.25	0.94	0.30***
Farm experience	25.39	12.31	21.72	11.89	3.66***
Distance to main road	0.06	0.05	0.07	0.05	0.01
Distance to market	0.62	0.63	0.43	0.37	0.18***
Extension contact	19.504	12.99	15.50	10.12	4

Dichotomous independent variables						
		No.	%	No.	%	χ^2 value
Gender	Male=0	218	93.96	209	90.08	2.37
Zone	Wolaita=1	136	58.62	145	62.50	0.73
Credit access	Yes	74	31.89	70	30.17	0.16
Irrigation access	Yes	93	40.08	81	34.91	1.32
Off/non-farm activity	Yes	124	53.44	130	56.03	0.31

Note: *, ** and *** represent statistical significance at 10, 5 and 1%, respectively.

Source: Survey result, 2018/19

4.4.2 Impact analysis

4.4.2.1 Propensity score analysis and matching quality tests

As discussed in the methodology part, there are four major steps in propensity score analysis, propensity score estimation, propensity score matching, matching quality evaluation, and outcome analysis after matching. The propensity score estimation was conducted using a Logit regression model (Appendix A) on the chosen covariates in Table 17 to obtain each individual's propensity score. The identification of covariates was made using reviews of works of literature in previous studies related to the current study. The covariates predictive about the dependent variable, participation in Moring production, and the outcome variables, food, and nutrition security were selected. Then the choice of identified variables was made using statistical significance relying on the statistical significance of each variable. The overall model fitness (Appendix A) and sensitivity and specificity report (Appendix A) of the model also shows its good fitness. After estimation of the Propensity score (Appendix A) for each individual's three algorithms of propensity score matching such as the nearest neighbor, radius, and the kernel were implemented. The fulfillment of balancing properties for each matching algorithm in Table 16 was then checked.

Before implementing outcome analysis after matching to evaluate the impact of Moringa production on food and nutrition security on households matching quality tests was performed. This part discusses some of these tests implemented in the study to check for the fulfillment of PSM assumptions of strongly ignorable conditions, the common support, and conditional independence or balancing property. The common support or overlap condition as shown in Figure 8 below was satisfied. It indicates that an adequate common support region was created in between treated and control groups. The propensity score lies strictly between zero and one is a good indicator of it. Therefore, it shows that there is sufficient overlap in the distribution of the estimated probability of Moringa production.

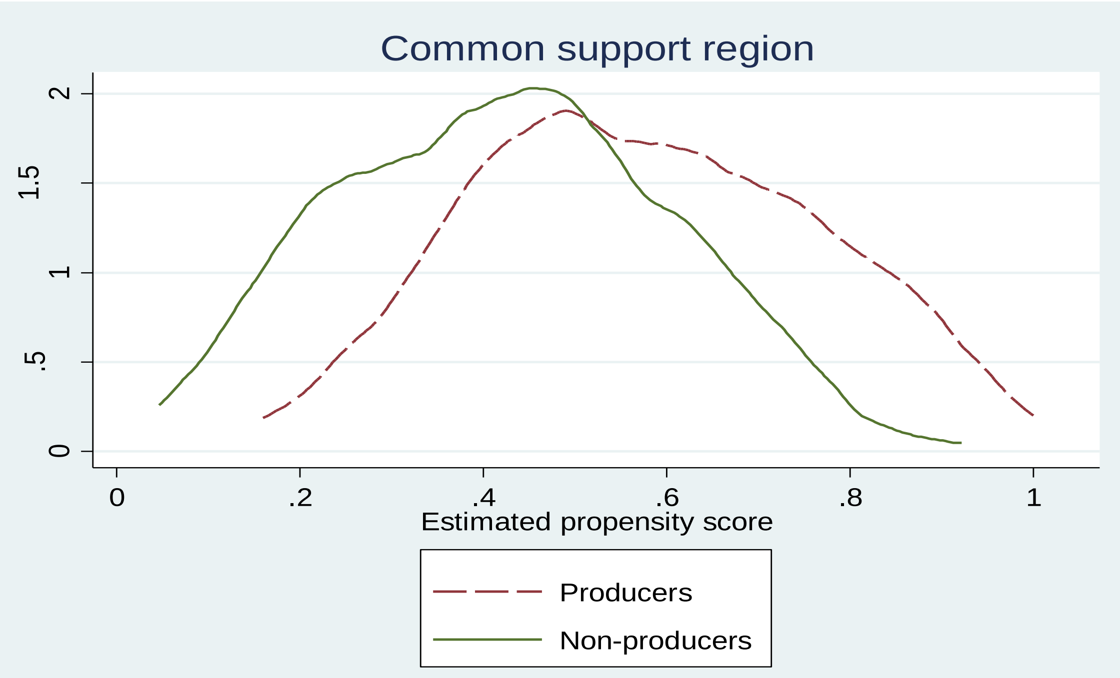


Figure 8: The density distribution of propensity scores for treated and control groups

Source: Survey result, 2018/19

As it is indicated in Table 16 below that the other assumption of conditional independence or balancing property is also satisfied. After performing the three matching algorithms (the nearest neighbor, kernel, and radius), the test for balancing property was made.

It is also important to choose the best matching estimator before evaluating the impact of Moringa production on food and nutrition security. The choice of matching estimator was conducted based on three different criteria as proposed by Dehejia and Wahba (2002). It is selected from among the commonly used matching algorithms (kernel matching, nearest neighbor matching, and radius matching). The criteria for the best fitting matching algorithm are selecting an estimator that has low pseudo-R^2, large matched sample size, and a large number of insignificant variables after matching, and mean standard bias between three and five. After the estimation results are obtained, the discussion is made on the direct outcomes of the nearest neighbor (1) matching algorithm. Therefore, lastly to evaluate the impact of Moringa production on food and nutrition security the estimation of ATT is performed on 450 (225 treated and 225 controlled) (Appendix D) samples remained after removing observation which is out of support region.

Table 16: Matching quality tests

Matching algorithms	Performance criteria			
	Pseudo-R^2	Matched sample size	Mean (Median) standard bias	No. of significant variables after matching
Kernel Matching				
Bandwidth of 0.1		450	5.5 (5.2)	0
Bandwidth of 0.5		450	12.9(17.1)	8
Bandwidth of 0.25		450	6.7(3.6)	2
Nearest Neighbor Matching				
Neighbor 1		450	5 (2.9)	0
Neighbor 2		450	5(4.9)	0
Neighbor 3		450	5.1(5.6)	0
Neighbor 4		450	5.3(4.9)	0
Neighbor 5		450	6(5.4)	0
Radius Matching				
Bandwidth of 0.1		450	5.4(4)	0
Band width of 0.5	0.076	450	15.6(23)	8
Bandwidth of 0.25		450	8.7(8.9)	2

Source: Survey result, 2018/19

In the wake of choosing the best performing matching algorithm, the following errand is to check the adjusting of propensity score and covariate applying various systems by choosed matching algorithm (closest neighbor (1) matching in the current case). As mentioned above the common support or overlap condition was adequately created for the two groups (Figure 8). Similarly, the assumption of conditional independence or balancing property is also satisfied. It has indicated that the mean differences for the mentioned covariates were significantly smaller after matching when compared with before matching. The mean standard bias and median bias after matching were reduced to a level below 20% for all covariates as shown in Table 17 below. Rosenbaum and Rubin (1985) suggested this to lay fairly below the critical level of 20%. The t-values after matching shows that all covariates are not significantly different between treated and control groups. This is the best quality indicator for the fulfillment of the PSM assumption of conditional independence.

Thus, if the two conditions (conditional independence and common support) are satisfied PSM model can be used as a good method for inferring the impact of Moring production on household food and nutrition security.

Table 17: Balancing test for covariates

Variable	sample	Mean		%bias	%reduct	t-test		V(T)V(C)
		Participant	Non-participant		/bias/	t	p>/t/	
Family size(a.e)	Unmatched	3.94	3.50	31.2		3.36	0.001	1.14
	Matched	3.91	3.93	-0.7	97.6	-0.07	0.94	0.87
Education	Unmatched	3.83	3.73	2.6		0.28	0.78	1.02
	Matched	3.8	3.91	-2.9	-12.1	-0.30	0.76	1.00
Gender	Unmatched	0.06	0.09	-14.3		-1.54	0.12	.
	Matched	0.06	0.08	-9.8	31.3	-1.07	0.28	.
Land size	Unmatched	1.56	1.25	31.1		3.35	0.001	1.18
	Matched	1.53	1.46	-7.2	76.9	0.77	0.44	1.22
TLU	Unmatched	2.54	1.93	35.1		3.78	0.00	1.49*
	Matched	2.47	2.60	-7.5	78.5	-0.78	0.43	1.06
Irrigation	Unmatched	0.40	0.34	10.7		1.15	0.25	
	Matched	0.38	0.37	1.8	82.8	0.19	0.84	
Farm	Unmatched	25.39	21.72	30.3		3.26	0.001	1.07
experience	Matched	25.04	23.72	10.9	64.1	1.13	0.26	0.94
Age	Unmatched	48.77	44.28	34.5		3.72	0.00	1.18
	Matched	48.61	47.10	11.6	66.3	1.25	0.21	1.26
Age square	Unmatched	2560.7	2115.2	31.5		3.40	0.001	1.30*
	Matched	2547	2364	13.0	58.9	1.40	0.16	1.45*
Zone	Unmatched	0.58	0.62	-7.9		-0.85	0.39	

	Matched	0.58	0.56	2.7	65.6	0.29	0.77	
Credit service	Unmatched	0.31	0.30	3.7		0.40	0.68	
	Matched	0.32	0.33	-2.9	22.7	-0.30	0.76	
Distance to road	Unmatched	0.06	0.06	-2.1		-0.22	0.82	0.74*
	Matched	0.06	0.06	-1.7	18.3	-0.19	0.84	1.07
Distance to	Unmatched	0.62	0.43	36.1		3.89	0.00	2.90*
market	Matched	0.58	0.59	1.9	94.7	-0.19	0.85	1.36*
Extension	Unmatched	19.50	15.50	34.3		3.70	0.00	1.65*
contact	Matched	18.74	18.74	0.0	100.0	0.00	1.00	1.04
Off/non-	Unmatched	0.53	0.56	-5.2		-0.56	0.57	
participation	Matched	0.52	0.52	0.0	100.0	-0.00	1.00	

Source: Survey result, 2018/19

4.4.2.2 Food and nutritional security impacts of Moringa

As outcome variables for food and nutrition security, weekly calorie intake and FCS were used to evaluate the impact of Moringa production on food and nutrition security. The estimated results of PSM using the first nearest neighbor matching algorithm are displayed in Table 18 below.

Table 18: PSM results of the average impact of producing Moringa on food and nutrition security (FNS)

Outcomes	Matching algorithms	Treated	Controls	ATT+	Std. Err.	T-stat
Weekly Calorie intake	Nearest neighbor (1)	74335	69230	5105.29	2102	2.43
FCS	Nearest neighbor (1)	50	44	6	2	3.01

Source: Survey result, 2018/19

The estimation results of ATT are obtained for weekly calorie intake and FCS using above mentioned matching algorithms. The first nearest neighbor ATT result of weekly calorie intake is 5105.29. Similarly, ATT results obtained from the first nearest neighbor matching algorithms for FCS are six. These estimations were made by using the “psmatch2” command in STATA 14. The standard error results were obtained by a bootstrap of 100 replications. The t-values of selected matching algorithms show the positive and significant difference of ATT results of weekly calorie intake and FCS in between treated and controlled groups.

Consequently, based on observable covariates listed in Table 17 above and controlling them, the PSM estimation result obtained from the first nearest neighbor matching algorithms in Table 16, indicate the positive and statistically significant impact of Moringa production on household food and nutrition security, as measured by weekly calorie intake and FCS. The ATT results indicate that Moringa producer households significantly on average receive 5105.29 more weekly calories than if they had not been Moringa producers and non-producers would have even received higher calorie intake than producers if they had produced Moringa. It also indicates that Moringa producer households on average receive six significantly more weekly FCS than if they had not been Moringa producer and non-producers would have even received higher FCS than producers if they had produced Moringa.

Generally, the above PSM result shows that producing Moringa production positively and significantly contributes to food and nutrition security than not producing Moringa. The result complies with the findings of Seifu (2015), Thurber and Fahey (2009), Yisehak *et al.* (2011), and others. Nevertheless, these authors used different analytical methods. These studies used a review, qualitative, and experimental methods to show the food security contribution of Moringa production in various parts of the world. The positive and significant effect of Moringa should not be considered only due to its direct contribution to food and nutrition security rather its possible multiplier effects in other livelihood issues, environment, health, and industry.

4.4.2.3 Sensitivity analysis

In observational studies, an intervention treat is not randomly allocated test units, randomization tests are not generally appropriate. In this manner, to make up for the absence of randomization, Moringa producer and non-producer households are matched based on observed covariates. Notwithstanding, in most cases, prospects survive from predisposition because of residual imbalance in undetectable covariates. Along these lines, sensitivity investigations were done to check the quality of comparison matching between Moringa producer and a non-produce group with observed covariates and chiefly to check robustness for unobserved covariates and the outcome demonstrates the ATT estimate result is insensitive. If the CIA fails in PSM, it tends to be effortlessly addressed the entanglement using the comparison between the simulated and baseline ATTs estimates. Hence, for any given configuration of the parameters Pij, the sensitivity investigation retrieves a point estimate of the ATT that is robust to the failure of the CIA assumption by that specific setup. Using a given arrangement of estimations of the sensitivity parameters, the matching assessment is repeated at different times and a simulated estimate of the ATT is retrieved as an average of the ATTs over the distribution of U. As it is indicated in Table 19 below, however, U is related with huge outcome effects ($\Gamma>1$) and selection effects ($\wedge>1$) for the closest neighbor (1) matching algorithms, the overall simulated ATTs of every participant of Moringa production are still an excess of closer to the baseline ATTs. Subsequently, both the estimations of outcome effect and selection effects are bigger than one each, and the difference in percentage between the baseline ATTs and simulated ATTs are below 10% make it more grounded in the validity of our assessed ATTs too. The simulated ATT of every one of the calorie intake and FCS are excessively near the baseline. This infers that it is just when U is simulated to give an incredibly huge outcome effect; the ATT can be driven a long way from the baseline estimate or considerably more closer to zero. Consequently, we can presume that our impact estimates ATT are insensitive toward unobserved selection bias and are a pure effect of participation in Moringa production. Generally, the results estimated uphold and strengthen the robustness of the matching analysis is reliable.

Table 19: Sensitivity analysis

Outcome variable	Baseline ATT(A1)	Simulated ATT(A2)	Outcome effect (Γ)	Selection effect(Λ)	Absolute difference (A1-A2)	The difference in % (A1-A2/A1)
Weekly Calorie intake	4576.17	4119.77	1.415	1.60	456.4	0.09
FCS	6.05	5.78	1.07	1.59	0.27	0.04

Source: Survey result, 2018/19

5. SUMMERY, CONCLUSION, AND POLICY IMPLICATIONS

5.1 Summary

The Agricultural sector in Ethiopia is characterized by its poor performance, whereas the population of the country, which largely depends on farming, is growing at a faster rate. This necessitates seeking a means to increase the productivity of smallholder farmers, the dominant producers, which could be met either through improving the state of technology or through enhancing the efficiency of producers. Improving the efficiency of the farmer plays a great role in increasing productivity, given the current state of technology. This study analyzed the technical efficiency, commercialization, and food and nutrition security of Moringa production of smallholder farmers in *Humbo and Mirab Abaya* districts of W*olaita and Gamo* zones, respectively in Southern Ethiopia. This is important because the study area has a growing population with limited cultivated land available and this demands productive agricultural strategies. The enormous challenge to increase the productivity of crop farming to feed the growing population may be met by improving farm efficiency. It is also found important to investigate the commercialization of high valued indigenous crops and evaluate the impact these crops on food and nutrition security.

Under literature reviewed the current research in the context of existing literature of developing countries including Ethiopia and efficiency, commercialization and food and nutrition security concepts and measuring techniques were presented.

The data collected from primary and secondary data sources. The study survey recruited enumerators using a structured questionnaires under the close supervision of researchers who collected the data. Stochastic frontier model with inefficiency effects, Heckman two-step sample selection model, and Propensity to score (PSM) models were used for analyzing cross-sectional data obtained from sample of 232 Moringa producing and 232 Moringa non-producing farmers in 2018/19 production year. The study measured the Moringa production efficiency based on the data of 117 homogeneous five-year Moringa production period farm household relative to ‘best practice” in Moringa production. On the other hand, various farm and farmer specific demographic, socio-economic, and institutional variables that are expected to determine the inefficiency and commercialization of Moringa producing farmers were estimated with the stochastic frontier model (two stage estimation procedure) and Heckman two-step sample selection model, respectively. Moreover, demographic, socio-economic, and institutional variables, Moringa producing and non-producing decision and outcome variables, such as calorie intake and FCS were estimated with the PSM model to evaluate the impact of Moringa production on food and nutrition security. Data analysis was carried out using descriptive, inferential statistics and econometric techniques using STATA version 14.

The stochastic frontier production function of the Cobb-Douglas functional form was found to be best fit the data and was applied to estimate the level of individual technical efficiency of Moringa production. Moreover, the production structure was characterized by increasing returns to scale at a decreasing rate since the summation of the inputs coefficient is 1.23. The positive and significant elasticity of Moringa yield concerning labor revealed that this input plays an important role in affecting the level of Moringa yield per unit of each input. Through using the Log-Likelihood Ratio statistic calculation, it was found that the stochastic frontier production function specification better represents the data set of Moringa production function. Hence, the parameters were estimated using the Maximum Likelihood estimation procedure of the stochastic production frontier (SPF) function, taking the inefficiency. The results obtained from the estimations indicate that the average efficiency scores were low and there exist efficiency variations among farmers. The technical efficiency estimates derived from the model were regressed on demographic, socioeconomic, and institutional variables that explain variations in efficiency across farm households using the Tobit regression model. This relied on SPF regression techniques, where inefficiency was expressed as functions of eight explanatory variables. Among them, education, family size, age, farmland size, credit access in Moringa production, and extension service negatively and significantly affected. Total cultivated land had a significant impact on technical and economic inefficiency. These factors had important policy implications to alleviate the existing level of inefficiency of farmers in Moringa production.

Due to observable sample selectivity biases, the Heckman sample selection model was found valid to identify determinants of Moringa commercialization. The model was used demographic, socioeconomic, and institutional variables that determine Moringa commercialization. The result identified that the location of households, access to irrigation, and distance to market are the main variables that determine the household participation in the Moringa yield market. Moreover, variables such as family size, credit access, and average frequency of extension contact, access to irrigation, access to credit, and distance to market and main all-weather road are the main variables that are significantly determine householders' intensity of Moringa market participation. These factors too had important policy implications to improve the commercialization of Moringa by smallholder farmers.

Lastly but not the least, the PSM model used to evaluate the impact of Moringa production on food and nutrition security tested for assumptions of the model and found binding. The model results indicated that based on observable covariates (demographic, socioeconomic, and institutional variables) Moringa production is significantly related to the household's food and nutrition security. The ATT results of outcome variables such as weekly calorie intake and FCS of Moringa producer households is greater than that of Moringa non-producer households. This implies that the greater contribution of Moringa to farmers' food and nutrition security improvement.

5.2 Conclusion

It is known that Moringa has been among vastly growing and trading commodities in different parts of Ethiopia for its multiple benefits. However, empirical researches analyzing its productivity at the smallholder farmer level were missing. Therefore, the current research aimed to analyze the technical efficiency of Moringa production in Wolaita and Gamo Zones. Moreover, it also aimed to identify factors determining the participation of smallholder farmers in the Moringa yield markets and factors affecting the degree of participation in the Moringa market and level of commercialization in Wolaita, and Gamo Zones of SNNPR state of Ethiopia. Lastly, the study focused on the evaluation of food and nutrition security impacts of Moringa production in Wolaita and Gamo Gofa zones of Southern Nation Nationalities and the Peoples Regional State of Ethiopia.

The study to analyze technical efficiency of Moringa production was made based on sampled 117 Moringa producer farmers having a five-year production period from 232 Moringa producer households sampled for investigation of commercialization. The SPF model used to estimate the level of efficiency and the Tobit model used to identify sources of Moringa production inefficiency in the area where there was no other study before as to the knowledge of the authors. The results of the model indicated that the positive relation between inputs and Moringa yield implying an increase in input leads to more increase in the level of yield. The required tests to check model fitting for data, the presence of inefficiency, and others were made. The estimated Cobb-Douglas functional form indicated in mean 48.78% level of technical efficiency among Moringa producing smallholder farmers. The estimated gamma value indicated that 79% of the total variation in Moringa yield is resulting from technical inefficiency. It is also considered that if the farmers operate through minimizing inefficiency problems of Moringa production they can increase their current production with the existing level of input and technology. The results of Tobit model estimation to identify the source of inefficiency indicated that distance to all-weather road, access to credit service, access to irrigation, and participation in off/non-farm activities, were significantly determine the level of technical inefficiency of Moringa production.

The study result of investigating commercialization found that the overall level of Moringa commercialization in the research area is at the subsistence level with a mean level of commercialization of 19.73 percent. It also revealed that the location of households, access to irrigation, and distance to market are the main variables that are statistically significant and have a causal impact on the ability of a household to participate in the Moringa yield market. Moreover, variables such as land size, credit access, distance to market, distance to main all-weather road, average frequency of extension contact, access to irrigation and access to credit are the main variables that are significantly affect householders' intensity of Moringa commercialization.

To evaluate the food and nutrition security impact of Moringa production, the PSM model was used on 464 sampled Moringa producing and non-producing households. The inferential statistical analysis, t-test results showed a positive and significant mean difference between Moringa produces and non-producers groups in observed outcome variables and covariates. The weekly calorie intake, FCS, age, family size, numbers of livestock holding, land size, farming experience, and distance to market are in mean significantly different between producer and non-producer groups. Before implementing PSM analysis, it has checked the fulfillment of the two important assumptions of PSM estimation, the assumptions of strongly ignorable conditions or the common support and conditional independence, or balancing property. The tests for assumptions of the PSM model and the main result were found to be valid. The PSM results indicated that based on observable covariates Moringa production is positively and significantly associated with the household's food and nutrition security. The ATT results of household food and nutrition security outcome variables, weekly calorie intake, and FCS are higher in amount for Moringa producer households than non-producers. Thus, it shows that producing Moringa positively and significantly contributes to food and nutrition security than not producing it.

5.3 Policy Implications

Based on the above findings the following recommendations were set:

The policymakers, the office of agriculture and rural development, and different levels of administrations should mainly work on development activities in the area. They should work on Moringa extension service to improve techniques of producing Moringa and provide value-added mechanisms of marketing Moringa, and create better market access and chain to Moringa in the local area to surge the contribution of Moringa for local as well as the national economy.

Moreover, future activities to improve Moringa production should consider important demographic characteristics such as land size, access to credit, age, farming experience, distance to market, livestock ownership, road infrastructural access, extension access, and access to irrigation of farmers. Particularly below raised points found essential.

The finding imply that larger farms have more likely to have Moringa in their farm and commercialize it. Therefore, policies that can enhance commercialization of Moringa by limited farmland can be taken as an alternative. The regional and local governments should give due attention to promoting the use of Moringa as an agroforestry tree and encourage it to commercialize its products for the smallholder farmers. It also needs arranging experience-sharing program in Moringa production.

It also requires creating better extension services and offering immediate practical training on techniques of market-oriented and value-added Moringa production and marketing systems. It needs solidification of the existing agricultural extension program, capacitating the existing farmers training centers, providing field level practical oriented training to farmers on production and commercialization of Moringa.

Further, backing the existing farm credit institution to improve input availability, affordability and provision of time bound subsidy and an alternative sources of income and modern credit institutions, as well as facilities, are required to improve the livelihood of Moringa producers in Wolaita and Gamo zones, Southern Ethiopia.

It also requires strengthening the existing livestock production system through providing better health services, better livestock feed, targeted credit and adopting agro-ecologically based high-yielding breeds and disseminating through artificial insemination to improve the livelihood of farmers in the area.

Moreover, proximity to market and all-weather road found an important factor on production and commercialization of Moringa. Therefore, policies and strategies should place more emphasis on strengthening the existing rural-urban market centers, rural-urban road, and other infrastructure development activities in the study areas by the regional and local government.

The development direction to enhance Moringa production should also consider households with limited access to irrigation. In general, apart from food and nutrition security contributions, Moringa has environmental, medicinal, and industrial benefits. Therefore, it needs activities to work on a means to increase the amount of Moringa production in dry parts of the country. Future research works on qualitative studies comparing Moringa based diets with other cultural meals in the Wolaita and Gamo zones are required.

Lastly, for more reliability of research results, future research works on Moringa production efficiency in the area should effectively consider the average Moringa production yield of at least 10-year data. It should also capture the variables such as access to credit, off/non-farm participation, and cooperative membership as the level of access to credit facilities, off/non-farm income, and co-operative society credit support, respectively.

6. REFERENCES

Abafita, J., and Kim, K.R. 2014. Determinants of household food security in rural Ethiopia: an empirical analysis. *Journal of Rural Development/Nongchon-Gyeongje*, *37*(1071-2016-86950): 129-157.

Abate, G. T., Francesconi, G. N., and Getnet, K. 2014. Impact of agricultural cooperatives on smallholders'technical efficiency: empirical evidence from Ethiopia. *Annals of Public and Cooperative Economics*, *85*(2): 257-286.

Abate, T. M., Dessie, A. B., and Mekie, T. M. 2019. Technical efficiency of smallholder farmers in red pepper production in North Gondar zone Amhara regional state, Ethiopia. *Journal of Economic Structures, 8*(1):18.

Abebe, G. G. 2014. Off-farm income and technical efficiency of smallholder farmers in Ethiopia. The MSc thesis. Swedish University of Agricultural Science. University in Uppsala, Sweden.

Abera, G. 2009. Commercialization of Smallholder Farming: Determinants and welfare outcomes. *A* Cross-sectional study in Enderta District, Tigrai, Ethiopia. M. Sc. thesis, Haramaya University, Haramaya, Ethiopia.

Abuye, C., Urga, K., Knapp, H., Selmar, D., Omwega, A., Imungi, J., and Winterhalter, P. 2003. A compositional study of Moringa stenopetala leaves. *East African Medical Journal, 80*(5):247-252.

Addison, M., Ohene-Yankyera, K., and Fredua-Antoh, E. 2016. Gender role, input use and technical efficiency among rice farmers at Ahafo Ano North District in Ashanti Region of Ghana. *Journal of Food Security,* 4 (2): 27-35.

Adedeji, I., Kazeem, A., Ogunjimi, S., and Otekunrin, A. 2013. Application of stochastic production frontier in the estimation of technical efficiency of poultry egg production in ogbomoso metropolis of oyo state, Nigeria. *World Journal of Agriultural Resources,* 1(6):119-123.

Afriat, S. N. 1972. Efficiency estimation of production functions. *International Economic review,* 568-598.

Agbogidi, O., and Ilondu, E. 2013. Effects of spent engine oil on the germination and seedling growth of Moringa oleifera (Lam.). *Scholarly Journal of Agricultural Science,* 3(5): 205-209.

Agidew, A.-m. A., and Singh, K. 2018. Determinants of food insecurity in the rural farm households in South Wollo Zone of Ethiopia: the case of the Teleyayen sub-watershed. *Agricultural and Food Economics*, 6(1): 10.

Ahmed, M. H., and Melesse, K. A. 2018. Impact of off-farm activities on technical efficiency: evidence from maize producers of eastern Ethiopia. *Agricultural and Food Economics, 6*(1): 3.

Aigner, D., Lovell, C. K., and Schmidt, P. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of econometrics, 6*(1): 21-37.

Aigner, D. J., and Chu, S.F. 1968. On estimating the industry production function. *The American Economic Review, 58*(4): 826-839.

Ajibefun, I. A. 2002. Analysis of policy issues in technical efficiency of small scale farmers using the stochastic frontier production function: With application to Nigerian farmers. *Paper prepared for presentation at the 13th International Farm Management Congres*s, July 7-12, 2002. Wageningen, the Netherlands.

Akinlade, R. J., Balogun, O. L., and Obisesan, A. A. 2016. Commercialization of urban vegetable farming. *International Journal of Vegetable Science, 22*(1): 24-34.

Alemu, D. 2007. *Determinants of smallholder commercialization of food crops: theory and evidence from Ethiopia* (Vol. 745): International Food Policy Research Institute.

Alemu, D., and Amare, H. 2005. Analysis of technical efficiency in sorghum production: The case of smallholder farmers in Raya-Azebo district, southern Tigray, Ethiopia. Ph.D. dissertation. Haramaya university, Ethiopia.

Alene, A. D., Manyong, V. M., and Gockowski, J. 2006. The production efficiency of intercropping annual and perennial crops in southern Ethiopia: A comparison of distance functions and production frontiers. *Agricultural Systems, 91*(1-2): 51-70.

Anang, B. T., Bäckman, S., and Rezitis, A. 2017. Production technology and technical efficiency: irrigated and rain-fed rice farms in northern Ghana. *Eurasian Economic Review, 7*(1): 95-113.

Apezteguía, B. I., and Gárate, M. R. 1997. Technical efficiency in the Spanish agro-food industry. *Agricultural Economics, 17*(2-3): 179-189.

Arnade, C. A. 1994. *Using data envelopment analysis to measure international agricultural efficiency and productivity* (No. 1831). US Department of Agriculture, Economic Research Service.

Asfaw, A., and Admassie, A. 1996. The impact of education on allocative and technical efficiency of farmers: The case of Ethiopian smallholders. *Ethiopian Journal of Economics, 5*(1): 1-26.

Astemir, A. 2014. Determinants of Food Security in Rural Farm Households in Ethiopia. Master of Arts in Development Studies thesis. The Hague, Netherlands.

Ateka, J. M., Onono, P. A., and Etyang, M. 2018. Technical efficiency and its determinants in smallholder tea production: Evidence from Nyamira and Bomet Counties in Kenya. *Global Journal of Science Frontier Research: D Agriculture and Veterinary*, 18: 43-54.

Azeez, F., Famuyide, O., Nosiru, M., Bello, G., Clement, N., and Amoo, M. 2013. Technical efficiency of Moringaoleifera production in Isokan Local Government Area of Osun State, Nigeria. *Discourse Journal of Agriculture and Food Science*, 1(2): 78-84.

Baba, M. D., Yakubu, G., Yelwa, J. M., and Haruna, L. 2015. Costs and returns of Moringa (Moringa oleifera) production in Zara local government area of Kebbi State, Nigeria. *Newyork Science Journal*, *8*(1): 36-40.

Battese, G. E., and Broca, S. S. 1997. Functional forms of stochastic frontier production functions and models for technical inefficiency effects: a comparative study for wheat farmers in Pakistan. *Journal of Productivity Analysis*, *8*(4): 395-414.

Battese, G. E., and Coelli, T. J. 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, *20*(2):325-332.

Battese, G. E., and Corra, G. S. (1977). Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*, *21*(3): 169-179.

Bekele, A., and Alemu, D. 2015. Farm-level determinants of output commercialization: In haricot bean-based farming systems. *Ethiopian Journal of Agricultural Sciences*, *25*(1): 61-69.

Bekele, A., Belay, K., Legesse, B., and Lemma, T. 2010. Effects of crop commercial orientation on productivity of smallholder farmers in drought-prone areas of the Central Rift Valley of Ethiopia. *Journal of Rural Development/Nongchon-Gyeongje*, *33*(1071-2016-86943): 105-128.

Berry, E. M., Dernini, S., Burlingame, B., Meybeck, A., and Conforti, P. 2015. Food security and sustainability: can one exist without the other? *Public Health Nutrition*, *18*(13): 2293-2302.

Beyan Ahmed, J. H., and Geta, E. 2013. Analysis of farm households' technical efficiency in production of smallholder farmers: the case of Girawa District, Ethiopia. *Journal of Agriculture and Environmental Science*, *13*(12): 1615-1621.

Binam, J. N., Sylla, K., Diarra, I., and Nyambi, G. 2003. Factors affecting technical efficiency among coffee farmers in Cote d'Ivoire: Evidence from the centre west region. *African Development Review*, *15*(1): 66-76. doi: 10.1111/1467-8268.00063. Accessed on June 02, 2019.

Bosch, C. 2004. Moringa oleifera Lam. *PROTA Foundation, Backhuys, CTA, Wageningen, The Netherlands*.

Boucher, S., and Guirkinger, C. 2007. Credit constraints and productivity in Peruvian agriculture. *Agricultural Economics*, *39*(3): 295-308.doi:10.1111/j.1574-0862.2008.00334.x. Accessed on July 22, 2019.

Bravo-Ureta, B. E., and Pinheiro, A. E. 1997. Technical, economic, and allocative efficiency in peasant farming: evidence from the Dominican Republic. *The Developing Economies, 35*(1): 48-67.

Charnes, A., Cooper, W. W., and Rhodes, E. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6): 429-444.

Chen, C. M., Delmas, M. A., and Lieberman, M. B. 2015. Production frontier methodologies and efficiency as a performance measure in strategic management research. *Strategic Management Journal, 36*(1): 19-36.

Coelli, T., Rao, D. P., and Battese, G. 1998. *An Introduction to efficiency and productivity analysis.* Dordrecht, Netherlands: Kluwer academic publishers.

Coelli, T. J. 1995. Recent developments in frontier modelling and efficiency measurement. *Australian Journal of Agricultural Economics, 39*(3): 219-245.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., and Battese, G. E. 2005. *An introduction to efficiency and productivity analysis*. Berlin, Germany: Springer Science and Business Media.

Cragg, J. G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica (pre-1986), 39*(5): 829.

CSA (Central Statistical Agency). 2013. Federal Democratic Republic of Ethiopia Central Statistical Agency Population Projection of Ethiopia for All Regions At Wereda Level from 2014 – 2017. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2007. Population and Housing Census of Ethiopia 2007: Statistical Report. Addis Ababa, Ethiopia.

Dehejia, R. H., & Wahba, S. 2002. Propensity score-matching methods for nonexperimental causal studies. *Review of Economics and statistics, 84*(1), 151-161.

Desalegn, G., Tadesse, W., and Yirgu, A. 2012. Forestry and Forest Products In Ethiopia: Technologies and Issues. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia.

Dessale, M. 2019. Analysis of technical efficiency of smallholder wheat-growing farmers of Jamma district, Ethiopia. *Agriculture and Food Security, 8*(1): 1.

Djurfeldt, A. A. 2018. Gender and Rural Livelihoods: Agricultural Commercialization and Farm/Non-Farm Diversification. *Agriculture, Diversification, and Gender in Rural Africa: Longitudinal Perspectives from Six Countries*, 81-112.

Dube, L., and Guveya, E. 2016. Determinants of agriculture commercialization among smallholder farmers in Manicaland and Masvingo Provinces of Zimbabwe. *Agricultural Science Research Journal, 6*(8): 182-190.

Ebert, A. 2014. Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. *Sustainability, 6*(1): 319-335.

Endalew, B., Muche, M., and Tadesse, S. 2015. Assessment of food security situation in Ethiopia: A Review. *Asian Journal of Agricultural Research, 9*(2): 55-68.

Endeshaw, H. 2003. Promoting the miracle tree of hope. *Ethiopian Herald, 19*.

Ethiopian Public Health Institute (EPHI). 2014. Opportunities and challenges of research, production, promotion of M stenopetala. *Paper presented at the Consultative Workshop on Moringa stenopetala to Maximize Its Potential Uses*, May 22 – 23, 2014. Bishoftu, Ethiopia.

Edwards, S., Tadesse, M., Demissew, S., and Hedberg, I. 2000. Flora of Ethiopia and Eritrea, Volume 2, part 1: Magnoliaceae to Flacourtiaceae. Addis Ababa, Ethiopia and Uppsala, Sweden: The National Herbarium, Addis Ababa University.

Ethiopian Health and Nutrition Research Unit (EHNRU). 1998. *Food Composition Table for use in Ethiopia. Part IV. 1995–1997*. Addis Ababa, Ethiopia.

Ethiopian Public Health Institute (EPHI). 2014. Developing Moringa value chain for food security and improved livelihoods of small holder farmers in Central Rift Valley (CRV) and South Omo: opportunities, constraints and prospects. *Paper presented at the Proceeding of Consultative Workshop on Moringa stenopetala to Maximize Its Potential Uses,* May 22 – 23 , 2014. Bishoftu, Ethiopia.

Food and Agricultural Organization (FAO). 2012. Coming to terms with terminology. *Rome, Italy: CFS*.

Food and Agricultural Organization (FAO). 2014. The role, impact and welfare of working (traction and transport) animals. Animal Production and Health Report. No. 5. Rome, Italy.

Food and Agricultural Organization (FAO) Forestry. 2014. Moringa oliefera: the miracle tree. InFO News, No. 20. http://forestry.fao.msgfocus.com/q/1bzr922cXdjGL8psnmp/wv

Färe, R., Grabowski, R., and Grosskopf, S. 1985. Technical efficiency of Philippine agriculture. *Applied Economics, 17*(2): 205-214.

Farrel, M. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. SeriesA (General), 120*(3).

Feleke, S. T., Kilmer, R. L., and Gladwin, C. H. 2003. *D*eterminants of food security in southern Ethiopia. *A selected Paper Presented at the 2003 American Agricultural Economics Association Meetings.* Montreal, Canada.

Foidl, N., Makkar, H., and Becker, K. 2001. The potential of Moringa oleifera for agricultural and industrial uses. *The miracle tree: The multiple attributes of Moringa*, 45-76.

Fredriksson, L., Bailey, A., Davidova, S., Gorton, M., and Traikova, D. 2017. The commercialisation of subsistence farms: Evidence from the new member states of the EU. *Land Use Policy*, 60: 37-47.

Frey, G. E., Fassola, H. E., Pachas, A. N., Colcombet, L., Lacorte, S. M., Renkow, M., Pérez, O., Cubbage, F. W. 2012. A within-farm efficiency comparison of silvopasture systems with conventional pasture and forestry in northeast Argentina. *Land Economics, 88*(4): 639-657.

Fuglie, L. J. 1999. The miracle tree: Moringa oleifera, natural nutrition for the tropics. Church World Service, Dakar. 68 pp.; revised in 2001 and published as The Miracle Tree: The Multiple Attributes of Moringa, 172.

Fuglie, L. J. 2005. The Moringa Tree: a local solution to malnutrition. *Church World Service in Senegal, 75*.

Gamo Zone Finance and Economic Development Department (GZFEDD). 2018. Annual Report. Arbaminch, Gamo Zone, Ethiopia.

Gebrekidan, B. H. 2012. Access to irrigation technology and technical efficiency: a comparison of households with and without access to irrigation technology, in 'Gorogutu district', Eastern Ethiopia. MA Thesis, University of Western Cape, South Africa.

Gebremedhin, B., and Jaleta, M. 2010. Commercialization of Smallholders: Is Market Participation Enough? *Contributed Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference*, September 19-23, 2010. Cape Town, South Africa.

Gebremedhin, B., Jaleta, M., and Hoekstra, D. 2009. Smallholders, institutional services, and commercial transformation in Ethiopia. *Agricultural economics*, 40: 773-787.

Gelaw, F., and Bezabih, E. 2004. Analysis of technical efficiency of wheat production: a study in Machakel Woreda, Ethiopia. An M. Sc Thesis Presented at the then Alemaya University, Ethiopia.

Geleta, B., Makonnen, E., Debella, A., and Tadele, A. 2016. In vivo antihypertensive and antihyperlipidemic effects of the crude extracts and fractions of Moringa stenopetala (Baker f.) Cufod. leaves in rats. *Frontiers in pharmacology, 7*: 97.

Getachew, B. and Temesgen, F. 2016. Analysis of Technical Efficiency of Coffee Production on Small Holder Farmers in Case of Sasiga and Limu Districts of East Wollega Zone. *Journal of Economics and Sustainable Development*, 7 (15).

Gibreel, T. M. 2013. Crop commercialization and adoption of gum-arabic agroforestry and their effect on farming system in western Sudan. *Agroforestry Systems, 87*(2): 311-318.

Gonzalez, Y. S., and van der Maden, E. 2015. *Opportunities for development of the Moringa sector in Bangladesh: Desk-based review of the Moringa value chains in developing countries and end-markets in Europe (No. 15-102).* Centre for Development Innovation, Wageningen UR, Netherlands.

Gopalan, C., Sastri, B. R., and Balasubramanian, S. 1989. *Nutritive value of Indian foods*: National Institute of Nutrition, *Revised Ed. Indian Council of Medical Research, Hyderabad, India.*

Govereh, J., Jayne, T., and Nyoro, J. 1999. Smallholder commercialization, interlinked markets and food crop productivity: Cross-country evidence in eastern and southern Africa. *Michigan State University, Department of Agricultural Economics and Department of Economics, 39*.

Greene, W. H. 2003. *Econometric Analysis.* Upper Saddle River, New Jersey, USA: Prentice-Hall.

Greene, W. H. 2008. Limited dependent variables—truncation, censoring and sample selection. *Econometric analysis*, 833-834.

Heckman, J., Ichimura, H., Smith, J., and Todd, P. 1998. *Characterizing selection bias using experimental data*. National bureau of economic research. Cambridge City in Massachusetts, USA.

Heckman, J. J. 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. In *Annals of economic and social measurement*, 5(4): 475-492

Heckman, J. J. 1979. Sample selection bias as a specification error. *Journal of the Econometric Society*, 153-161.

Hegde, S., & Hegde, V. 2013. An overview of Moringa production in Ethiopia. *International Journal of Science and Research, 4*: 826-829.

Humbo District Finance and Economic Development Office (HDFEDO). 2018. Physical and socio economic profile of Humbo district, Humbo, Wolaita, Ethiopia.

Hussain, A., and Thapa, G. B. 2012. Effect of Credit on Agricultural Commercialization and Household Food Security: Insights of Smallholders in Pakistan. *Paper presented at the Conference on Sustainable Business in Asia,* Bangkok, Thailand.

Israel, G. D. 1992. *Sampling the evidence of extension program impact*. Gainesville, FL: University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS.

Jahn, S. A. A. 1979. African plants used for the improvement of drinking water. *Curare, 2*(3): 183184.

Jahn, S. A. A. 1991. The traditional domestication of a multipurpose tree Moringa stenopetala (Bak. f.) Cuf. in the Ethiopian Rift Valley. *Ambio*: 244-247.

Jaleta, M., Gebremedhin, B., and Hoekstra, D. 2009. Smallholder commercialization: Processes, determinants and impact. Discussion Paper No. 18. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project, ILRI (International Livestock Research Institute), Nairobi, Kenya.

James, A., and Zikankuba, V. 2017. Moringa oleifera a potential tree for nutrition security in sub-Sahara Africa. *American Journal of Research Communication, 5*(4): 1-14.

Kalirajan, K. P., Obwona, M. B., and Zhao, S. 1996. A decomposition of total factor productivity growth: the case of Chinese agricultural growth before and after reforms. *American journal of agricultural economic*s, 78(2): 331-338.

Kebede, M. 2009. The gender perspective of household food security in Meskan district of the Gurage zone, Southern Ethiopia. *African Research Review, 3*(4).

Kelemu, K., Kindu, M., and Yetneberk, S. 2012. Establishing Value Chain Model to Commercialize Moringa Production. *Proceedings of The National Workshop on Forestry Research Technologies Dissemination*, 29-31 May 2012, EIAR, Addis Ababa, Ethiopia.

Kiros, A. 2018. Food and health security of moringa tree – the source of food and energy for the 21st century: the case Study of Ethiopia. International Journal of Current Research, 10 (07): 71600-71608.

Koopmans, T. C. 1951. An analysis of production as an efficient combination of activities. *Activity analysis of production and allocation*.

Kopp, R. J., and Smith, V. K. 1980. Frontier production function estimates for steam electric generation: A comparative analysis. *Southern Economic Journal*, 1049-1059. doi:10.2307/1057240. Accessed on November 10, 2019.

Kothari, C. R. 2004. *Research methodology: Methods and techniques*: New Age International.

Kumbhakar, S., and Lovell, C. 2000. Stochastic Frontier Analysis. Cambridge University Press, Cambridge. http://dx. doi. org/10.1017/cbo9781139174411. Accessed on July 22, 2018.

Kumbhakar, S. C., Ghosh, S., and McGuckin, J. T. 1991. A generalized production frontier approach for estimating determinants of inefficiency in US dairy farms. *Journal of Business and Economic Statistics, 9*(3): 279-286.

Kumssa DB, Joy EJM, Young SD, Odee DW, Ander EL, Magare C, et al. (2017) Challenges and opportunities for Moringa growers in southern Ethiopia and Kenya. PLoS ONE 12(11): e0187651. https://doi.org/10.1371/journal.pone.0187651

Kyaw, N. N., Ahn, S., and Lee, S. H. 2018. Analysis of the factors influencing market participation among smallholder rice farmers in magway region, central dry zone of Myanmar. *Sustainability, 10*(12): 4441.

Leakey, R. R., and Simons, A. J. 1998. The domestication and commercialization of indigenous trees in agroforestry for the alleviation of poverty. *Agroforestry Systems*, 38: 165–176.

Leavy, J., and Poulton, C. 2007. Commercialisations in agriculture. *Ethiopian Journal of Economics, 16*(1), 1-37.

Lele, U., Masters, W. A., Kinabo, J., Meenakshi, J., Ramaswami, B., Tagwireyi, J., and Goswami, S. 2016. Measuring food and nutrition security: An independent technical assessment and user's guide for existing indicators. *Food Security Information Network.*

Lerman, Z. 2004. Policies and institutions for commercialization of subsistence farms in transition countries. *Journal of Asian Economics, 15*(3): 461-479.

Leta, E. T. 2018. Determinants of commercialization of teff crop in Abay Chomen District, Horo Guduru wallaga zone, Oromia Regional State, Ethiopia. *Journal of Agricultural Extension and Rural Development*, 10(12): 251-259.

Li, M. 2013. Using the propensity score method to estimate causal effects: A review and practical guide. *Organizational Research Methods, 16*(2): 188-226.

Lindara, L., Johnsen, F., and Gunatilake, H. 2006. Technical efficiency in the spice based agroforestry sector in Matale district, Sri Lanka. *Agroforestry Systems*, *68*(3): 221-230. doi:10.1007/s10457-006-9012-y. Accessed on September 13, 2019.

Liu, Z., and Zhuang, J. 2000. Determinants of technical efficiency in post-collective Chinese agriculture: Evidence from farm-level data. *Journal of Comparative Economics*, *28*(3): 545-564.

Llewelyn, R. V., and Williams, J. R. 1996. Nonparametric analysis of technical, pure technical, and scale efficiencies for food crop production in East Java, Indonesia. *Agricultural economics, 15*(2): 113-126.

Luangmany, D. 2014. Analysis of the relationship between rubber tree plantation and forest resource dependency: A case study of smallholder rubber plantation in Northern Laos. Doctoral dissertation, Hiroshima University, Japan.

Maddala, G. 1977. *Econometrics. Economics Handbook Series*. New York, USA: McGraw-Hills Publication Company.

Maddala, G. S. 1986. *Limited-dependent and qualitative variables in econometrics.* Cambridge, England: Cambridge university press.

Manca, A., and Austin, P. C. 2008. Using propensity score methods to analyse individual patient level cost effectiveness data from observational studies. *The University of York: Health Economics and Data Group Working Paper, 8*, 20.

Mango, N., Makate, C., Hanyani-Mlambo, B., Siziba, S., and Lundy, M. 2015. A stochastic frontier analysis of technical efficiency in smallholder maize production in Zimbabwe: The post-fast-track land reform outlook. *Cogent Economics and Finance, 3*(1): 1117189.

Marchenko, Y. V., and Genton, M. G. 2012. A Heckman selection-t model. *Journal of the American Statistical Association, 107*(497): 304-317.

Mechri, A., Lys, P., and Cachia, F. 2017. Productivity and Efficiency Measurement in Agriculture: Literature Review and Gaps Analysis. Technical Report Series GO-19-2017. Rome, Italy: Food and Agriculture Organization of United Nations.

Meeusen, W., and van Den Broeck, J. 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. *International economic review*, 18(2): 435-444. doi:10.2307/2525757. Accessed on September 29, 2019.

Mekonnen, Y. 2003. The multi-purpose Moringa tree: Ethiopia. Institute of Pathobiology, Addis Ababa University, Addis Ababa, Ethiopia.

Melesse, A., Bulang, M., and Kluth, H. 2009. Evaluating the nutritive values and in vitro degradability characteristics of leaves, seeds and seedpods from Moringa stenopetala. *Journal of the Science of Food and Agriculture*, *89*(2): 281-287.

Melesse, A., Getye, Y., Berihun, K., and Banerjee, S. 2013. Effect of feeding graded levels of Moringa stenopetala leaf meal on growth performance, carcass traits and some serum biochemical parameters of Koekoek chickens. *Livestock Science, 157*(2-3): 498-505.

Melesse, A., Tiruneh, W., and Negesse, T. 2011. Effects of feeding Moringa stenopetala leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. *Tropical and Subtropical agroecosystems, 14*(2): 485-492.

Mercer, D.E., G.E. Frey, and F.W. Cubbage. 2014. Economics of Agroforestry. In: Kant S. and J.R.R. Alavalapati (eds.). Handbook of Forest Economics. Earthscan from Routledge. New York. Pp. 188-209.

Mirab Abaya District Finance and Economic Development Office (MADFED). 2018. Physical and socio economic profile of Mirab Abaya district, Birribir, Gamo, Ethiopia.

Ministry of Finance and Economic Development (MoFED). 2010. 'Growth and transformation plan (GTP) 2010/11 2014/15', draft. In: Ministry of Finance and Economic Development, Government of Ethiopia Addis Ababa, Ethiopia.

Mohammed, B., and Abdulquadri, A. 2012. Comparative analysis of gender involvement in agricultural production in Nigeria. *Journal of Development and Agricultural Economics, 4*(8): 240-244.

Mohammed, D., Bukar, U., Umar, J., Abdulsalam, B., and Dahiru, B. 2016. Analysis of food security among smallholder farming households in arid areas of Borno State, Nigeria. *Continental Journal of Agricultural Economics, Wilolud Journals, 2016,* 8 (1), pp.1-8. ff10.5707/cjae.2014.8.1.1.8ff. ffhal-01326657. Accessed on may 16, 2019.

Mukasa, Adamon N., Simpasa, Anthony M. and Salami, Adeleke O. 2017. Credit constraints and farm productivity: Micro-level evidence from smallholder farmers in Ethiopia, Working Paper Series N° 247, African Development Bank, Abidjan, Côte d'Ivoire.

Ndamitso, M., Mathew, J., Ajai, E. S. A., Etsuyankpa, B., and Salihu, A. 2014. Comparative Nutritional values of Selected Curcubit Seeds in Minna, Niger State, Nigeria. *IOSR Journal of Applied Chemistry (IOSR-JAC, 7*(7): 26-28.

Neff, D. L., Garcia, P., and Nelson, C. H. 1993. Technical efficiency: a comparison of production frontier methods. *Journal of Agricultural Economics, 44*(3): 479-489.

Ngango, J., and Kim, S. G. 2019. Assessment of Technical Efficiency and Its Potential Determinants among Small-Scale Coffee Farmers in Rwanda. *Agriculture, 9*(7): 161. doi:10.3390/agriculture9070161. Accessed on December 15, 2019

Ngema, P. Z., Sibanda, M., and Musemwa, L. 2018. Household food security status and its determinants in Maphumulo local municipality, South Africa. *Sustainability, 10*(9): 3307.

Otieno, D. J., Omiti, J., Nyanamba, T., and McCullough, E. 2009. Market participation by vegetable farmers in Kenya: A comparison of rural and peri-urban areas. *African Journal of Agricultural Research*, *4*(5), 451-460.

Parvin, L., and Rahman, M. W. 2009. Impact of irrigation on food security in Bangladesh for the past three decades. *Journal of Water resource and Protection, 3*: 216-225.

Pender, J. L., and Alemu, D. 2007. *Determinants of smallholder commercialization of food crops: Theory and evidence from Ethiopia*. IFPRI Discussion Paper 00745. International Food Policy Research Institute.

Quisumbing, A. R., Brown, L. R., Feldstein, H. S., Haddad, L., and Peña, C. 1996. Women: The key to food security. *Food and Nutrition Bulletin, 17*(1): 1-2.

Rabbi, F., Ahamad, R., Ali, S., Chandio, A. A., Ahmad, W., Ilyas, A., and Din, I. U. 2019. Determinants of commercialization and its impact on the welfare of smallholder rice farmers by using Heckman's two-stage approach. *Journal of the Saudi Society of Agricultural Sciences, 18*(2): 224-233.

Rabirou, K., Ayanwale, A. B., Idowu, E. O., and Williams, S. B. 2012. Effect of rural transportation system on agricultural productivity in Oyo State, Nigeria. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 113*(1): 13-19.

Reifschneider, D., and Stevenson, R. 1991. Systematic departures from the frontier: a framework for the analysis of firm inefficiency. *International economic review*, 32(3: 715- 723.

Rosenbaum, P. R., and Rubin, D. B. 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika, 70*(1): 41-55.

Rosenbaum, P. R., and Rubin, D. B. 1985. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician, 39*(1): 33-38.

Rubin, D. B. 1974. Estimating causal effects of treatments in randomized and nonrandomized studies. *Journal of educational Psychology, 66*(5): 688.

Saiyut, P., Bunyasiri, I., Sirisupluxana, P., and Mahathanaseth, I. 2018. The impact of age structure on technical efficiency in Thai agriculture. *Kasetsart Journal of Social Sciences*, xxx(2007): 1-7.

Schreyer, P., and Pilat, D. 2001. Measuring productivity. *OECD Economic Studies, 33*(2): 127-170.

Schwarz, D. 2001. Water clarification using Moringa oleifera *GATE-ESCHBORN-*, (1): 17-20

Sebatta, C., Mugisha, J., Katungi, E., Kashaaru, A., and Kyomugisha, H. 2014. Smallholder farmers' decision and level of participation in the potato market in Uganda. *Modern Economy, 5*(08): 895.

Seifu, E. 2015. Actual and potential applications of Moringa stenopetala, underutilized indigenous vegetable of Southern Ethiopia: a review. *International Journal of Agricultural and Food Research, 3*(4).

Sekhar, C., Venkatesan, N., and Vidhyavathi, A. 2018. Factors influencing moringa cultivation in Tamil Nadu–an economic analysis. *Horticult Int J, 2*(5): 223-230. doi:10.15406/hij.2018.02.00056. Accessed on April 13, 2019.

Sharma, K. R., Leung, P., and Zaleski, H. M. 1999. Technical, allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and nonparametric approaches. *Agricultural economics, 20*(1): 23-35.

Sianesi, B. 2004. An evaluation of the Swedish system of active labor market programs in the 1990s. *Review of Economics and Statistics, 86*(1): 133-155.

Siassi, F. 2015. Nutrition security versus food security. *Journal of Nutritional Sciences and Dietetics*, 1(3): 114-115.

Smith, J. 2000. A critical survey of empirical methods for evaluating active labor market policies, Research Report, No. 2000-6, The University of Western Ontario, Department of Economics, London (Ontario).

Smith, J. A., and Todd, P. E. 2005. Does matching overcome LaLonde's critique of nonexperimental estimators? *Journal of econometrics, 125*(1-2): 305-353.

Storck, H., and Doppler, W. 1991. *Farming systems and farm management practices of smallholders in the Hararghe Highlands*: Wissenschaftsverlag Vauk Kiel.

Strasberg, P. J., Jayne, T. S., Yamano, T., Nyoro, J. K., Karanja, D. D., and Strauss, J. 1999. *Effects of agricultural commercialization on food crop input use and productivity in Kenya*. MSU International Development Working Papers no.71. Michigan, USA.

Tamene, S., and Megento, T. L. 2017. The Effect of Rural Road Transport Infrastructure on Smallholder Farmers'agricultural Productivity in Horro Guduru Wollega Zone, Western Ethiopia. *AUC Geographica, 52*(1): 89-99.

Tauer, L. W. 1984. Productivity of farmers at various ages. *North Central Journal of Agricultural Economics*, 81-87.

Teferra, B., Legesse, B., Haji, J., and Kassie, G. T. 2018. Farm Level Efficiency of Crop Production in the Central Highlands of Ethiopia. *American Journal of Rural Development, 6*(2): 49-58.

Tekle, A., Belay, A., Kelem, K., Wodajo, B., and Tesfaye, Y. 2015. Nutritional Profile of Moringa stenopetala Species Samples Collected from Different Places in Ethiopia. *European Journal of Nutrition & Food Safety*, *5*(5): 1100-1101.

Thiam, A., Bravo-Ureta, B. E., and Rivas, T. E. 2001. Technical efficiency in developing country agriculture: a meta-analysis. *Agricultural economics, 25*(2-3): 235-243.

Thurber, M. D., and Fahey, J. W. 2009. Adoption of Moringa oleifera to combat under-nutrition viewed through the lens of the "Diffusion of Innovations" theory. *Ecology of food and nutrition, 48*(3): 212-225.

Tipi, T., Yildiz, N., Nargeleçekenler, M., and Çetin, B. 2009. Measuring the technical efficiency and determinants of efficiency of rice (Oryza sativa) farms in Marmara region, Turkey. *New Zealand Journal of Crop and Horticultural Science, 37*(2): 121-129.

Tiruneh, W. G., and Geta, E. 2016. Technical efficiency of smallholder wheat farmers: The case of Welmera district, Central Oromia, Ethiopia. *Journal of Development and Agricultural Economics, 8*(2): 39-51.

Tobin, J. 1958. Estimation of relationships for limited dependent variables. *Econometrica: Journal of the Econometric Society*: 24-36.

Tufa, A., Bekele, A., and Zemedu, L. 2014. Determinants of smallholder commercialization of horticultural crops in Gemechis District, West Hararghe Zone, Ethiopia. *African Journal of Agricultural Research, 9*(3): 310-319.

Tura, E. G., Goshub, D., Demise, T., and Kenead, T. 2016. Determinants of market participation and intensity of marketed surplus of teff producers in Bacho and Dawo districts of Oromia State, Ethiopia. *Journal of Agricultural Economics and Development,* 5(2): 020-032.

Venugopal, K. 1999. Food security vs. nutrition security. *Health for the Millions, 25*(2): 18-19.

Vhurumuku, E. 2014. Food security indicators. *Nutrition and food security response analysis in emergency contexts*, 1-2.

Von Braun, J. 1995. Agricultural commercialization: impacts on income and nutrition and implications for policy. *Food policy, 20*(3): 187-202.

Von Braun, J., De Haen, H., and Blanken, J. 1991. Commercialization of agriculture under population pressure: Effects on production, consumption, and nutrition in Rwanda (Vol. 85): International Food Policy Research Institute.

Von Braun, J., and Kennedy, E. T. 1994. Agricultural commercialization, economic development, and nutrition: Published for the International Food Policy Research Institute [by] Johns Hopkins University Press, USA.

Von Cramon-Taubadel, S., and Saldias, R. 2014. Access to credit and determinants of technical inefficiency of specialized smallholder farmers in Chile. *Chilean Journal of agricultural research, 74*(4): 413-420.

Weingärtner, L. 2009. The concept of food and nutrition security. *Achieving Food and Nutrition Security, 3*: 21-52.

Weir, S. 1999. The effects of education on farmer productivity in rural Ethiopia. The Centre for the Study of African Economies Working Paper Series, 91. University of Oxford, United Kingdom.

Weldegebriel, H. 2014. The Determinants of Technical Efficiency of Farmers in Teff, Maize and Sorghum Production: Empirical Evidence from Central Zone of Tigray Region. *Ethiopian Journal of Economic*s, XXIII(2).

Wolaita Zone Finance and Economic Development Department (WZFEDD) (2018). Annual Report. Wolaita Sodo, Wolaita Zone, Ethiopia.

World Agroforestry. 2014. Moringa tree gaining popularity in Ethiopia. Agroforestry news from around the world.

Wu, H., Ding, S., Pandey, S., and Tao, D. 2010. Assessing the Impact of Agricultural Technology Adoption on Farmers' Well-being Using Propensity-Score Matching Analysis in Rural China. *Asian Economic Journal, 24*(2): 141-160.

Yao, S., and Liu, Z. 1998. Determinants of grain production and technical efficiency in China. *Journal of Agricultural Economics, 49*(2): 171-184.

Yisehak, K., Solomon, M., and Tadelle, M. 2011. Contribution of Moringa (Moringa stenopetala, Bac.), a highly nutritious vegetable tree, for food security in South Ethiopia: a review. *Asian Journal of Applied Sciences, 4*(5): 477-488.

Zhao, Z. 2003. Data issues of using matching methods to estimate treatment effects: an illustration with the NSW data set. *China Center for Economic Research*, 1-7.

7. APPENDIX

Appendix A: STATA Outputs for PSM and Food and Nutrition Security Indicators

Table A. 1: Logistic Regression

Number of observation = 464

LR Chi2(20) = 71.21

Prob > Chi^2 = 0.0000

Pseudo R^2 = 0.1107

Moringa Production	Coef.	Std.err.	Z	p>/z/	[95% Conf. interval]	
Age	.0610996	.0472827	1.29	0.196	-.0315728	.1537721
Age square	-.000261	.0004281	-0.61	0.542	-.0011	.000578
Gender	-.1471203	.3891111	-0.38	0.705	-.909764	.6155234
Family size	.1704111	.0849416	2.01	0.045	.0039287	.3368935
Education	.038985	.0328443	1.19	0.235	-.0253886	.1033585
Livestock (TLU)	.2653687	.0745658	3.56	0.000	.1192223	.411515
Land size	.0053755	.1271597	0.04	0.966	-.2438529	.254604
Farm experience	-.0069152	.0175392	-0.39	0.693	-.0412914	.027461
Zone	.0668155	.4435754	0.15	0.880	-.8025764	.9362073
Distance to main road	-4.738022	2.221455	-2.13	0.033	-9.091994	-.3840491
Distance to market	.7014284	.2697175	2.60	0.009	.1727919	1.230065

Irrigation	.7184528	.4533398	1.58	0.113	-.1700769	1.606983
Credit Access	.4947632	.2335977	2.12	0.034	.0369203	.9526062
Participation in the non-farm activity	-.1265021	.2235594	-0.57	0.571	-.5646706	.3116664
Extension contact	.0273524	.0104839	2.61	0.009	.0068044	.0479004
Constant	-4.33777	1.316832	-3.29	0.001	-6.918714	-1.756826

Table A. 2: An estimated propensity score

	Percentiles	Smallest		
1%	.1692802	.1499156		
5%	.2252759	.1585916		
10%	.2597295	.1662398	Obs	457
25%	.3707558	.1668283	Sum of wgt.	457
50%	.4964933		Mean	.5057098
		Largest	Std. Dev.	.1848192
75%	.6383995	.9385782		
90%	.7655652	.9391524	Variance	.0341582
95%	.8419775	.9398137	Skewness	.2595284
99%	.9310183	.9878394	Kurtosis	2.403325

Table A. 3: Sensitivity and specificity

	True		
Classified	D	`D	Total
+	147	79	226
-	85	153	238
Total	232	232	464

Classified + if predicted pr(D) >= .5

True D defined as Moringa production decision ! =0

Sensitivity	Pr(+/ D)	63.36%
Specificity	Pr(-/ `D)	65.95%
Positive predictive value	Pr(D/ +)	65.04%
Negative predictive value	Pr(`D/ -)	64.29%
False + rate for true `D	Pr(+/ D)	34.05%
False + rate for true D	Pr(-/ `D)	36.64%
False + rate for classified +	Pr(`D/ +)	34.96%
False + rate for classified -	Pr(D/ -)	35.71%
Correctly classified		64.66%

Table A. 4: Common support

Psmatch2: Treatment assignment	Psmatch2: Common support		
	Off suppo	On suppor	Total
Untreated	7	225	232
Treated	7	225	232
Total	14	450	464

Table A. 5: Food groups and weights in FCS

S. N	Food Group	Food Items belonging to group	Food groups	Weight for FCS
1	Cereals and grain	Rice, .pasta, bread / cake and / or donuts, sorghum, millet, maize	1.Cereals and Tubers	2
2	Roots and tubers	Potato, yam, cassava, sweet potato, taro and / or other tubers		
3	Legumes/nut	Beans, cowpeas, peanuts, lentils, nut, soy, pigeon, pea and/or other nuts	2. Pulses	3
4	Orange vegetables (rich in Vitamin A)	Carrot, red pepper, pumpkin, orange sweet potatoes	3. Vegetables	1
5	Green leafy vegetables	Moringa, Spinach, broccoli, amaranth and/or other dark green leaves, cassava leaves		
6	Other vegetables	Onion, tomatoes, cucumber, radishes, green beans, peas, lettuce, etc.		
7	Orange fruits (Fruits rich in Vitamin A)	mango, papaya, apricot, peach	4. Fruit	1
8	Other Fruits	banana, apple, lemon, tangerine		
9	Meat	goat, beef, chicken, pork (meat in large quantities and not as a condiment)	5. Meat and fish	4
10	Liver, kidney, heart and /other organ meats			
11	Fish / Shellfish	fish, including canned tuna, escargot, and/or other seafood (fish in large quantities and not as a condiment)		
12	Eggs			
13	Milk and other dairy products	fresh milk/sour, yogurt, cheese, other dairy products (Exclude margarine/butter or small amounts of milk for tea/coffee)	6. Milk	4
14	Oil / fat / butter	vegetable oil, palm oil, shea butter, margarine, other fats / oil	7. Oil	0.5
15	Sugar, or sweet	sugar, honey, jam, cakes, candy, cookies, pastries, cakes and other sweet (sugary drinks)	8. Sugar	0.5
16	Condiments / Spices	Tea, coffee/cocoa, salt, garlic, spices, yeast/baking powder, Unwin, tomato/sauce, meat or fish as a condiment, condiments		

Source: Vhurumuku, 2014

Table A. 6: Calorie value of food items

Food item	Unit	Kcal
Moringa (Leaf)	Kg	920
Teff	Kg	3589
Wheat	Kg	3623
Sorghum	Kg	3805
Maize	Kg	3751
Barley	Kg	3723
Oat	Kg	3599
Peas	Kg	3553
Rice	Kg	3660
Lentils	Kg	3522
Irish potato	Kg	1037
Onion	Kg	713
Meat	Kg	1148
Milk	Lt	737
Egg	Each	61
Butter	Kg	7364
Edible oil	Lt	8964
Coffee	Kg	1103
Sugar	Kg	3850
Spaghetti/Macaroni	Kg	3550*

Source: Ethiopian Health and Nutrition Research Unit (EHNRU), 1998, * Dire Dawa Food Complex

Table A. 7: The various kinds of nutritional sources from Moringa

Chemical Analytical Parameters	Pods	Leaves	Leaf Powder
Moisture	86.90	75.00	7.50
Calories (100g)	25.00	92.00	205.00
Protein(g)	2.50	6.70	27.10
Fat	0.10	1.70	230
Carbohydrate(g)	3.70	13.40	38.20
Fiber(g)	4.80	0.90	19.20
Minerals(g)	2.00	2.30	-
Calcium(mg)	30.00	440.00	2003.00
Magnesium (mg)	24.00	24.00	363.00
Phosphorous(mg)	110.00	70.00	204.00
Potassium(mg)	259.00	259.00	1324.00
Copper (mg)	3.10	1.10	0.60
Iron (Fe)(mg)	5.30	7.00	23.20
Sulfur (mg)	137.00	137.00	870.00
Oxalic acid	10.00	101.00	0.00
Vitamin A-B carotene (mg)	0.10	6.30	16.30
Vitamin B- choline(mg)	423.00	423.00	-
Vitamin B1-thiamin(mg)	0.05	0.21	260
Vitamin B2 riboflavin(mg)	0.07	0.05	20.50
Vitamin B3-nicotinic acid(mg)	0.20	0.80	8.20
Vitamin C ascorbic acid(mg)	120.00	220.00	17.30
Vitamin E tocopherol acetate(mg)	-	-	113.00
Arginine (g/16g N)	3.60	6.00	0.00
Histidine(g/16g N)	1.10	2.10	0.00
Lysine (g/16g N)	1.50	4.30	0.00
Tryptophan (g/16g N)	0.80	1.90	0.00
Phenylalanine (g/16g N)	4.30	6.40	0.00
Methionine (g/16g N)	1.40	2.00	00
Threonine (g/16g N)	3.90	4.90	0.00
Leucine (g/16g N)	6.50	9.30	0.00
Isoleucine (g/16g N)	4.40	6.30	0.00
Valine (g/16g N)	5.40	7.10	0.00

Source: Yisehak *et al.*, 2011

Appendix B: Models and model testes implemented in commercialization analysis

Table A. 8: Multicollinearity test for continues variables used in the Heckman two-step model

Variable	VIF	1/VIF
Age	1.68	0.595435
Education	1.50	0.667433
Market distance	1.74	0.576319
Land size	1.45	0.690001
Extension contact frequency	1.45	0.6888275
Distance to road	1.29	0.77320
Family size (adult equivalent)	1.14	0.878004
Mean VIF	1.66	

Table A. 9: Correlations of the categorical variable used in the Heckman two-step model

	Gender	Cooperative membership	Irrigation access	Zone	Credit service
Gender	1.0000				
Cooperative member ship	-0.4598	1.0000			
Irrigation access	-0.0577	0.0978	1.0000		
Zone	-0.0905	0.2548	-0.8910	1.0000	
Credit service	-0.1577	0.6135	-0.2726	0.3569	1.0000

Table A. 10: Heteroscedasticity test of Heckman two-step model explanatory variables

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Ho: Constant variance

Variables: fitted values of commercialization

chi2(1) = 1.01

Prob > chi2 = 0.3138

Table A. 11: STATA outputs of Heckman two-step models

Market participation & commercialization, respectively	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Family size (a.e)	-.0033802	.0075517	-0.45	0.654	-.0181812	.0114208	
Education	0.53	.0030408	.001598	0.599	-.0043613	.0075583	
Gender	.0088207	.0412046	0.21	0.830	-.0719388	.0895802	
Land size	.0142813	.0139835	1.02	0.307	-.0131259	.0416885	
Zone	-.2209846	.0640095	-3.45	0.001	-.3464408	-.0955284	***
Irrigation	-.2768532	.0737464	-3.75	0.000	-.4213936	-.1323128	***
Age	.0009722	.0010089	0.96	0.335	-.0010052	.0029496	
Cooperative membership	.0030041	.0187697	0.16	0.873	-.0337839	.0397921	
Credit service	-.0272921	.0382391	-0.71	0.475	-.1022394	.0476552	
Market distance	-.2094802	.0662911	-3.16	0.002	-.3394083	-.0795521	***
Extension Contact frequency	.0006305	.0017232	0.37	0.714	-.002747	.004008	
Constant	1.174535	.0811552	14.47	0.000	1.015474	1.333596	***
Family size (a.e)	.0820644	.0630068	1.30	0.193	-.0414268	.2055555	
Distance to road	-3.898671	2.179314	-1.79	0.074	-8.170048	.3727046	*
Zone	-.5825432	.3921226	-1.49	0.137	-1.351089	.1860029	
Education	-.0157571	.0290644	-0.54	0.588	-.0727222	.041208	

Gender	.2254428	.3836137	0.59	0.557	-.5264261	.9773118	
Land size	.2090402	.1065402	1.96	0.050	.0002253	.4178551	*
Age	-.0100593	.0087046	-1.16	0.248	-.0271201	.0070015	
Irrigation	-.9536094	.3859747	-2.47	0.013	-1.710106	-.1971128	***
Credit service	-.6217304	.2109706	-2.95	0.003	-1.035225	-.2082356	***
Market distance	-.9895457	.2368435	-4.18	0.000	-1.45375	-.525341	***
Contact frequency	.0321258	.0095327	3.37	0.001	.0134421	.0508095	***
Constant	1.191401	.6778034	1.76	0.079	-.1370696	2.519871	
Lambda	.1242852	.0920426	1.75	0.077	-.056115	.3046854	*
Mean dependent var		19.733	SD dependent var			21.526	
Number of obs		232.000	Chi-square			22.505	

*** *p<0.01*, ** *p<0.05*, * *p<0.1*

Table A. 12: Cragg hurdle regression

Cragg hurdle regression Number of obs = 232

LR chi2(25) = 86.36

Prob > chi2 = 0.0000

Log likelihood = -657.95053 Pseudo R^2 = 0.0616

Commercialization	Coef.	Std.Err.	Z	P>z	95%Conf.	Interval]
Family size	0.813	1.152	0.710	0.480	-1.445	3.071
Education	-0.777	1.290	-0.600	0.547	-3.306	1.751
Gender						
Female	-2.372	5.948	-0.400	0.690	-14.031	9.287
1.coopretivemembership	-2.485	3.452	-0.720	0.472	-9.250	4.280
Land size	-1.336	1.977	-0.680	0.499	-5.210	2.538
1.irrigation	19.038	9.046	2.100	0.035	1.308	36.769
Age	-0.625	0.818	-0.760	0.445	-2.228	0.979
Credit service						
If received credit	0.237	3.721	0.060	0.949	-7.056	7.530
zone						
Wolaita	10.881	8.761	1.240	0.214	-6.291	28.053
Market distance	-9.152	5.355	-1.710	0.087	-19.646	1.343

Extension Contact	0.151	0.126	1.200	0.231	-0.096	0.397
_cons	42.293	22.985	1.840	0.066	-2.758	87.343
Selection_ll						
Family size	0.135	0.072	1.880	0.060	-0.006	0.276
Education	-0.094	0.081	-1.150	0.249	-0.253	0.066
Gender						
Female	0.276	0.395	0.700	0.485	-0.498	1.050
Land size	0.123	0.111	1.110	0.265	-0.094	0.340
Age	-0.059	0.045	-1.310	0.190	-0.148	0.029
zone						
Wolaita	0.334	0.231	1.450	0.148	-0.118	0.786
Distance to road	-3.990	2.268	-1.760	0.079	-8.436	0.456
Credit service						
if received credit	-0.613	0.218	-2.820	0.005	-1.039	-0.187
Market distance	-0.678	0.207	-3.280	0.001	-1.083	-0.272
Extension contact	0.033	0.010	3.380	0.001	0.014	0.052
constant	1.241	1.194	1.040	0.299	-1.100	3.582
Ln sigma						
_cons	2.705	0.072	37.790	0.000	2.565	2.846
/sigma	14.960	1.071			13.002	17.214

Table A. 13: Tobit regression

Commercialization	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Family size	4.577	1.866	2.45	0.015	0.899	8.255	**
Distance to road	-77.605	51.952	-1.49	0.137	-180.002	24.792	
Zone	-12.619	10.480	-1.20	0.230	-33.275	8.037	
Education	-0.537	0.726	-0.74	0.460	-1.969	0.894	
Gender	3.326	9.076	0.37	0.714	-14.563	21.215	
Land size	3.678	2.695	1.37	0.174	-1.634	8.990	
Age	-1.119	1.149	-0.97	0.331	-3.383	1.145	
Irrigation	-13.996	10.383	-1.35	0.179	-34.461	6.469	
Credit service	-14.477	5.273	-2.75	0.007	-24.869	-4.084	***
Market distance	-27.314	6.046	-4.52	0.000	-39.230	-15.398	***
Extension contact	0.802	0.205	3.91	0.000	0.397	1.206	***
Constant	49.260	31.754	1.55	0.122	-13.327	111.848	

Mean dependent var	19.733	SD dependent var	21.526
Pseudo r-squared	0.043	Number of obs	232.000
Chi-square	61.937	Prob > chi2	0.000
Akaike crit. (AIC)	1420.300	Bayesian crit. (BIC)	1482.341

**** p<0.01, ** p<0.05, * p<0.1*

Appendix C: SFP Model Tests and Estimations of Technical Efficiency

Table A. 14: Multicollinearity test for continues variables used in the Tobit model

Variance inflation factor

	VIF	1/VIF
Education	1.367	0.732
Age	1.358	0.736
Distance to road	1.011	0.989
Mean VIF	1.245	

Table A. 15: Correlations of Categorical variables used in the Tobit model

Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)
(1) Gender	1.000				
(2) Irrigation	0.066	1.000			
(3) Credit service	0.051	-0.306	1.000		
(4) Participation in non-farm activities	0.077	-0.442	0.461	1.000	
(5) Cooperative membership	-0.129	-0.242	0.210	0.269	1.000

Table A. 16: Multicollinearity test of SFP model input variables

Variance inflation factor

	VIF	1/VIF
Ln land	1.002	0.998
Ln labor	1.001	0.999
Ln fertilizer	1.001	0.999
Mean VIF	1.001	

Table A. 17: Heteroscedasticity test of Tobit model sources of inefficiency variables

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Ho: Constant variance

Variables: fitted values of technical inefficiency

chi2(1) = 0.02

Prob > chi2 = 0.8831

Table A. 18: Omitted variable test of Tobit model sources of inefficiency variables

Ramsey RESET test using powers of the independent variables

Ho: model has no omitted variables

F(9, 99) = 0.76

Prob > F = 0.6517

Table A. 19: Heteroscedasticity test of SFP model input variables

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Ho: Constant variance

Variables: fitted values of ln production

chi2 (1) = 2.09

Prob > chi2 = 0.1480

Table A. 20: OLS output

Generalized linear models

Generalized linear models		No. of obs =	117
Optimization : ML		Residual df =	113
		Scale parameter =	.3930624
Deviance =	44.4160502	(1/df) Deviance =	.3930624
Pearson =	44.4160502	(1/df) Pearson =	.3930624
Variance function: V(u) = 1		[Gaussian]	
Link function : g(u) = u		[Identity]	
		AIC =	1.93768
		Log likelihood = -110.3542856	BIC = -493.7096

Ln total Moringa production	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln land	0.014	0.062	0.22	0.824	-0.107	0.135	
Ln fertilizer	0.127	0.122	1.04	0.299	-0.112	0.365	
Ln labor	1.203	0.123	9.81	0.000	0.962	1.443	***
Constant	-0.631	0.462	-1.37	0.172	-1.537	0.274	

Mean dependent var	3.783	SD dependent var	0.840
Number of obs	117.000	Chi-square	96.358
Prob > chi2	0.000	Akaike crit. (AIC)	226.072

*** *p<0.01*, ** *p<0.05*, * *p<0.1*

Table A. 21: SFP model outputs

Stoc. frontier normal/tnormal model Number of obs = 117

Wald chi2(3) = 135.35

Prob > chi2 = 0.0000

Log likelihood = -107.8506

Ln total Moringa production	Coef.	Std.Err.	Z	P>z	[95%Conf.	Interval]
Frontier						
Ln land	0.017	0.063	0.280	0.781	-0.106	0.141
Ln fertilizer	0.130	0.117	1.110	0.269	-0.100	0.360
Ln labor	1.232	0.106	11.610	0.000	1.024	1.440
_cons	0.033	0.480	0.070	0.946	-0.907	0.973
Mu						

_cons	0.545	0.479	1.140	0.255	-0.394	1.484
Usigma						
_cons	-0.848	0.508	-1.670	0.095	-1.845	0.148
Vsigma						
_cons	-2.046	0.539	-3.800	0.000	-3.103	-0.989
sigma_u	0.654	0.166	3.930	0.000	0.398	1.077
sigma_v	0.360	0.097	3.710	0.000	0.212	0.610
lambda	1.820	0.214	8.520	0.000	1.401	2.239

Table A. 22: SFP model output (one-stage)

Stoc. Frontier normal/tnormal model Number of obs = 117

Wald chi2 (3) = 138.10

Prob > chi2 = 0.0000

Log likelihood = -95.7785

Ln total production	Coef.	Std.Err.	Z	P>z	[95%Conf.	Interval]
Frontier						
Ln labor	1.204	0.102	11.750	0.000	1.003	1.405
Ln fertilizer	0.005	0.022	0.240	0.811	-0.037	0.048
Ln land	0.007	0.060	0.130	0.900	-0.109	0.124
Constant	0.267	0.463	0.580	0.564	-0.640	1.174
Mu						
Age	0.005	0.008	0.630	0.528	-0.010	0.020
Gender	-0.611	0.484	-1.260	0.207	-1.560	0.339
Education	0.024	0.022	1.090	0.276	-0.019	0.068
Distance to road	2.455	1.421	1.730	0.084	-0.330	5.240
Credit service	-0.309	0.167	-1.850	0.065	-0.637	0.019
Cooperative membership	-0.194	0.166	-1.170	0.242	-0.520	0.131
Off/Non-Participation	0.756	0.265	2.850	0.004	0.236	1.276

Irrigation access	0.556	0.214	2.600	0.009	0.136	0.975
_cons	-0.176	0.737	-0.240	0.812	-1.620	1.269
Usigma						
_cons	-1.333	0.458	-2.910	0.004	-2.230	-0.436
Vsigma						
_cons	-2.148	0.487	-4.410	0.000	-3.103	-1.193
sigma_u	0.513	0.118	4.370	0.000	0.328	0.804
sigma_v	0.342	0.083	4.100	0.000	0.212	0.551
lambda	1.503	0.180	8.350	0.000	1.150	1.856

Table A. 23: Trans log and Cobb Douglas SFP outputs

Stochastic frontier normal/hnormal model Number of obs = 76

Wald chi2 (5) = 128.63

Prob > chi2 = 0.0000

Log likelihood = -64.3752

Ln total production	Coef.	Std.Err.	Z	P>z	[95%Conf.	Interval]
Frontier						
Ln land	-0.101	0.700	-0.140	0.886	-1.474	1.272
Ln fertilizer application		0.000		(omitted)		
Ln labor	-18.818	6.781	-2.780	0.006	-32.109	-5.528
Ln land _ln fertilizer application		-0.000		(omitted)		
Ln land ln labor	-0.040	1.089	-0.040	0.971	-2.174	2.095
Ln fertilizer application ln labor		-0.000		(omitted)		
Ln land_2	-0.211	0.165	-1.280	0.202	-0.535	0.113
Ln fertilizer aplication_2		0.000		(omitted)		
ln labor_2	18.726	5.544	3.380	0.001	7.860	29.593
_cons	13.189	4.127	3.200	0.001	5.100	21.278
Usigma						
_cons	-0.228	0.272	-0.840	0.401	-0.761	0.305
Vsigma						

_cons	-2.763	0.604	-4.580	0.000	-3.946	-1.580
sigma_u	0.892	0.121	7.350	0.000	0.683	1.165
sigma_v	0.251	0.076	3.310	0.001	0.139	0.454
lambda	3.551	0.177	20.060	0.000	3.204	3.898

Table A. 24: Tobit model inefficiency determinants outputs
Tobit regression

Inefficiency	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Age	0.001	0.002	0.58	0.563	-0.002	0.004	
Gender	-0.090	0.080	-1.13	0.260	-0.248	0.068	
Education	0.005	0.005	1.04	0.299	-0.004	0.014	
Distance to road	0.568	0.319	1.78	0.078	-0.065	1.200	*
Credit service	-0.071	0.036	-1.99	0.049	-0.141	0.000	**
Cooperative membership	-0.050	0.036	-1.39	0.167	-0.122	0.021	
Off/Non-farm	0.154	0.040	3.84	0.000	0.074	0.233	***
Irrigation	0.119	0.037	3.22	0.002	0.045	0.192	***
Constant	0.335	0.096	3.51	0.001	0.146	0.525	***

Mean dependent var	0.512	SD dependent var	0.186
Pseudo r-squared	-0.366	Number of obs	117.000
Chi-square	22.927	Prob > chi2	0.003
Akaike crit. (AIC)	-65.555	Bayesian crit. (BIC)	-37.933

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix D: Conversion Factors used

Table A. 25: Conversion factors to estimate Tropical Livestock Unit equivalents

Animal Category	TLU	Animal Category	TLU
Calf	0.25	Donkey (young)	0.35
Weaned Calf	0.34	Camel	1.25
Heifer	0.75	Sheep and Goat (adult)	0.13
Cow and Ox	1.00	Sheep and Goat (young)	0.06
Horse	1.10	Chicken	0.013
Donkey (adult)	0.70		

Source: Storck and Doppler, 1991

Table A. 26: Conversion factors to estimate workforce in adult male equivalents

Age group in years	Conversion factor		The workforce in the adult male equivalent
	Male	Female	
0 to 8	0	0	
9 to 15	0.5	0.5	
16 to 55	1	0.8	
56 and above	0.6	0.4	

Source: Storck and Doppler, 1991

Appendix E: Cover Pages of Published Journals

Appendix Figure 1: Cover page of food and nutrition security impacts of Moringa: Evidence from Southern Ethiopia Manuscript

Tafesse et al., Cogent Food & Agriculture (2020), 6: 1733330
https://doi.org/10.1080/23311932.2020.1733330

cogent food & agriculture

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Food and nutrition security impacts of Moringa: Evidence from Southern Ethiopia

Alula Tafesse[1*], Degye Goshu[2], Fekadu Gelaw[3] and Alelign Ademe[4]

Received: 12 December 2019
Accepted: 18 January 2020

*Corresponding author: Alula Tafesse, Department of Agricultural Economics, WolaitaSodo University, WolaitaSodo, Ethiopia
E-mail: alulatafesse@yahoo.com

Reviewing editor:
Fatih Yildiz, Food Engineering and Biotechnology, Middle East Technical University, Turkey

Additional information is available at the end of the article

Abstract: The contributions of Moringa to the livelihoods of smallholder farmers in developing countries were massive. Its production has to be more than increased to maintain its potential role in-curving food and nutrition insecurity sufferings in these areas. However, empirical researches evaluating its impact at smallholder farmer level were missing to confirm. The current research aims to add to fill the missing literature gaps through a survey study on selected 464 producer and non-producer smallholder farmers from Wolaita and Gamo Gofa zones, southern Ethiopia. The Propensity to Score Matching (PSM) model was used to estimate the impact of Moringa production on household food and nutrition security. The validity of the model was checked and found binding to observe the causal effect of dependent and outcome variables in controlling selection bias. The finding indicated positive and significant differences among Moringa producer and non-producer smallholder farmers in selected food and nutrition security proxy variables, weekly calorie intake and food consumption score (FCS). Farmers producing Moringa were found more food and nutritionally secure than non-producers. It requires policies and development actions to perform on ways to advance the production and intensification of Moringa production in dry parts of the country.

Subjects: Agriculture and Food; Rural Development; Microeconomics

Alula Tafesse

ABOUT THE AUTHORS

Alula Tafesse is a Ph.D. scholar at Haramaya University, School of Agricultural Economics and Agribusiness. He is an Assistant Professor at the Department of Agricultural Economics, College of Agriculture, Wolaita Sodo University. His research interests include themes on natural resource and environmental economics, food and nutrition security, agricultural value chain analysis, impact analysis, agricultural productivity, and marketing.

Degye Goshu (Ph.D.) is an Associate Professor at the Department of Economics, Kotebe Metropolitan University.

Fekadu Gelaw (Ph.D.) is Assistant Professor of Agricultural Economics, Institutional and Behavioral Economics, School of Agricultural Economics and Agribusiness, College of Agriculture and Environmental Sciences, Haramaya University.

Alelign Ademe (Ph.D.) is Assistant Professor, Department of Agricultural Economics and Management, University of Swaziland.

PUBLIC INTEREST STATEMENT

The contributions of the Moringa tree to the Ethiopian economy remain largely untapped and underutilized. Every part of Moringa (such as roots, fruits, leaves, or seeds) is beneficial. It has socio-economic, medicinal, industrial and environmental values. In recent times Moringa has got a glimpse of attention from governmental and non-governmental sides. However, Moringa still needs massive consideration for its nutritional or economic values. It is highly required to invest in mechanisms to strengthen production and marketing on the benefits of indigenous tree species. Increased utilization of Moringa thus can contribute to food and nutrition security, health, livelihood, environment, and industries. This study confirmed the food and nutrition impact of Moringa. It informs policymakers to act on the possible means and interventions which can be employed to improve production and commercialization of the indigenous Moringa tree.

cogent oa

Page 1 of 16

Appendix Figure 2: Cover Page of commercialization of Moringa: Evidence from Southern Ethiopia Manuscript

Tafesse et al., Cogent Economics & Finance (2020), 8: 1783909
https://doi.org/10.1080/23322039.2020.1783909

cogent economics & finance

GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Commercialization of Moringa: Evidence from Southern Ethiopia

Alula Tafesse[1*], Degiye Goshu[2], Fekadu Gelaw[3] and Alelign Ademe[4]

Received: 13 January 2020
Accepted: 14 June 2020

*Corresponding author: Alula Tafesse, Department of Agricultural Economics, Wolaita Sodo University, Wolaita Sodo, Ethiopia
E-mail: alula.tafesse@yahoo.com

Reviewing editor:
Goodness Aye, Agricultural Economics, University of Agriculture, makurdi Benue State, Nigeria

Additional information is available at the end of the article

Abstract: The policies in Ethiopia to advance the commercial orientation of farmers need identification of challenges at farmer level and exhaustive actions to shift the farm sector. Further activities have to be done to change the country's present subsistence-oriented farm production system of different crops. The research has aimed at investigating factors determining the Moringa commercialization in southern Ethiopia. The cross-sectional survey method was used to identify 232 Moringa producing smallholder farmers from Wolaita and Gamo zones. Heckman's two-step sample selection model is adopted to find factors determining the probability of Moringa market participation and the intensity of participation. The study result revealed that the likelihood of the Moringa output market participation is influenced by the variables such as location, access to irrigation, and distance to market. On the other hand family size, per capita income, frequency of extension contact, access to irrigation, access to credit, and distance to market are among significantly influencing factors of the extent of Moringa marketing. Therefore, policy agents should mainly consider these variables on any development activities to improve Moringa marketing. Furthermore, it requires improving extension services and offering immediate practical training on techniques of market-oriented and value-added Moringa production and marketing systems.

Alula Tafesse

ABOUT THE AUTHORS

Alula Tafesse is a Ph.D. candidate at Haramaya University, School of Agricultural Economics and Agribusiness. He is an Assistant Professor at the Department of Agricultural Economics, College of Agriculture, Wolaita Sodo University. His research interests include themes on natural resource and environmental economics, food and nutrition security, agricultural value chain analysis, impact analysis, agricultural productivity, and marketing.

Degiye Goshu (Ph.D.) is an Associate Professor at the Department of Economics, Kotebe Metropolitan University.

Fekadu Gelaw (Ph.D.) is Assistant Professor of Agricultural Economics, Institutional and Behavioral Economics, School of Agricultural Economics and Agribusiness, College of Agriculture and Environmental Sciences, Haramaya University.

Alelign Ademe (Ph.D.) is Assistant Professor, Department of Agricultural Economics and Management, University of Swaziland.

PUBLIC INTEREST STATEMENT

It is known that agriculture is the mainstay for the Ethiopian economy. However, the sector is embedded with several constraints. It is perceived that advancing the commercial orientation of smallholder farmers will have higher implications in improving the country's agricultural sector. The process should consider untapped, highly valuable, and indigenous tree potentials including Moringa. The recent activities to better utilize Moringa from different sides should be appreciated. However, it still requires more attention for the ample of benefits could be obtained from it. The research has observed the determinants of Moringa marketing in southern Ethiopia. It informs policymakers to act on the possible means and interventions which can be employed to improve marketing of the Moringa tree.

Page 1 of 15

Appendix Figure 3: Cover page of Technical Efficiency of Moringa production: A case Study in Wolaita and Gamo Zones, Southern Ethiopia Manuscript

Sustainable Agriculture Research; Vol. 9, No. 2; 2020
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

Technical Efficiency of Moringa Production: A case Study in Wolaita and Gamo Zones, Southern Ethiopia

Alula Tafesse[1], Degye Goshu[2], Fekadu Gelaw[3] & Alelign Ademe[4]

[1]Department of Agricultural Economics, Wolaita Sodo University, Ethiopia

[2]Department of Economics, Kotebe Metropolitan University, Ethiopia

[3]Department of Agricultural Economics, Haramaya University, Ethiopia

[4]Department of Agricultural Economics and Management, University of Swaziland, Swaziland

Correspondence: Alula Tafesse, Department of Agricultural Economics, Wolaita Sodo University, Ethiopia. E-mail: alula.tafesse@yahoo.com

Received: January 3, 2020 Accepted: January 23, 2020 Online Published: February 8, 2020

doi:10.5539/sar.v9n2p30 URL: https://doi.org/10.5539/sar.v9n2p30

Abstract

Moringa has been becoming among vastly growing and trading commodities in different parts of Ethiopia for its multiple benefits. However, empirical researches analyzing its productivity at smallholder farmer level were missing. This study aimed to fill the existing gap with a cross-sectional survey study on sampled 117 Moringa producer farmers from southern Ethiopia. The Stochastic Frontier Model was used to estimate the level and factors determining the technical efficiency of Moringa production. The collected data fitted Cobb-Douglas production function with inputs, labor and the numbers of trees positively and significantly determined the output of Moringa. An estimated level of efficiency shows farmers have the possibility to increase Moringa output by 47.81% with existing inputs and technology. The land, off-farm activities, access to road, credit, and irrigation were significant factors affecting the technical efficiency of Moringa. It requires policies and development actions to perform on mechanisms to advance the production of Moringa. Hence, any development direction to enhance Moringa production should consider households with limited access to land and irrigation. Furthermore, the development of road infrastructure is required to increase agricultural productivity. In sum, modern credit institutions, as well as facilities, found essential to improve the livelihood of Moringa producers in the area.

Keywords: technical efficiency, stochastic frontier model, Moringa, Ethiopia

Appendix F: Survey Questionnaire

This is a questionnaire for Ph.D. dissertation research on Technical Efficiency, Commercialization, and Food and Nutrition Security Impacts of Moringa Production in the SNNPR state of Ethiopia.

Date ---------------- Starting time ------------- End Time.........

Name of Enumerator: ....

Phone number...

1. District: ....
2. Name of the Keble ------------------------

I am Alula Tafesse, a Ph.D. candidate at Haramaya University, College of Agriculture and Environmental Science. I am researching the Technical efficiency, Commercialization, and Food Security Impacts of Moringa in your area so that I could get some information that will help me in my dissertation. This schedule is part of a study to investigate the contribution and challenges in Moringa production of communities and Moringa producing individuals. Hence, your opinion and perception will help me in this regard. Your answer was not be related to your name and it is confidential.

Thank you for your co-operation.

Identification

1. Household identification number: ....
2. Date of Interview: ..../..................... /2011
3. Zone Name: ....
4. Woreda Name: ....
5. *Kebele* Name: ....
6. Name of the head of the household..............................Gender..........Male........Female
7. Phone number of household head....................................
8. Age of household head.........................years
9. Marital status of household head..........Married........Single......Widowed......Divorced
10. Education level of household head (completed years of formal schooling)............. years or............ Illiterate....................Adult education
11. Farming experience: ....years

I. Household Roster

S. N	**Name**	**Sex** **0= male** **1= female**	**Age**	**Relation to hh head (code 1)**	**Marital status (code 2)**	**Can read/ write (code 3)**	**Education level (code 4)**	**If age >6 years of occupation during the last 12 months (code 5) ID**		**Does this member have any chronic illness (e.g. chronic fever, heart disease, etc?) or disabilities (e.g. blindness, a family member lost, etc) (code 6)**	**Please estimate expenditures on clothing and footwear (per person!) during the last 12 months in ETB**
								Main	**Secondary**		

Code 1: Relation to hh head	***Code 2: Marital status***	***Code 3: Can read/ write***	***Code 4: Education***	***Code 5: Occupation***	***Code 6: Illness / disability***
Household head..... ….1 Wife/ husband..............2 Son or daughter............3 Grandparent................ 4 Grandchild........……. 5 Brother or sister..……. 6 Other relative.......... ....7 Other non-relative....... 8	Single... 1 Married with wife/ husband permanently present in the household……..................... 2 Married with the wife/ husband migrant………………………………….. 3 Widow/widower.................................... 4 Divorced/separated……………….. 5	Cannot read or write..... 0 Can read only.......... 1 Can read and write......... 2	Not yet in school.......... 0 Primary school (1-4)..... 1 Primary school (5-7)..... 2 O-level sec. certificate.3 A-level sec. certificate 4 Diploma........................ 5 Advanced diploma......... 6 1st ° - Bachelor............. 6 Masters.......................... 7 PhD.................................8 Never attended school...9	Too young .... 0 Self-employed in agriculture................. 1 Self-employed in the nonfarm enterprise. ..2 Student/pupil... 3 Government employee............................ 4 Nongovernment employee..................... 5 Casual labor .... 6 Daily agricultural labor.......................... 7 Daily nonagricultural labor.....................8 Domestic worker (household work)..…9 Unemployed Looking for a job.................................. 10 Disable to work..................................... 11 Retired... 12	Chronic illnesses. ….1 Disability… 2 None…... 3

II. Household Income and Expenditure

12. What were the sources of income for your family?

No.	Sale / barter of:	**Tick**	**Cash income** (in last 12 months (ETB))
1	Crops		
2	Processed food		
3	Animals		
4	Eggs		
5	Fish		
6	Wild; fruits, coffee, mushrooms/medical plants		
7	Firewood		
8	Bamboo		
9	Sugarcane		
10	Mats/other crafts		
11	Poles		
12	Timber		
13	Charcoal		
14	Clay/bricks/pottery		
15	Honey		
16	Beeswax		
17	Animal products (milk, cheese, butter, etc…)		
18	Others		
19	**Other income;**		
20	Salaried employment		
21	Business/shop/retail		
22	Casual job (labor on anther's farm, specify________)		
23	Remittances		
24	Government support		
25	Other___________		

13. What are your main sources of income (scale their importantnce1-5)? 1= very good, 2=good, 3=fair, 4=least and 5= not that much

Crop sale.......... Livestock sale........... Off-farm income........ Other/s specify....................

14. How much is your average expenditure per year/month? ---------------in ETB

III. Housing and Asset Based Indicators

15. What type of house do you live in? (Tick all that apply)

Brick walls		Wooden window or doors	
Thatch/grass roof		Cement	
Iron Roof			

16. Is the place you live at owned by a member of your household? ....Yes.....................No

17. If you sell the **house** you live in **and** the **land** that you own, how much do you think would you receive... …………….ETB

18. Please estimate the amount of money you could receive as rent if you lent your **house and** the **land** plot to someone............................. ETB per month/ year

19. What is the source of energy for this household? ....Fuelwood................Charcoal........... Electric city.................Gas................................Other (specify)

20. How much did your household pay in the past 12 months for the following goods and services in ETB? ....Electricity..................Water................... Telephones/ mobile phones...................Fuelwood.....................Charcoal....................................... other energy sources

Household assets owned	Number owned (#)	Price on the local market (ETB per piece)
General		
Machinery (e.g. motor tiller)		
Car /Motorbike		
Bicycle		
Mobile phone		
TV/Cassette/CD/VHS/VCD/DVD/radio		
Wooden cart/wheelbarrow		
Watch		
Stove for cooking (gas/electric)		
Others................Worth more than appro. 50 USD purchasing price		
Animals		
Cow (dry)		
Cow (milky)		
Ox		
Bull		
Heifer		
Calves		
Donkey		

Horse		
Mule		
Goat		
Sheep		
Chicken		
Beehives		
Honey sold in kg		
Other(specify)		

IV. Farming System

21. Is the land you live at owned by a member of your household? ....Yes..................No

22. How you got this land? ....Inheritance...............Purchased........................Other

23. Do you have a land certificate? ....Yes.............. No

24. How big is the total land area you own? [...........ha/.............m^2/ or.................]

25. Land owned (through sharecropping and hiring arrangement) [............ha/........m^2/ or...........]

No	Land use particulars	Area cultivated in 2010/11 E.C cropping season (in ha)
1	Total land owned	
2	Leased-in land (in ETB)	
3	Shared-in land (in-kind)	
4	Leased-out land (in ETB)	
5	Shared-out land (in-kind)	
6	Land allocated for grazing	
7	Land covered by Eucalyptus	
8	Others (specify)	

25. How many land plots do you have? ....A number of fields.............Grazing land...........Cultivated land.............. Fallow land.............................Other/s specify

26. What types of crops do you grow in your land plots?

(Food Crops)	(Fruits and Vegetables)	(Commercial Crops)	(Others)
_____ Maize	_____ Mango	______ Sugarcane	
_____ Sorghum	_____ Banana	______ Coffee	
_____ Beans	_____ Papaya	______ Cotton	
_____ Pumpkin	_____Avocado	______ Tobacco	
_____ Cassava	_____ Orange		
_____Yam	_____ Cabbage		
_____Taro	_____ Tomatoes		
_____ Sweet Potato	_____Onion		

____Pigeon Pea ____Chicken pea ____ Enset	____ Pepper ____ Lettuce _____Moringa		

27. How large and how do you use these plots

Fields	Area/size	Which crops do you grow or which animals do you keep on this plot at the moment?			
		First(main) use		Second(additional) use	
		(code 1)	Share	(Code 1)	Share
1					
2					
3					
4					
5					
6					

Code 1: Moringa.............1 Maize.............. …2 Barley................. 3 Cassava.......... …..4 Enset......... ……...5 Beans.............. ….6 Vegetables........... 7	**Cotton................ 8** Groundnuts.... …..9 Sunflower .... 10 Fruit............... …11 **Sugarcane……..12** **Coffee .... ….13** **Chat .... …14**	Livestock.......................... 15 Forestry .... 16 Uncultivated land/ fallow....... 17 House .... 18 Worship/ grave .... 19 Fruit…………………………20 Other (specify)................ 21

N.B Bold ones are commercial crops

28. Land resource allocation and crop production in 2010 E.C production year

No.	Land use activities	Area cultivated in 2009/10 E.C (ha)	Area cultivated in main season of 2010/11 E.C (ha)	Total quantity produced in 2010/11E.C (kg)	Quantity sold in 2010/11 E.C (kg)	Average selling price/kg (ETB)
1	Moringa					
2	Maize					
3	Teff					
4	Wheat					
5	Barley					
6	Inset					
7	Sorghum					

8	Chickpea					
9	Faba bean					
10	Lentil					
11	Nug					
12	Grass pea					
13	Vegetables					
14	Others (specify)........					

29. Who and how many people are working on your primary agricultural land?

Activities	The time required (Months, weeks, days, hours, etc.)	Family members (≥15 years)		Children (≤14 years)		Neighbors/ friends		Employees (hired labor)	
		Sex		Sex		Sex		Sex	
		M	W	M	F	M	W	M	W
Land preparation									
Seeding/planting									
Weeding									
Pest control									
Harvesting									
Post-harvest activities									

30. If you hired labor, what would be the cost for one acre of work (wage + food)................... ETB/Acre

31. Production and utilization

Farm enterprise [source]	How many acres do you have/ did you have in the past 12 months? (acres, pieces, etc.	Quantity harvested in the past 12 months? (e.g. kg, bails, bags, sacks, etc	How do you use your harvest? (Share, part, bags, etc.)			Price on the local market (ETB/ kg, bag, etc)
			Home consumption	Sold		
				Processed	Raw	

Farm inputs in the year (tick all that apply)	Tick		Cost(ETB)				
Seeds							
Fertilizer	Urea	DAP	NPK	Others			
Manure							
Irrigation							
Transport							
Pesticides/herbicides							
Machinery/hired tools							
Hired labor							
Other______________							

32. Who and how many people are working on your Secondary agricultural land?

Activities	The time required (Months, weeks, days, hours, etc.)	Family members (≥15 years)		Children (≤14 years)		Neighbors/ friends		Employees (hired labor)	
		Sex		Sex		Sex		Sex	
		M	W	M	W	M	W	M	W
Land preparation									
Seeding/planting									
Weeding									
Pest control									
Harvesting									
Post-harvest activities									

33. If you hired labor, what would be the cost for one acre of work (wage + food)................... ETB/Acre

34. Production and utilization

Farm enterprise	How many acres do you have/ did you have in the past 12 months? (acres, pieces, etc.	Quantity harvested in the past 12 months? (e.g. kg, bails, bags, sacks, etc	How do you use your harvest? (Share, part, bags, etc.)			Price on the local market (ETB/ kg, bag, etc)
			Home consumption	Sold		
				Processed	Raw	

Farm inputs in year (tick)		Tick		Cost (ETB)		
Seeds						
Fertilizer		Urea	DAP	NPK	Others			
Manure						
Irrigation						
Transport						
Pesticides/herbicides						
Machinery/hired tools						
Hired labor						
Other______________						

V. Production and Marketing of Moringa by the Household a. Production

35. Do you grow Moringa?. ....Yes......................No

36. If yes, number of Moringa trees under farmland. …….Plot 1………..plot 2…….other plot

37. How long have you cultivated *Moringa?* ....years.

38. How many quintals/basket of Moringa did you get last year? ....Kg

39. What amount did you sell? .... Amount......................Where ....When

40. How is this year's output as compared to the previous year's yield? ....Better ....Same ....Worst

41. Size of land allocated to *Moringa* production during the 2010/11 E.C cropping season?

Plot ID	Plot location name	Area cultivated (in ha)	Land ownership Codes 1	Plot distance from home (minutes of walk) (Code 2)
Codes 1: 1. Own land 2. Rented-in 3. Shared-in 4. Gift **Codes 2:** 1. Good 2. Medium 3. Poor				

42. Do you grow other crops inside the Moringa tree? ....Yes............No

43. If yes, put the list of other crops inside Moringa shed, cost and benefits only from them.

			Amount of labor used (in)					

List of other crops inside Moringa shed	Amount of Seed used (in kg)	The total cost of seed (in ETB)	Preparing the land/Plowing	Planting	Harvesting	Other costs	Total Produced	Total consumed	Sold to Market	Selling price(in ETB)
Total										

44. Inputs used in *Moringa* production and cost of these inputs in 2010/11 E.C)?

Plot ID	Amount of Seed used (in kg)	The total cost of seed (in ETB)	Amount of fertilizers used (in kg)						Did you use compost 1? Yes 2. No		Did you use Animal waste? 1. Yes, 2. No		Herbicide used (in liter)	
			NPS	Cost	Urea	Cost	Others	Cost		Amount		Cost	Amount	Cost

45. Labors used in *Moringa* production during the last cropping season (2010/11 E.C)?

Plot ID	Labors used (man-days): Preparing the land/Plowing				Planting	Weeding			Harvesting	Threshing	Oxen used for plowing (oxen days)			
	1st	2nd	3rd	4th		Herbicide spray	1st	2nd			1st	2nd	3rd	4th

NB: Convert the # of days and hour spent on farming activities on man-days or oxen days basis

46. If you used rented land, what is the rental value of one timad (0.25 ha) of and............ETB

47. What are your labor sources for *Moringa* production in 2010/11 E.C? 1. Family labor 2. Hired labor 3. Both family and hired labor 4. Daily laborer 5. Cooperation 6. Others (specify).......................................

48. Have you hired labor for *Moringa* production in 2010/11E.C? ....Yes...............No

49. If yes, how many laborers you hired and what is the wage rate per day in 2010/11 E.C?

Plot ID	Hired labor used (man days)												Wage/day (ETB)
	Plowing				Sowing	Wage/day(ETB)	Weeding				Harvesting	Threshing	
	1st	2nd	3rd	4th			Herbicide spray	1st	2nd	Wage/day (ETB)			

50. What are the major sources of the Improved plant for *Moringa* in 2010/11 E.C? .....MoARD..............Own.............Local market.............Research center ....Cooperatives/unions.....................Others (specify)

51. What are the major sources of Fertilizers for Moringa 2010/11 E.C? ....MoARD.............Local market..........Cooperatives /Unions......Others (specify)

52. What are the major sources of Herbicide for *Moringa* in 2010/11 E.C? .....MoARD.........Local market.......Cooperatives /Unions..........Others (specify)

53. What problems did you encounter in accessing the following inputs in 2010/11 E.C?

Type of inputs needed	Problems (Codes 1)	How did you solve the problems (Codes **2**)
Improved plantation tree		
Fertilizer		
Herbicides/pesticides		
Labor		
Others (specify)		
Codes 1: 1. Not available on time 2. Shortage of supply 3. Too expensive 4. Cash shortage 5. Far distance 6. Others (specify)..............**Codes 2:** 1. Purchasing from market 2. Own seed 3. Borrowing from relatives 4. Others (specify)........................		

54. Would you like to expand *Moringa* production in the future? ....Yes.................No

55. If yes, why............. The main source of income.........Main consumption crop..........Resist water logging........... Resist insect pests......................... Others (specify) ....

56. If no, why? ....Shortage of land............Cash constraints for input...........Lack of improved seed..........Lack of fertilizers ....Others (specify)

57. Is there any natural hazard in the production year in the production of Moringa? ….Yes……No

58. Natural and artificial hazards................Storm...........Drought...........Frost............Animal damage............Flood.....................Other

59. What are the major *Moringa* production constraints in 2010/11E.C... ....Shortage of improved seed...........The high cost of inputs........Weather change ....Lack of technical training...........Shortage of land...........Lack of Market............Others (specify)

60. The total quantity of *Moringa produced* in the 2010/11E.C production year?

Type of Moringa	The quantity of *Moringa*(in kg or credit)						
	Total Produced	Shared	Consumed at home	Sold to market	Gift for others	Stored	Others (specify)
Leave							
Pods							
Seed							
Leaf powder							

b. Marketing

61. Experience in *Moringa* sales.................................... Years.

62. What is the distance from home to the main all-weather road to sale your *Moringa* produce? ....km.

63. What is the distance from home to market you mainly sell your *Moringa* produce? ....Km or hr.

64. What is the distance from your home to the market for the following activity 2010/11 E.C?

No	Marketplace for	To the nearest market (minutes of walk)	To alternative market minutes of walk)
1	*Moringa* produce (to sale)		
2	*Moringa* seed (to purchase)		
3	Fertilizers (to purchase)		

65. Did you know the market price before you transport *Moringa* produce to the market?.........Yes......No

66. How do you measure your Moringa Product in the market?.........Kg........Isir........kertit..........other

67. How many quantities and to whom did your sale last year *Moringa* produce (2010 E.C)?

Type of Moringa	The quantity of *Moringa* sold (kg/ keretit)	Average selling price (ETB/25/50/100kg or keretit)	Amount sold to each (in Kg)				Mainly place of Sale (Codes 1)
			Wholesalers	Retailers	Consumers	Cooperative	

Leaves							
Pods							
Leave powder							
Codes 1: 1. At home 2. Local market 3. District market 4. Other (specify)							

Note: If you sold to more than one market outlet please indicated the quantity sold to each

68. If you did not sell *Moringa* in 2009/10 E.C, why?...... Doesn't have cash constraint................ *Moringa* produced is low and kept for home consumption.............. Shortage of land.........................Others (Specify)

69. In 2009/10 E.C in selling your *Moringa* produce, which market outlet do you select primarily? ....Wholesalers............... Retailers ....Collectors .... Consumers............. Cooperative

70. Why do you prefer the selected market outlet (what factors do you consider)? ....Better price offered............ Fairness of scaling (weighing)..............Closeness in distance ....Transport availability............Others (specify)

71. Do you stored/not sold last year *Moringa* produce to get better price?..........Yes.........No

72. When did you sell a large proportion of *Moringa* produced in 2009/10 E.C?...............December...........January......... February..........March.........April ..... May.......June........July........August

73. If you, sale immediate after harvest, why you did that?....... Cash constraints........Storage problem........Better price ....Others (specify)

74. Who usually sets the selling price of *Moringa*? .... Farmers........Wholesalers.........Retailers..........Collectors ....Consumers ....Negotiated.........................Others (specify)

75. Is there a difference in price due to differences in buyer.................. Yes.................. No

76. If yes, what is the reason for difference........................

77. How many you played in selling *Moringa* in 2009/10 E.C?

No	Activity paid for	Total amount paid/year (in ETB)	What is the media of information that is paid? (Codes) 1 Mobile phone 2. Newspaper 3. Others (specify)........
1	Negotiations/bargaining		
2	Handling (sack)		
3	Market information		

78. Is there any grading activity for *Moringa* before selling?...... Yes......... No

79. If yes, what was the basis of your grading? ....Color.........Quality............. Others (specify)

VI. Trends in the Market Price of *Moringa*

80. What was the trend of the selling price of *Moringa* for the last two years (2008 E.C and 2009 E.C)? ....Increasing ....The same ....Decreasing

81. What is the main reason for such a trend?..........Low production...... Population growth...........High production cost.........Market information availability...........Others

82. What is the price of selling 25/50/100kg or credit of *Moringa* during the last two years?

Years	Selling price per 25/50/100kg or Basket of *Moringa* (in ETB)			
	When it is low		When it is high	
	Moringa stenopetela	Moringa olifera	Moringa stenoptela	Moringa olifera

VII. Means of Transportation of *Moringa* Product

83. What are the means of transport you use in last year transporting *Moringa* produce to market?........... Manpower.......Equines.........Animal cart...........Public transport.........Others (specify)

84. If you used your own Equines, what is the advantage over others…..............? Good to select best market outlets ....Accessible........ No cost ....Others (specify)

85. Do you use others (Equines or Animal cart) as a means of transport? ....Yes......... No

86. If yes, what was the cost of transport per 100kg of *Moringa* up to marketplace…..............ETB

87. Do you use vehicles as a means of transport of *Moringa* produce to market?.........................1. Yes……………2. No

88. If yes, what was the cost of transportation per 25/50/100kg or kept it up to the marketplace? ....ETB

89. If you did not use vehicles, why? ....Using your own equines....... Unavailable.....High cost..................Others (specify)

VIII. Extension contacts

90. Do you know development agent..................Yes................No

91. What is his/her name.......................................

92. How many times did he/she come to see you (from starting from September 2011)? ....days

93. Did you get agricultural extension service in 2010/11 E.C?...............Yes ....No

94. If no, why? ....No service provider nearby……………………...... The advice is not agriculture-related........ ....Do not have time to get the service .... Others (specify).................................

95. Did you receive extension services in relation to *Moringa* production in 2010/11 E.C? ....Yes...................No

96. If no, why?..................... The service is general/not specific to *Moringa*................ The advice is not related to *Moringa* .... Do not have time to get the service................ No service provider....................... Others (specify)

97. Who gets extension service in relation to *Moringa* production? .... Husband ....Wife.............Both husband and wife equally........... Female HH...................Youths

98. What is the distance from your home to the development center (FTC) (minutes of walk)? ....

99. How often the extension agent contacts you last year (frequency)? .... days in a year?

100. What type of extension advice do you get specifically on Moringa production?

Activities	Reason (a type of visit) Codes M)	How many times during the year	Who provides the extension service? (Codes1)
Using good varieties			
Plowing; plantation methods			
Fertilizer; Compost application			
Weeding; Herbicide/pesticide application			
Harvesting; post-harvest handling			
Marketing of Moringa			
Soil conservation			
Others (specify)			
Codes 1: 1. Development agents 2. MoARD experts 3. NGOs (specify) 4. Research centers (specify) ....5. Others (specify)			

IX. Credit Service

101. Did you get credit service in 2009/10 E.C? ....Yes ....No

102. If yes, how is the trend of credit service? ....Highly improving............Slowly improving...........Rather declining.............. No change

103. Did you receive credit for *Moringa* production purpose in 2010/11 E.C?.............Yes.............No

104. How much you received for *Moringa* production in 2010/11 E.C? ....ETB, at an interest rate of.............................%.

105. If you received credit in kind (like seed) specify the amount?............................. Kg

106. If you received credit in kind (like fertilizer) specify the amount?........................ Kg

107. For what purpose did you take the credit in relation to *Moringa* production? ....To purchase fertilizer for *Moringa* .... To purchase oxen/bull.........To rent in the land to extend *Moringa* production ....To purchase equines for transporting.................Others (specify)

108. From whom did you get the credit for *Moringa* production in 2010/11E.C?............................Relatives/Friends.................Bank ....Microfinance institution ....Traders............Cooperatives ....Others (specify)

109. If you haven't received credit in 2009/10 E.C for *Moringa* production what is the reason? ....Self-sufficient...........Unfavorable bureaucracy............High-interest rates ....Don’t want to take credit............Unavailability......................Others (specify)

X. Cooperative Membership

110. Are you a member of any cooperative?..........................Yes........................No

111. If yes, who is a member of cooperative?............. Husband........Wife...........Both

112. If yes, what benefits (services) do you received from the cooperative you belong to you in 2010/11 E.C? ....Improved seeds supply........... Fertilizers supply.............Herbicide supply.............Fair farm gate yield price...........Profit delivery ....Training ....Marketing information.........Credit... Others (specify)

113. If no Q84 why? ....No cooperative in the village.................Bureaucrat ....not interested ....Other

114. Are you a member of any community leadership? ....Yes ....No

115. If yes, did it have a positive impact on your farming activities? ....Yes........No

XI. Non/off-farm Income

116. Did you receive any income from off-farm activities or AID in 2010/11 E.C? ....Yes.......No

117. What amount of income did you receive from off-farm activities in 2010/11 E.C?

No	Non/off-farm activities in 2009 E.C	Any yearly income
1	Selling of charcoal/ firewood	
2	Petty trade	
3	Remittance	
4	Salary	
5	Wage	
6	Animal cart	
7	Grinding mill	
8	Fattening of oxen	
9	Sheep trading	
10	NGO (from soil and water conservation)	
11	Others	
Total		

Note: Non/off-farm incomes are incomes generated by excluding income from own farming.

118. Why you engaged in non/off-farm activities? ....Attractive income from off-farm activities...........Shortage of land ....Excess family labor ....Other (specify)

119. If you did not participate in non/off-farm income activities last year what is the reason?……..... Self-sufficient...............................No non/off-farm income activity.......... Not interested to participate ....Other specify

XII. Irrigation

120. Do you have an irrigation facility? (.......Yes/.........No)

121. If yes, then which one:

Seasonal Well----------	Perennial Well--------	Seasonal Stream-------------	Perennial Stream------	Others-----------------------------

XIII. Food Consumption

122. Did you buy any food from the market last 12 months (Yes/No): .... (if no, go to Q123)

123. If yes, then for how many months: ....

124. How much money did you spend buying food last 12 months: ....

125. How many meals were served to the household members during the last two days (*without any special event*)? ---------# of meals

126. During the last seven days, (*without any special event),* for how many meals were the following foods served in the main meal eaten by the household?

No	Food Group	Food Items belonging to group, amount and frequency	Frequency
1	Cereals and grain	..............Rice.......pasta..............bread / cake and / or donuts, ...sorghum………………......millet..................maize,	
2	Roots and tubers	.................Potato.............yam………….....cassava.............sweet potato..................taro ....and / or other tubers	
3	Legumes/nut	...............beans..............cowpeas...........peanuts..........lentils… ……..nut......soy.......pigeon ....pea ....and / or other nuts	
4	Orange vegetables (rich in Vitamin A)	...............carrot…………......red pepper………......pumpkin……………......orange sweet potatoes	
5	Green leafy vegetables	…………Moringa……....Spinach…….. broccoli………. amaranth and/or other dark green leaves, cassava leaves	
6	Other vegetables	…………onion……….tomatoes…..……cucumber,……….radishes……….green beans…..……peas………..lettuce, etc.	
7	Orange fruits (Fruits rich in Vitamin A)	................mango, ...papaya, ...apricot, ...peach	
8	Other Fruits	...........banana, ...apple, ...lemon, ...tangerine	
9	Meat	..............goat, ……....beef, ...chicken, ...pork (meat in large quantities and not as a condiment)	
10	Liver, kidney, heart and /other organ meats		
11	Fish / Shellfish	...................fish, including canned tuna, escargot, and/or other seafood (fish in large quantities and not as a condiment)	
12	Eggs		

13	Milk and other dairy products	.................fresh milk / sour, yogurt, cheese, other dairy products (Exclude margarine/butter or small amounts of milk for tea/coffee)	
14	Oil / fat / butter	..................vegetable oil,………...... palm oil, ...shea butter, margarine, ...other fats/oil	
15	Sugar, or sweet	..........sugar, ...honey, ...jam, ...cakes, ...candy, ...cookies, pastries, ...cakes and ....other sweet (sugary drinks)	
16	Condiments / Spices	...........tea,…. .....coffee / cocoa, salt, garlic, spices, yeast / ...baking powder, ….......lanwin, ...tomato / sauce, ...meat or fish as a condiment, ...condiments	

127. During the last seven days (*without any special event),* for how many days did the main meal consist of Moringa and vegetables **only**? *(i.e. without any animal protein)*.....................# Days Moringa.............. # Vegetables

128. During the last 30 days, was there some days where your household did not have enough food to eat? Yes......................... No...................................

129. If yes, how many days? .... # of days

130. In the past 12 months did you and your household members feel that your food would run out? (Before you had money to buy more/ or before the harvest?)............Yes...................No

131. List of food items and amount consumed per 7 days/week

No	Staple food item	Amount consumed in 7 days or per week (Kg/ week)	The amount consumed per day (Kg/ day)	Remark
1	Wheat			
2	Teff			
3	Barely			
4	Maize			
5	Sorghum			
6	Rice			
7	Oat			
8	Lentil			
9	Bean			
10	Field peas			
11	Chickpeas			
12	Grass peas/Guaya			
13	Finger millet			
14	Coffee			

15	Salt			
16	Sugar			
17	Pepper/Berbere			
18	Cooking oil*			
19	Onion			
20	Garlic			
21	Potatoes			
22	Tomatoes			
23	Milk*			
24	Cheese			
25	Beef			
26	Chicken			
27	Egg			
28	Fish			
29	Pasta /Macaroni			
30	Moringa			
31	Cabbage and other vegetables			
30	Others (specify)			

132. In the past 12 months, how did you handle this situation of running out of food?

Not applicable 0

Buy additional food (higher prices) 1

Buy additional food (normal/average price) 2

Borrow food from relatives or neighbors.................3

Skip meals..4

Other (specify) 5

Code number

[ ]

Interviewer Name: ....Signature: …………………….