SOKOINE UNIVERSITY OF AGRICULTURE (SUA)

PhD Thesis

THE INFLUENCE OF IMPROVED COFFEE VARIETIES ON PRODUCTIVITY AND PROFITABILITY AMONG SMALLHOLDER COFFEE FARMERS IN TANZANIA: THE CASE OF MBINGA AND MBOZI DISTRICTS

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Summary of the Thesis

This study was conducted in Mbinga and Mbozi districts in Tanzania to understand the performance of improved coffee varieties in terms of productivity and profitability under farmers' management practices. Understanding this information would help improve strategies for increasing coffee productivity and profitability in Tanzania. The key findings of this study show that the adoption of improved coffee varieties has increased. The yield gained by farmers is below the national average research yield. The adopters of improved coffee varieties gain higher profits compared to non-adopters. Therefore, the government should strengthen extension services to speed up the dissemination of developed technologies to increase coffee productivity. Coffee stakeholders should promote coffee yield-increasing technologies to minimize the yield gap and smallholder farmers should be encouraged to adopt improved coffee varieties and invest in the implementation of good agricultural practices as a strategy for minimizing cost and optimising profitability.

THE INFLUENCE OF IMPROVED COFFEE VARIETIES ON PRODUCTIVITY AND PROFITABILITY AMONG SMALLHOLDER COFFEE FARMERS IN TANZANIA: THE CASE OF MBINGA AND MBOZI DISTRICTS

Thesis Submitted to Sokoine University of Agriculture in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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EXTENDED ABSTRACT

The current world coffee demand is estimated to exceed production due to an increase in global coffee consumption aligned with number of dynamics on social, economic and environmental aspects to meet sustainable globe markets requirements. These dynamics such as imbalances in income distribution among market players, climate change and urbanizations due to population growth in coffee growing areas and shifting of consumers' taste and preference where producers need to be more innovative to increase productivity and quality can threaten the livelihood of millions of smallholder producers. Thus the strategies to ensure farmers increase coffee productivity and maximize profit are through producing coffee under sustainable manner. Tanzania Coffee Research Institute (TaCRI) initiated a hybridization programme to breed new varieties combine high-yielding and good beverage quality with resistance to coffee leaf rust (CLR) and coffee berry disease (CBD) for Arabica and coffee wilt disease (CWD) for Robusta. The average productivity of improved coffee varieties under good agricultural management practices is 2000 kg/ha higher than 1000 kg/ha from traditional varieties. The adoption of improved coffee varieties will contribute to minimise the use of fungicides to control coffee pest and diseases and contribute to increase productivity of high quality coffee produced under sustainable manner. The specific objectives of this study include the assessment of factors influencing the adoption of improved coffee varieties among smallholder farmers;, the assessment of the coffee yield gap among adopters and non-adopters of improved coffee varieties; and analysis of the profitability of coffee production among adopters and non-adopters of improved coffee varieties in Mbinga and Mbozi Districts. This study was conducted in six wards covering ten villages in Mbinga and Mbozi districts in Ruvuma and Mbeya Regions respectively. The adoption in this study is defined as the use of improved coffee varieties developed and disseminated to farmers by the Tanzania Coffee Research Institute (TaCRI). Adopters of improved coffee varieties refer to farmers who planted a minimum of 300 improved coffee varieties and non-adopters mean farmers growing the traditional coffee varieties. The study used primary and secondary data. Primary data was collected from a sample of 122 adapters and 198 non-adopters of improved coffee varieties making a total of 320 farmers using a household survey semi-structured questionnaire. The survey was complemented by Focus Group Discussions (FGDs) at the ward level and observation. Secondary data were captured from different sources such as TaCRI, Tanzania Coffee Board (TCB) reports. Descriptive statistics were used to capture the rate of the adoption of improved coffee varieties. The five-point Likert scale was used to assess smallholder farmers' perception of improved coffee varieties. The logit regression model was used to assess factors influencing the adoption of improved coffee varieties. The descriptive statistics and Soil Analysis for Fertility Evaluation and Recommendation on Nutrient Application to Coffee (SAFERNAC) model were used to analyse the coffee yield gap and the logit regression model was used to determine factors influencing coffee yield. The Gross Margin (GM), the Benefit-Cost Ratio (BCR), the Break-even analysis for yield and price and the sensitivity of gross margin were used to examine the economic profitability of coffee production among adopters and non-adopters of the improved coffee varieties.

The findings from descriptive statistics show that the rate of adoption of improved coffee variety is 38 %. Findings from the Likert scale revealed that smallholder coffee farmers' have a positive attitude toward adopting improved coffee varieties as they consider them to have high yields, good beverage quality, and disease resistance. The findings from the logistic regression model showed that contact with extension officers, membership in primary cooperative society and access to improved coffee varieties positively and statistically significance influence farmers' adoption decision of improved coffee varieties($p<0.05$). However, factors such as access to market information, access information about the attributes of improved coffee varieties and total land size owned (ha) had a negative and statistically significance influence on the adoption of improved coffee varieties ($p<0.05$). From these findings generally, it can be concluded that both adopters and non-adopters of improved coffee varieties have a positive perception of improved coffee varieties. However, the lack of enough information about improved coffee varieties and access to improved coffee seedlings hinders the adoption of these varieties and creates room for farmers to plant coffee seedlings with unknown sources of plant materials. Therefore, this study recommends that the coffee industry should strengthen extension services to disseminate appropriate information to farmers. The government should provide support and encourage different players in coffee seedling multiplications and distributions to farmers to meet the demand. Meanwhile, TaCRI should develop a seed certification system to avoid and minimize the risk of farmers collecting seeds and seedlings from unknown coffee varieties that are not recommended. These recommendations will contribute to an increase in the rate of adoption of improved coffee varieties hence increasing productivity and profitability.

The findings revealed that the average fertilizer application for both adopters and non-adopter was below the recommended rate. Fungicide application to control Coffee Berry Diseases (CBD) and Coffee Leaf Rust (CLR) was below the recommended rates. The findings showed that the average yield attained by adopters is 1250 kg/ha and non-adopters is 512 kg/ha. The descriptive analysis showed that the yield gap for adopters is 750 kg/ha equivalent to 38 % of the research yield and the yield gap for non-adopters was 488 kg/ha equivalent to 49 % of the research yield. The findings imply that adopters of improved coffee varieties gained 62 % of the yield potential while non-adopters gained 51 % of the yield potential. Likewise, the farmers' actual yield was below the estimated yield with Soil Analysis for Fertility Evaluation and Recommendation on Nutrient Application to Coffee (SAFERNAC) model. The main factors positively influencing coffee yield at a 5 % level of significance include coffee variety planted, plant population, access to extension services, fertilizer applications, pruning and amount of fertilizer applied (g/tree). Therefore, farmers are encouraged to adopt improved coffee varieties to increase coffee yield through the improvement on implementation of recommended good agricultural practices which include proper fertilizer application, planting recommended coffee varieties, having enough plant population per unit area and proper weeding, pruning of coffee trees, soil moisture conservation, control of coffee pests and diseases.

The descriptive statistics, Gross Margin (GM), Benefit-Cost Ratio (BCR), the Break-even analysis for yield and price and the sensitivity analysis of gross margin were used to compare profitability among adopters and non-adopters of improved coffee varieties for high-yielding, diseases resistance and with good beverage quality in the study area. The findings showed that the average variable costs of coffee production was 2 398 355 TZS/ha for adopters higher compared to 1 487 581 TZS/ha for non-adopters and also was statistically significance ($p=0.000$). The average variable cost per kilogram of parchment coffee produced was 2549 TZS for adopters and 3384 TZS for non-adopters. The GM for adopters was 5 451 666 TZS/ha higher compared to 1 727 389 TZS/ha of non-adopters with statistically significant difference ($p=0.000$). Likewise, the BCR for adopters was 2.16

higher compared to 1.18 for non-adopters with statistically significant difference (p=0.000). Meanwhile, the break-even price for adopters was relatively low compared to non-adopters and the break-even yield of adopters was relatively higher compared to non-adopters. The findings provide evidence that coffee farming using improved varieties was profitable for adopters compared to non-adopters because of high, GM, the BCR, the Break-even analysis for yield and price and the sensitivity of gross margin.

Based on the findings of this study, the null hypothesis was rejected in favour of the alternative hypothesis that the government efforts of promoting and disseminating improved coffee varieties has positive impact on productivity and profitability among farmers. The socio-economic characteristics, institutional factors and farm characteristics showed a significantly influence the rate of adoption of improved coffee varieties. It is, therefore, recommended that government should continue supporting research and development of infrastructures to increase coffee seedlings multiplication and distributions. TaCRI in collaboration with TCB, LGAs, NGOs and private sector should speed-up the rate of coffee seedlings multiplication and dissemination to farmers. Also the government in collaboration with NGOs and private sector continue strengthen extension services in coffee growing zones. Finally farmers should be encouraged to adopt the improved coffee varieties and implement good agricultural practices to increase coffee productivity and profitability.

DECLARATION

I, Leonard Kauwedi Kiwelu, do hereby declare to the Senate of the Sokoine University of Agriculture that this thesis is my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted to any other institution.

Leonard Kauwedi Kiwelu	**Date**
(PhD Candidate)	

The above declaration is confirmed by:

Dr. Damas Philip	**Date**
(Main Supervisor)	

Dr. Zena Mpenda	**Date**
(Co-Supervisor)	

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DEDICATION

This thesis is dedicated to my parents late Mr. Kauwedi Boaz Kiwelu and Ms. Uyonyimo Elisamehe Mangowi, and my beloved wife, Beatrice Aloyce Lyamuya, and my three childrens James, Jackson, and Jesca for nursing me with affection and love and for their dedicated partnership in the success of my life.

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LIST OF ABBREVIATIONS AND ACRONYMS

AMCOS	Agricultural Market Cooperative Societies
ASDP II	Agriculture Sector Development Programme
BCR	Benefit Costs Ratio
BOT	Bank of Tanzania
CBD	Coffee Berry Disease
CDP	Coffee Development Programme
CLR	Coffee Leaf Rust
CWD	Coffee Wilt Disease
DOI	Diffusion of Innovation
DCSMS	District Coffee Subject Matter Specialist
FGDs	Focus Group Discussions
g	gram
GAPs	Good Agricultural Practices
GM	Gross Margin
GoT	Government of Tanzania
ha	hectare
ICO	International Coffee Organization
IPM	Integrated Pest Management Practices
ISFM	Integrated Soil Fertility Management Practices
Kg	Kilogram
LGAs	Local Government Authorities
masl	Meters Above Sea Level
MDC	Mbozi District Council
MT	Metric Tons
NGOs	Non-Governmental Organizations
^{o}C	degree Celsius
SAFERNAC	Soil Analysis for Fertility Evaluation and Recommendation on Nutrient Application to Coffee
STATA	Statistics and data
SPSS	Statistical Package for Social Sciences
TaCRI	Tanzania Coffee Research Institute
TADB	Tanzania Agricultural Development Bank
TCB	Tanzania Coffee Board
TCGA	Tanzania Coffee Growers Association
TVC	Total Variable Cost
TZS	Tanzania Shillings
URT	United Republic of Tanzania
USA	United State of America
WCR	World Coffee Research

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information of the Study

1.1.1 World coffee production and consumption

Coffee represents one of the world's most important commodities and widely consumed beverages produced by 70 countries globally, of which fifty countries produce coffee on their own soil (ICO, 2018a). Brazil is the largest coffee producer in the world followed by Vietnam, Colombia and Indonesia while in Africa, Tanzania rank the fourth after Ethiopia, Uganda and Côte d'Ivoire (ICO, 2018b). In contrast, coffee is mostly consumed in the developed world which is in America and Europe, thus making it the world's highest-traded commodity after petroleum (WCR, 2021). According to WCR, (2021), world coffee consumption has increased by 1.9 % from 9 847 800 MT recorded in coffee year 2019/20 to 10 035 600 MT for coffee year 2020/21 as a result of an increase in the population consuming coffee in coffee-producing countries, emerging economies and a stronger interest in speciality coffee produced sustainably and product innovations in developed countries. Speciality coffee produced sustainably refers to coffee that adhere to various combinations of social, environmental, and economic standards, and that are independently certified by an accredited third party (Potts, 2010). According to WCR, (2021) during the 2020/21 season, Africa account for 7.36% coffee consuming after Europe (32.5%), followed by Asia-Pacific ranks second 24 %, and Latin America and North America 19 %.

1.1.2 Coffee production and productivity in Tanzania

1.1.2.1 Geographical and climatic Conditions for coffee production

Tanzania produces Arabica and Robusta types of coffee grown commercially in the world. Arabica coffee which contributes about 70 % of the total coffee produced in Tanzania grows well in high-altitude areas ranging from 1000 to 2500 masl which receiving 800 - 2500 ml/year of rainfall. The ideal temperature ranges from 15-25 ^{o}C, while absolute minimum temperatures should not be below 4-5 ^{o}C and absolute maximum temperatures should not exceed 30-31^{o}C. It prefers very deep soil (usually more than 1.5 m), well-drained friable loamy and clay soils with high available water holding capacities and a pH in the range of 5-7 or 5.8-6.2. The regions that grow Arabica type of coffee include Kilimanjaro, Arusha, Mbeya, Songwe, Ruvuma, Tanga, Iringa, Morogoro, Kigoma, Manyara, Mwanza, Katavi, Njombe and Mara. Due to its distinct body and flavour, Arabica is normally used to be blended with other coffees like ordinary mild, hard Arabica and Robusta; thus, the demand for Tanzanian coffee is always higher than the supply.

Robusta coffee is mainly grown in Kagera Region under the shade of banana trees contributing 30 % of the total coffee produced in Tanzania. Robusta coffee grows well in medium altitude areas ranging from 800 to 1500 masl, receiving 1200 - 3000 ml/year of rainfall. The ideal temperature ranges from 18 ^{o}C to 30 ^{o}C. It prefers deep soil (over 100 cm depth) with good texture and structure, over 2.6 % organic matter and a pH between 4.5 and 7.0. Other regions suitable for Robusta coffee include Morogoro, Mwanza, Geita, Tanga and Mara (TCB, 2021). Ecological factors in these coffee-producing regions provide an opportunity for Tanzania to increase the productivity of high-quality Robusta coffee that meets the growing demand of the speciality coffee market in the world.

1.1.2.2 Trend of coffee production

In Tanzania coffee is produced by smallholder farmers approximately 450 000 families of which 120 000 are found in the Robusta growing areas of the Kagera Region. Additionally, about 2.4 million people are indirectly engaged in the industry directly and indirectly (TCB, 2021). The smallholder farmers owning an average of 1 to 2 ha accounts for 90-95 % of the total coffee production in Tanzania. The average productivity ranging from 250 to 300 kg/ha of green coffee for Arabica and 450 kg/ha for Robusta coffee regardless of the type of coffee varieties planted (whether improved or traditional coffee varieties). The five to ten per cent of the total coffee production in Tanzania comes from 110 large coffee estates with average productivity ranging from 1800 kg/ha to 2500 kg/ha.

According to the trend line equation indicated in Figure 1.1, coffee production has been increasing at a mean rate of 732.06 tons annually from the assumed baseline of 43 288 tons. The absolute minimum of 32 489.00 tons of coffee was recorded in 2003/04 while the absolute maximum of 73 027.01 tons was produced in 2020/21. The low coefficient of determination (R^2) which is 0.16 was expected due to the famous phenomenon of biennial bearing in coffee and emerging challenges such as unpredictable weather, the existence of old coffee trees, the use of traditional coffee varieties and low usage of inputs due to their high prices, resulting in high cost of production at volatile and falling coffee prices.

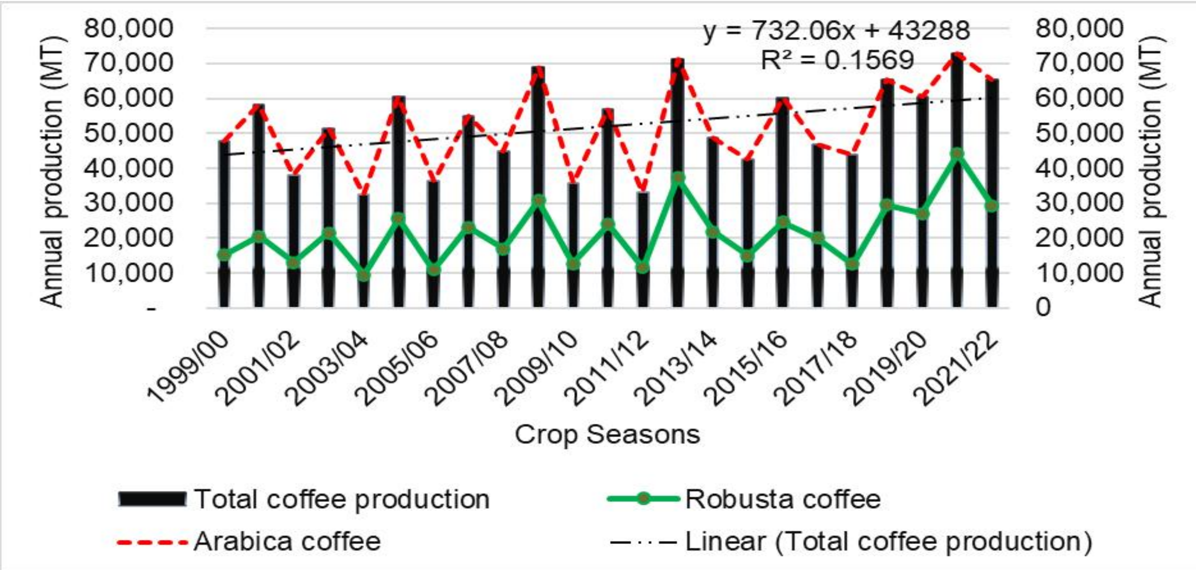

Figure 1.1: Coffee production trends in Tanzania

Source: TCB 2021/22 crop season

Meanwhile, the profitability of coffee production has been reported by farmers to be low expectation. This situation has become one of the main disincentives for household involvement in coffee production. Furthermore, despite of the low coffee profitability from coffee farming there domestic coffee consumption also is still low. According to TCB, (2021) the Tanzanian domestic coffee market range between 7 % to 10 % of coffee produced in the country. In the 2018/19 crop season, Tanzania exported a total of 68 147 MT of the total production of green coffee beans to Japan accounting for 34 % of this volume, followed 18 %, to Italy, 11 %, to Germany, 10 % to Belgium, 10 % to USA and 17 % to other countries.

Tanzanian coffee productivity under farmers management practices is still low compared to those from other East African countries such Kenya which is 302 kg/ha (ICO, 2019a), Ethiopia is 802 kg/ha (Bickford, 2019), Rwanda is 880 kg/ha (Nzeyimana, 2018) and Uganda is 2100 kg/ha ICO, (2019b). In general, it can be argued that coffee productivity from smallholder farmers in Tanzania is low. The main reason for low coffee productivity among others is the use of traditional coffee varieties (N 39, KP 423 and H 66 Arabica coffee varieties) with low yielding and susceptible to coffee leaf rust (CLR) and berry disease (CBD) (Kilambo *et al.,* 2015). According to van der Vossen *et al.* (2015) coffee breeding for disease resistance in combination with vigour, productivity and quality started in the early 1920s in India. The van der Vossen *et al* continued asserted that in the second half of the 20th-century comprehensive breeding programmes have been implemented in several other coffee producing countries including Tanzania. TaCRI initiated a hybridization programme to breed new varieties of Arabica coffee that combined resistance to CBD and CLR with improved yield, and quality and meet the required standards of profitable and sustainable crop production. Thus the aim of this study is to assess the adoption of improved coffee varieties and factors influencing adoption of improved coffee varieties, effect of improved coffee varieties on productivity and profitability.

1.2 Problem Statement and Justification

The demand for coffee in the world is growing with the number of dynamics aligned with sustainability aspects such as social, economic and environmental aspects (BOT, 2019). These aspects create the development of niche markets that suit consumers' tastes and preferences with more concern for the health benefits of coffee consumption. The niche markets also provide opportunities for producers to increase the production of high-quality coffee that meets the market requirements hence increasing farmers' incomes through the premium price offered. However, smallholder coffee farmers in Tanzania have not been able to fully exploit this opportunity largely due to low coffee productivity. Various efforts have been made by the government of Tanzania (GoT) to increase coffee productivity and increase profitability (TCB, 2012). Despite these efforts such as supporting the development and dissemination of appropriate coffee research technologies including use of improved coffee varieties, strengthening of extension services and primary cooperatives and farmers' training on the implementation of good agricultural practices (GAPs), productivity among smallholder coffee farmers is still observed to be very low. It is estimated to be 250 to 300 kg/ha for Arabica coffee and 450 kg/ha for Robusta coffee TCB, (2021) compared with the yield potential of 2000 kg/ha for Arabica coffee and 3330 kg/ha for Robusta coffee for Robusta coffee recorded at coffee research stations annually. This situation of low coffee productivity among smallholder coffee farmers despite government effort to promote use of improved coffee varieties calls for an empirical enquiry that will shed light on the extent of use of the improved coffee varieties, factors influencing their adoption and the effect of the improved coffee varieties on productivity and profitability of coffee production among smallholder farmers. The low coffee productivity is a major challenge towards access to the niche market and increase profitability among smallholder farmers in Tanzania.

The use of improved coffee varieties and implementation of good agricultural practices (GAPs) have been cited by many authors as the key approaches to raising agricultural productivity (Khonje *et al.,* 2015; TCB, 2012; Udensi *et al.,* 2011). In addition, it is claimed that since the improved varieties are not infested with CBD and CLR they are fungicide free hence easy for the farmer to meet the requirement of access to the niche markets. Likewise, the progressive promotion of high-yielding coffee varieties and advocating for the implementation of GAPs are expected to contribute to increasing coffee yield and profitability. Different studies have been conducted in the coffee sector to assess various aspects including agricultural practices of coffee farming, production, marketing, and profitability (Jeremiah *et al.,* 2018*;* Kilambo *et al.,* 2015*;* Mhando and Mdoe, 2018*;* Mtenga, 2016; Otieno *et al.,* 2019). However, none of these studies examined the productivity and profitability of the adopted improved coffee varieties in Tanzania. The current study seeks to provide empirical evidence on factors influencing adoption of the improved coffee varieties and their influence of improved coffee varieties on productivity and profitability among smallholder farmers in Tanzania. The findings from this study will contribute to the body of knowledge on the adoption and non-adoption of improved coffee varieties in terms of productivity and profitability. Also, the findings of this study will help researchers, coffee stakeholders, and the government to identify the key information which are miss in setting priorities on strategies that can help to achieve an increase in coffee productivity and hence increase the benefits coffee farmers get from the production of the crop.

1.3 Study Objectives

1.3.1 Overall objective

The overall objective of this study is to assess the effect of improved coffee varieties on productivity and profitability among smallholder farmers in the Mbinga and Mbozi Districts, Tanzania.

1.3.2 Specific objectives

The specific objectives of this study are:

i. To assess factors influencing the adoption of improved coffee varieties among smallholder farmers in the Mbinga and Mbozi districts;
ii. To assess the coffee yield gap among adopters and non-adopters of improved coffee varieties in Mbinga and Mbozi Districts and
iii. To analyse the profitability of coffee production among adopters and non-adopters of improved coffee varieties in the Mbinga and Mbozi Districts.

1.4 Hypotheses

i. Factors such as age, sex, marital status, level of education, house hold size, extension services, membership of primary cooperative, membership of farmer groups producing coffee seedlings, access to coffee varieties, land size, plant populations, farm management practices strongly influence farmers' adoption decision.
ii. There is no significant difference in the coffee yield gap among adopters and non-adopters of improved coffee varieties in the study area.
iii. Adoption of improved coffee varieties incurs higher profitability levels among farmers.

1.5 Scope of the Study

This study was conducted in Mbinga and Mbozi districts in Ruvuma and Songwe regions respectively. The adoption of improved coffee varieties in this study is defined as the use of improved coffee varieties that have been developed by the Tanzania Coffee Research Institute since 2003. In this study, adopters of improved coffee varieties are defined as farmers who grow only improved coffee varieties with a minimum of 300 coffee trees and non-adopters refer to farmers who grow only the traditional varieties with a minimum of 300 coffee trees. Farmer growing improved and traditional coffee varieties in combination were not considered in this study. The aim of the study, however, is to assess the effect of adopted coffee varieties on productivity and profitability, assessment of coffee yield gap for adopters and non-adopters and finally analyse the profitability of coffee production in the study area. The study used cross-sectional data as it was not possible to use other methods such as longitudinal and panel data due to the resources and complex research logistics.

1.6 Literature Review

1.6.1 Introduction

The literature review explores the relationships between many variables which have been explored in relation to adoption of improved coffee varieties and factors influencing adoption of improved coffee varieties, effect of improved coffee varieties on productivity and profitability. It extrapolates the gaps and assesses the approaches taken with similar research. The review encompasses the conceptual definitions /theoretical descriptions and empirical evidences related to adoption of agricultural technologies, farmers' decision making behavior in adoption of improved crop varieties. Also, overview of coffee varieties and production in Tanzania and tracking diffusion of improved agricultural technologies has been reviewed which encompasses the conceptual frame work of the study.

1.6.2 Adoption of improved coffee varieties

Diffusion of Innovation (DOI) theory by Rogers, (1962) is the theory guiding adoption of technology. Rogers, (1995) described innovation as an idea, practice, or project that is perceived as new by an individual or other unit of adoption. It may have been invented a long time ago, but if individuals perceive it as new, then it may still be an innovation for them. The newness characteristic of an innovation is more related to the three steps, namely knowledge, persuasion, and decision of the innovation-decision process. According to Khonje *et al. (*2015) and Udensi *et al.* (2011) adoption is a process consists of three stages namely pre- adoption, adoption and post- adoption. At the pre-adoption stage, people may examine a new technology and then consider adopting it. At the adoption stage, they form an intention to adopt the technology, and they eventually purchase and use it. At the post-adoption stage, people can either continue or discontinue using the technology. The study conducted by Ray (2001) revealed that adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not always be practiced by farmers to adopt new technology, they may adopt the new technology by passing the trial stage.

To increase the contribution of coffee to economic growth through enhancing coffee production and productivity, Tanzania coffee research institute (TaCRI) has developed and released 19 Arabica coffee hybrids: 10 lines of Arabica coffee 1st generation tall (single parent) which released in September 2005. Another one was released in November 2011, five lines of Arabica coffee 2nd generation tall (two parents) was released in January 2012 and four Arabica 3rd generation (two parents compact) were released in December 2013. Four Robusta varieties were released in January 2011 as shown in Table 1.1. These varieties combine high-yielding and good beverage quality with resistance to coffee leaf rust (CLR) and coffee berry disease (CBD) for Arabica and coffee wilt disease (CWD) for Robusta (Kilambo *et al.,* 2015). The average productivity of improved coffee varieties under good practices found to be 2000 kg/ha and for traditional varieties was 1000 kg/ha. However, the information on adoption of these varieties and the yield attained at farmers' management practices is limited.

Table 1.1: List of coffee varieties grown by farmers in Tanzania

Name of coffee varieties	Descriptions	Bean size (AA+A%)	Class	Cup quality	Yield (Kg/ha)
N39-1	Arabica Hybrid tall varieties first generation September 2005	77	4++	Good	2058
N39-2		77	4++	Good	2708
N39-3		74	5+	Good	2763
N39-4		80	4+	Good	1961
N39-5		62	5+	Good	2633
N39-6		72	4+	Good	2891
N39-7		72	5+	Good	2526
KP423-1		80	4++	Good	2225
KP423-3		77	5+	Good	1578
KP423-2	Arabica Hybrid tall varieties January 2011	68	5+	Good	1851
Maruku2	Robusta coffee varieties released in January 2011	90	4	Good	3900
Bukoba1		91	5	Good	780
Maruku1		98	5	Good	2400
Muleba1		94	6	Good	2400
N39-8	Arabica Hybrid tall varieties Second generation January 2012	76	4+	Good	2000
N39-9		68	4+	Good	2700
N39-10		71	4	Good	2400
N39-11		68	4+	Good	2700
N39-12		79	4	Good	2400
TaCRI 1F	Arabica Hybrid compact varieties December 2013	69	4+	Good	6000
TaCRI 3F		64	4+	Good	5050
TaCRI 4F		74	4+	Good	4800
TaCRI 6F		68	5	Good	6000
N39	Traditional Arabica coffee varieties	57	4+	Good	1000
KP423				Good	1000
MS	Traditional Robusta			Good	1000

Sources: Kilambo *et al.* (2015)

1.6.3 Factors influencing adoption of improved coffee varieties

It was found that even though the improved coffee varieties have proven a better performance than traditional coffee varieties in terms of productivity and resistance to major coffee diseases, the adoption of these varieties reported to be low among farmers. According to the mid-term review report of the Tanzania coffee Industry development strategy, low adoption of improved coffee varieties in Tanzania was due to lack of knowledge and access of these varieties, limited extension services, and lack of capital required to purchase improved varieties and invest in a renovation of the coffee farm (Mhando & Mdoe, 2018). The studies as cited by Kimbi et al. (2020) in (Mpangwa, 2011; Simtowe & Mausch, 2018; Kaliba *et al.*, 2018) have reported age, income, cooperative membership, education, resources, extension services, subsidies and output markets to influence adoption of coffee varieties among farmers. Similarly the study conducted by Luzinda *et al.* (2018) on the factors influencing adoption of improved Robusta coffee technologies in Uganda revealed that access to credit, availability of off-farm income, level of education, labour availability and access to extension services significantly influenced adoption of improved coffee varieties. Therefore, the adoption pattern for a technological change in agriculture is a comprehensive process which requires an interaction of well-coordinated research for development, extension services, marketing system and other stakeholders along the value chain. The Utility Maximization Theory by Rogers, (1995) describe that in agricultural production, farmers are expected to make decisions on technologies use based on their expected maximum utility. Farmers will look for necessary production technologies with minimum costs while expecting to attain increased levels of production, profits and improved food and nutrition security.

1.6.4 The effect of improved coffee varieties on coffee production and productivity

Technology adopted is expected to be converted into valuable output increase (productivity, profitability and income levels). Considering the presence of improved and traditional coffee varieties, farm households have choices of planting either traditional varieties, improved varieties or a combination of the two to maximize his or her utility. The empirical literature that explores the direct impacts of improved varieties in rural areas provides evidence on the impact of improved varieties on crop production and productivity. The household production theory by Muellbauer, (1974) explains the relationship between inputs and outputs The rational coffee farmers/producers combines two or more inputs of production to attain a certain level of output for profit maximizations (Thomas & Maurice, 2008). The studies conducted by Asfaw *et al.* (2012), Luzinda *et al.* (2018); Mmbando, (2016), Nyanga, (2012) and Moshi, (1997) have shown that adoption of improved varieties can be very effective in increasing agricultural production and productivity, thus leading to a reduction in smallholder farmers' poverty. Meanwhile, the studies conducted by Khonje *et al. (*2015); TCB, (2012a) and Udensi *et al.* (2011) indicated that adoption of improved varieties was found to reduce adopting households' likelihood of falling below the poverty line. Diro et al, (2019) studied the impacts of adoption of improved coffee varieties on farmers' coffee yield and income in Jimma Zone Ethiopia and found that the mean clean coffee yield per hectare of land for adopters is significantly higher (861 kg) than their non-adopters counter parts (646 kg). Other studies conducted by Diro *et al.,* (2021) on the the role of improved coffee variety use on the adoption of key agricultural technologies in the coffee-based farming system of Ethiopia showed a clear positive impacts.

According to TaCRI, (2011, 2016) indicated that application of recommended good agricultural management practices is important for high yield from improved coffee varieties. Among of these practices includes: First preparation of a hole of 60 cm x 60 cm x 60 cm size in soils with normal strata, filled with topsoil mixed with well-decomposed farmyard manure or compost (one tin of 20 litres) and application of DAP fertilizers (100 g/hole) or rock phosphate fertilizers (150 g/hole to 300 g/hole).

The plant spacing of improved coffee varieties was 2 metres by 2.5 metres for compact and tall varieties with an average plant population of 2000 per ha (Kilambo *et al.,* 2015; TaCRI, 2011, 2016). The traditional Arabica coffee varieties are planted in a space of 2.74 metres by 2.74 metres with an average plant population of 1330 per ha. While Robusta coffee varieties are planted in a space of 3 meters by 3 meters with an average plant population of 1111 trees. Second is to obtain coffee seedlings with a minimum of 6 to 8 paired leaves from the registered coffee nurseries for planting (Magesa *et al.,* 2018).

Third is to continue with farm management practice such as weeding, soil moisture conservation, application of recommended fertilizers as indicated in Table 1.2, coffee pruning and canopy management, control of coffee pests and diseases (Magina, 2011; Kilambo *et al.,* (2015), and finally harvest and post-harvest handling (TaCRI, 2011).

Table 1.2: Nutritional requirements and recommended fertilizer for the coffee

	Recommended fertilizer application (g/tree)					
Year	**SA**	**NPK**	**CAN**	**ASN**	**UREA**	**DAP**
Year 0	75	75	60	60	30	100
Year 1	110	110	90	90	50	NIL
Year 2	145	145	120	120	65	NIL
Year 3	180	180	145	145	80	NIL
Year 4	215	215	175	175	100	NIL

Source: TaCRI, (2011)

1.6.5 The effect of improved coffee varieties on coffee profitability

The major concern in coffee production among farmers is the minimization of cost(s) for a given level of output, and the maximization of profit for a given level of inputs. However, some farmers incurred high costs of coffee production because they lack alternative means of minimizing the costs and maximizing profit as emphasized by Debertin, (1986) in the profit maximization theory. The studies suggested that farmers may be motivated to produce based on their attitude towards risk; the utility derived from production; and for-profit reasons (Huffman, 2011; Muellbauer, 1974). Technology adoption is a vital component when one thinks investing on coffee farming as a profit venture. According to Kilambo *et al.* (2015), improved coffee varieties prove to be beneficial to farmers under research trials in many ways including early maturing (improved coffee varieties start bearing after 18 and traditional varieties start bearing after 36 months of planting), resistance to major coffee diseases (CBD, CLR and CWD), and high-yielding and good beverage quality. Developing and promoting adoption of improved coffee varieties and application of recommended farm management practices is suitable to improve farmers' livelihood (Magesa *et al.,* 2018). The study conducted by Diro et al. (2019) showed that adopters of improved coffee varieties in Ethiopia have high profit compared to non-adopters. Similarly the study conducted by Hajaratu (2019) on the impact of improved variety adoption on farm income in Tolon district of Ghana showed that adoption of agricultural technologies had a positive influence on farmers' income. Likewise, the study conducted by Kimbi *et al.* (2020) on a probit analysis of determinants of adoption of improved technologies among farmers in Tanzania showed that adopters obtained higher profitability than non-adopters of improved varieties. Moreover, the study conducted by Samuel Diro *et al.* (2021) on the the role of improved coffee variety use on the adoption of key agricultural technologies in the coffee-based farming system of Ethiopia showed that adopters obtained higher profitability than non-adopters of improved varieties.

1.7 Theoretical and Conceptual Framework

1.7.1 Theoretical Framework

The theory of Diffusion of Innovation (DOI) by Rogers, (1962) underpins the first objective. The decision to adopt improved technologies is modelled in a random utility maximization theory for farmer decision of alternatives from among a set of discrete measures (Rogers, 1995). This theory explains why farmers choose to adopt new ideas. Likewise, the theory predicts how and at what rate an innovation will be adopted by farmers in the community. The second objective is guided by the household production theory by Muellbauer, (1974).

This theory explains the relationship between inputs and outputs, which is the transformation of factor inputs into outputs (Thomas & Maurice, 2008). Generally, production always includes at least two, and often more inputs. This theory assumes a multi-dimensional illustration providing a simultaneous relationship between output and all inputs. Productivity can be briefly defined as production (output) divided by input. According to Hailu (2003), agricultural productivity is identical to resource productivity which is the ratio of total output to the resource or inputs used. Productivity is measured as the market value of the final output. This output value may be compared to different types of inputs such as return to resource use (return to labour productivity, return to the land and return to capital). The third objective of this study is guided by the theory of profit maximization by Debertin (1986). Profits are the difference between the firm's revenue and total costs (Huffman, 2011; Muellbauer, 1974). That is rational coffee farmers/producers invest in coffee production for profit maximization. Therefore, economic profit is defined to be the difference between the revenue a firm receives and the costs that it incurs (Cellini, 2015). The strategies for increasing coffee productivity and profitability among smallholder farmers include encouraging the adoption of high-yielding, disease-resistant good beverage quality coffee varieties and implementation of good agricultural practices.

1.7.2 Conceptual Framework

The following conceptual framework (Fig 1.2) was constructed based on the empirical research reviewed, understanding from cases related to the adoption of technologies, productivity and profitability. It is vital to understand the interaction between the socio-economic characteristics, farm characteristics, institutional characteristics, and agricultural practices of that particular technology. Socio-economic factors such as level of education, sex, age, marital status, level of education and household size were hypothesized to influence farmers' perception of that technology. Perception may influence people to adopt or not adopt a particular technology. The adoption as used in this study growing a minimum of 300 coffee trees of the improved varieties and implementing good agricultural practices. Smallholder farmers can adopt improved coffee varieties and plant them directly or after realizing that these varieties have superior attributes over traditional varieties. This means that to adopt the improved varieties one must have a positive perception towards those varieties. Institutional factors including access to extension services, and membership in primary cooperatives and farmer groups producing coffee seedlings are among the key variables hypothesized to influence the adoption of improved coffee varieties. This is because farmers who access extension services are in a better position to make effective resource allocation and use that will have a positive impact on productivity and profitability. Also being a member of the primary cooperative and or farmer groups' producing coffee seedlings assures farmers access to information and connection to the market hence better prices which contributes to farmers' profitability. This study is guided by this framework which helps to assess how each variable or factor influences the adoption of improved coffee varieties, coffee productivity and profitability among adopters and non-adopters in the study area.

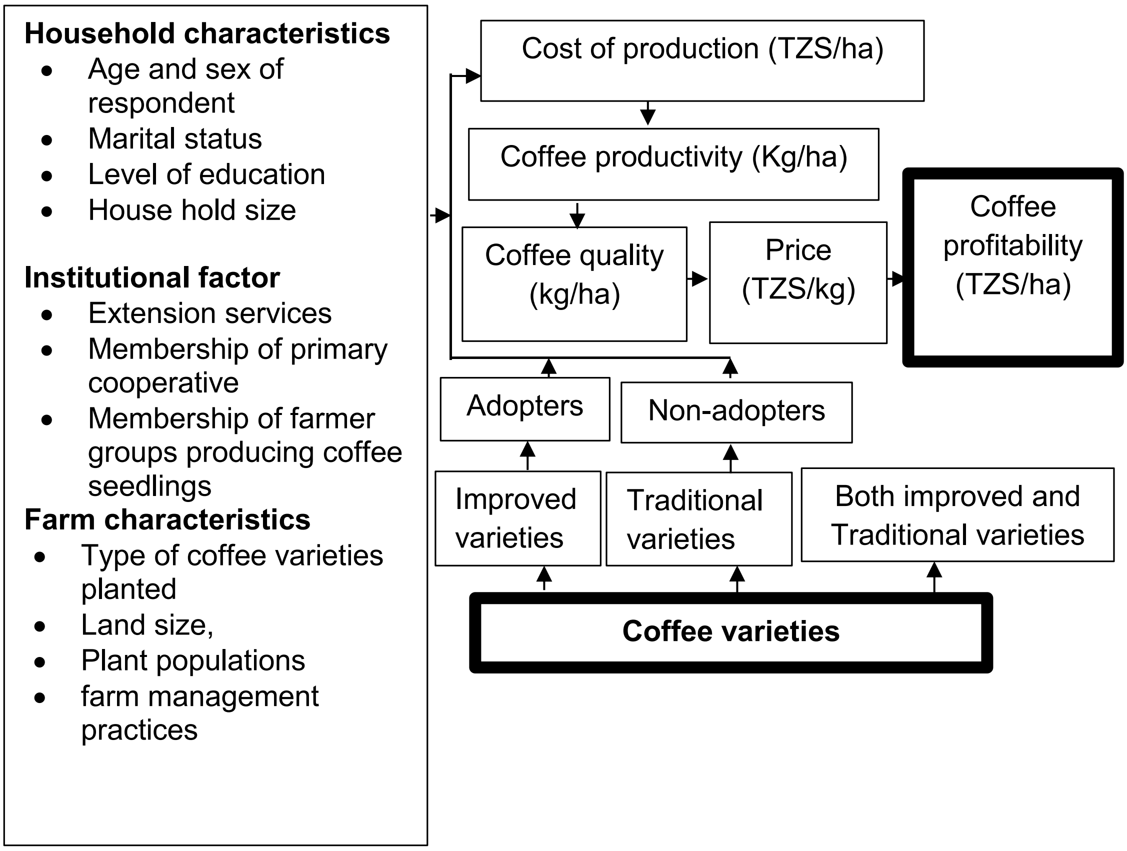

Figure 1.2: Conceptual framework

Source: Modified concept from (Feder & Umali, 1993)

1.8 Description of the Study Area

1.8.1 Location and physical features

This study was conducted in Mbozi and Mbinga districts in Songwe and Ruvuma Regions respectively (Fig. 1.3). The two districts were picked because they were producing 50 % of Arabica coffee in Tanzania and they have the potential the area for land expansion suitable for coffee production as documented by (TCB, 2021). According to data from the TCB (2021), Mbinga district has an average total land area of 40 644 hectares and Mbozi has 36 862 hectares under coffee production producing an average of 10 400 and 94 000 tons respectively where coffee is cultivated as a pure stand and some areas are intercropped with banana and shed trees. The dissemination of improved coffee varieties to smallholder farmers has been going on in these districts since 2005 to date (Kilambo *et al.,* 2015).

Mbozi district is located in the South Western corner of the Mbeya Region, between Latitudes 8^{o} and 9^{o} 12 South of the Equator and Longitudes 32^{o} 7' 30" and 33^{o} 2' 0" East of Greenwich Meridian. To the South the district is bordered by the Ileje district, to the East by the Mbeya Rural district at the mark of Songwe river, to the North, the Mbozi district extends to Lake Rukwa where it is bordered by Chunya district, whereas to the West it shares borders with Rukwa Region and the Republic of Zambia (MDC, 2010). Mbinga District is one of the five districts of the Ruvuma Region of Tanzania. Mbinga District lies between Latitude 10°49'60" S and Longitude 34°49'60" E. The District is bordered to the North by Njombe Region, to the East by Songea Rural and Songea Urban Districts, to the South by Mozambique, and to the West by Lake Nyasa.

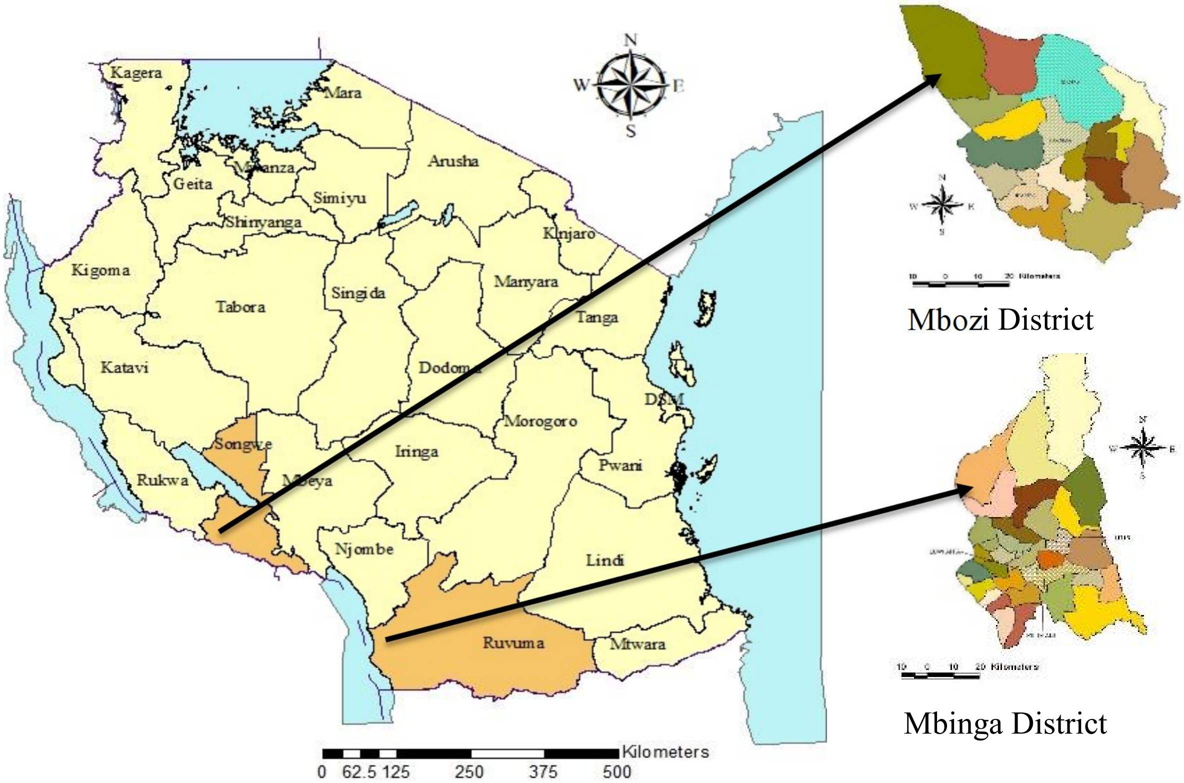

Figure 1.3: Map of Tanzania indicating study sites Mbozi and Mbinga Districts.

1.8.2 Population in the study area

As projected in 2012, the population of Mbozi District was estimated to be 446 339 among these 48 % are males and 52 % are females and Mbinga District was estimated to be 353 683 among these 51 % are males and 49 % are females (URT, 2013). The population density in Mbozi and Mbinga districts was 116 and 73 people per km^2 in 2012 respectively. More than 80 % of the total population of the study area were rural inhabitants and its inhabitants depend on agriculture and livestock production which accounts for over 80 % of the district's earnings. Agricultural production is mainly done by smallholder farmers.

1.8.3 Agro-climatic Zone

The altitude of the Mbozi District lies between 900 and 2750 metres above sea level. The District receives average rainfall between 1350 mm and 1550 mm per annum; while temperatures range between 20 ^oC to 28 ^oC (MDC, 2010). The altitude of the Mbinga district lies between 900 and 1350 metres above sea level; with some points in the highland reaching over 2000 metres above sea level. The District receives average rainfall between 1200 and 1500 mm per annum; while temperatures range between 13 °C in the highland to 30 °C on the lakeshore.

1.8.4 Farming system

The farming system of the Mbinga and Mbozi districts constitutes complex production units involving a diversity of interdependent mixed cropping and livestock activities. The cash crops predominantly produced are coffee, semis, and sunflower. The main staples are maize, paddy, sorghum, finger millet, bulrush millet, sweet potatoes, round potatoes, groundnuts, and beans. Livestock keeping is also an integral activity of farmers in the study areas of which nearly 80 % of the households own at least one type of livestock (MDC, 2010). The common types owned are cattle, goats, sheep, pigs, poultry, donkeys, and turkeys. Farmers' income from livestock and crop production thereof accounts for more than 80 % of household income (MDC, 2010; URT, 2016). This implies that farmers in the study areas allocate resources to various farm production activities. According to Ruben et al. (2018), the majority labour force for coffee maintenance of coffee farm activities including weeding and harvest is provided by women while men play a significant role in pruning and control of pests and diseases. Men controlled 40 – 80 percent of cash income gained from coffee trading activities this is because the account used for the transaction of coffee sales are owned by men (Mhando & Mdoe, 2018). Rubin, (2019) documented that gender equality in production activities increases competitiveness and participation in economic activities, which contributes to economic growth.

1.9 Research Design and Sampling Techniques

The present study employed a cross-sectional research design to collect data from two major Arabica coffee-producing Districts which were Mbinga and Mbozi. In this design, all data collected from the sampled population was done at a single point in time. A multi-stage sampling procedure was used at the first stage to select Arabica-producing wards from Mbinga and Mbozi Districts. Secondly, a random sampling procedure was applied in selecting villages from the selected coffee-growing wards. The third stage involved the development of a sampling frame followed by data sets of coffee farmers with improved varieties and traditional coffee varieties from the selected villages. The traditional coffee varieties were freely distributed by TCB under Coffee Development Programme (CDP) from 1998 to 2003 while improved coffee varieties were sold by TaCRI from 2005 to 2016. A required sample of respondents was proportionally selected from the list of coffee growers developed in the third stage per village following Krejcie and Morgan's (1970) formula as presented in Equation 1. Finally, random sampling was applied in selecting 100 % improved and traditional coffee varieties growing households. Therefore, a 320 sample size of coffee growers was selected from ten villages namely Mwanda (39), Itepula (15), Isansa (21), Hanseketwa (15), Masangula (42), Isangu (23) in Mbozi district and Buruma (42), Sepukila (56), Utiri (47) and Luwaita (20) in Mbinga District as shown in Table 1.3.

$$S = \frac{X^2 NP(1-P)}{d^2(N-1)+X^2P(1-P)} \quad \text{.......} (1.1)$$

Where: S = required sample size, X = z value (assumed to be 1.96 for 95% confidence level), N = Population size, P = Population proportion (assumed to be 0.5 since this would provide the maximum sample size), d = degree of accuracy (5%), expressed as a proportion (0.05). Accordingly, the Mbozi district consists of 930 households, and the Mbinga district consists of 990 households, making a total of 1920 target households.

$$n = \frac{1.96^2 x 1920 x 0.5 x 0.5}{0.05^2 x (1920-1)+(1.96^2 x 0.5 x 0.5)} = 320$$

Table 1.3: Sample Districts and Number of Sample Households

District	Approx. sub-pop. (20-30% are coffee farmers)	Sampling fraction	Sub-sample	100% of the tree on the farm were improved coffee varieties	100% of the tree on the farm were traditional coffee varieties
Mbozi	930	0.48	155	49	106
Mbinga	990	0.52	165	73	92
Total	**1920**		**320**	**122**	**198**

1.10 Data Collection

Secondary data such as coffee auction price was collected from TCB websites http://coffeeboard.or.tz/auctions.php, the contribution of coffee to the national economy, and the trends of coffee productions were collected from Tanzania Coffee Industry Development Strategy 2021-2025 TCB (2021) and the average national research yield was collected from Tanzania Coffee Research Institute Strategic Plan IV (TaCRI, 2017). In addition, the trend of coffee yield from farmers was collected from data provided by AMCOs reports in the study area to provide the necessary support to the primary data accumulated.

1.11 Primary Data Collection

The primary data were collected during the 2019/20 crop season from household heads growing only traditional and only improved coffee varieties using a semi-structured questionnaire. This questionnaire was administered to 320 respondents composed of closed, qualitative, and quantitative. The information collected includes household demographic characteristics such as sex, age, family size, number of years of informal education of the household head, household labour capacity; institutional factors such as access to extension services and group membership; farm characteristics such as land size, type of coffee varieties planted, plant population, costs of variable inputs such as fertilizer, herbicides, fungicides, pesticides, labour cost for weeding, pruning, spraying for coffee pests and diseases, harvesting, and coffee yield. Other data collected include costs for establishing a coffee farm such as includes land preparations, layout, pegging, holing, and costs of seedlings, fertilizer and manure for planting (Appendix 1).

Focus Group Discussions (FGDs) were also used to collect primary data. A total of 42 respondents were involved in making two groups from each district; one for adopters of improved coffee varieties and the other for non-adopters making a total of six groups one from each ward namely Igamba, Ihanda, Isansa from Mbozi district and Kilimani, Utiri and Luwaita from Mbinga. Each group comprised 7 - 8 participants (including 1 to 2 females) who were purposively selected among coffee producers. Participants in FGDs were different from those involved in questionnaire interviews to help to capture in-depth information related to this study and to validate some information gathered from the households in the study area.

1.12 Organization of the Thesis

This thesis is organized into five chapters. The remaining part of the thesis is organized as follows. Chapter Two presents the first manuscript, which focuses on factors influencing the adoption of improved coffee varieties among smallholder farmers in the Mbinga and Mbozi Districts. This paper has been published in the ***International Journal of Agricultural Economics*** (DOI: https://doi.org/10.11648/j.ijae.20210601.13). Chapter Three focuses on the assessment of the factors causing the coffee yield gap among smallholders in the study area. This paper has been published in the ***International***

Journal of Current Research and Academic Review ***(***DOI: https://doi.org/10.20546/ijcrar.2022.1002.002). Chapter Four is to analyses the profitability of coffee production among adopters and non-adopters of improved coffee varieties in the Mbinga and Mbozi districts. This paper has been published in the *International Journal of Innovative Science and Research Technology* *(***DOI:** https://doi.org/10.5281/zenodo.7109498). Finally, a conclusion of the major findings and recommendations is presented in Chapter Five.

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CHAPTER TWO

MANUSCRIPT ONE

2.0 FACTORS INFLUENCING ADOPTION OF IMPROVED COFFEE VARIETIES AMONG SMALLHOLDER FARMERS IN MBINGA AND MBOZI DISTRICTS[1]

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2.1 Abstract

Tanzania Coffee Research Institute (TaCRI) has released 19 Arabica coffee hybrid varieties that combine high-yielding and good beverage quality with resistance to Coffee Leaf Rust (CLR) and Coffee Berry Disease (CBD). The high-yielding attribute of these improved varieties and reduced fungicide costs would normally motivate smallholder farmers to adopt them. However, their level of adoption and the factors influencing it have not been studied in detail. This study aimed to assess smallholder farmers' perception of the varieties and determine factors influencing their adoption in Mbinga and Mbozi districts. Data were collected from a sample of 122 adapters and 198 non-adopters making a total of 320 farmers using a household survey semi-structured questionnaire. The perception of smallholder farmers on attributes of improved coffee varieties was gauged using a five-point Likert scale. A logistic regression model was employed to determine factors influencing their adoption. The descriptive analysis shows that the rate of adoption of improved coffee variety is 38 %. The findings from the Likert scale show that smallholder farmers in the study area have a positive perception of the attributes of improved coffee varieties. Meanwhile, the findings from the logistic regression model show that the coefficient of visits by extension officers (0.039), membership of primary cooperative (0.406) and access to improved coffee varieties (0.407) influence farmers' adoption decision of improved coffee varieties positively. However, factors such as access to market information (0.150), access to information about coffee varieties (0.149) and total land size owned (ha) (0.057) had a negative coefficient influence on the adoption of improved coffee varieties. From these findings, it can be concluded that both adopters and non-adopters of improved coffee varieties have positive perceptions of improved coffee varieties. For more farmers to adopt these varieties continuous dissemination, and promotion of awareness creation to extension officers and farmers about these varieties is required. Therefore, this study recommends that the coffee industry should capacitate extension services and update them with new technologies and innovations related to coffee to ensure they disseminate the right information to farmers. Also, the government should provide support to coffee seedling multiplications nurseries and distribution players to meet the demand.

Keywords: Adopter, Non-adopter, Coffee, Varieties, and Perception

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2.2 Introduction

Coffee is one of the most widely consumed beverages all over the world. The global coffee market is anticipated to reach US$144.68 billion in 2025, growing at a CAGR of 7.60 % for the period spanning 2021-2025 (ICO, 2019a). Brazil contributed about 35 % of all coffee produced in the world for the crop year 2017/18 followed by Vietnam 13 %, Colombia 10%, Indonesia 7%, Ethiopia 4 %, Uganda 3 %, Côte d'Ivoire 2 %, Kenya 0.9 %, and Tanzania 0.7 % (ICO, 2018b). Tanzania produces both Arabica and Robusta. For the past five years from 2016 to 2020, coffee contributes about 18.03 % to the annual agricultural foreign currency earnings (BOT, 2019). The average trend of coffee production in Tanzania for the last 23 years production has been increasing at a mean rate of 732.06 tons annually from the assumed baseline of 43 288 tons. The absolute minimum of 32 489.00 tons was recorded in 2003/04 while the absolute maximum of 73 027.01 tons was produced in 2020/21 with average productivity ranging from 250 to 300 kg/ha for smallholder farmers (TCB, 2021). In Kenya the average coffee productivity from smallholder farmers is estimated to be 302 kg/ha (ICO, 2019a), whereas the yield in Ethiopia is 802 kg/ha (Bickford, 2019), Rwanda is 880 kg/ha (Nzeyimana, 2018) and Uganda is 2100 kg/ha (ICO, 2019b). In general, it can be argued that coffee productivity from smallholder farmers in Tanzania is low.

Tanzania Coffee Research Institute (TaCRI) has released 19 Arabica coffee hybrids as follows: 10 lines of Arabica coffee 1st generation tall (single parent) were released in September 2005 and one was released in November 2011, five lines of Arabica coffee 2nd generation tall (two parents) was released in January 2012 and four Arabica 3rd generation (two parents compact) were released in December 2013. Four Robusta varieties were released in January 2011 (Kilambo *et al.,* 2015). These varieties combine high yields (2000 kg/ha on average), good beverage quality, and are resistant to Coffee Leaf Rust (CLR) and Coffee Berry Disease (CBD) for Arabica and Coffee Wilt Disease (CWD) for Robusta (Kilambo *et al.,* 2015). Farmers adopt new technology after perceiving them to be beneficial and profitable (Rogers, 1995). The high yield of improved coffee varieties from research trials is expected to motivate smallholder farmers to adopt the improved coffee varieties (Magesa *et al.,* 2018). However, adoption rates of improved coffee varieties and factors affecting the adoption of these varieties among smallholder farmers remain unknown. Therefore, this study aims to assess factors influencing the adoption of improved coffee varieties and to determine farmers' perceptions about these varieties in Mbinga and Mbozi districts. The findings from this study will help in formulating policies and strategies which can help to encourage more farmers to adopt the improved coffee varieties and optimize their yield potential hence increasing profitability.

2.3 Theoretical, Empirical, and Conceptual Frameworks

2.3.1 Theoretical framework

Diffusion of Innovation (DOI) theory Rogers (1962) is the theory guiding this study. This theory explains why farmers choose to adopt new ideas. Likewise, the theory predicts how and at what rate an innovation will be adopted by farmers in a community. Adoption is defined as a means that a person does something different than what they had previously (Rogers, 1995). The key to adoption is that the person must perceive the idea, behaviour, or product as new or innovative (Rogers, 1995). Additionally, by using the theory, coffee stakeholders and government could assist farmers to develop a receptive mind, hence improving knowledge transfer to them on improved coffee varieties and implementation of GAPs and decide to accept or reject innovation.

2.3.2 The empirical framework

The implicit theory supporting the decision to adopt improved technologies is modelled in innovation-diffusion theoretical perspectives (Rogers, 1995). This study adopts and modifies the conceptual framework of diffusion as a linear model that shows a linear relationship between the background variables (socio-economic), independent variables, and dependent variables (Rogers, 1995). However, the socio-economic context includes variables such as age, gender, marital status, income, and education level which are thought to affect the thinking and perceptions of smallholder farmers to adopt a new coffee variety developed by TaCRI. This study integrates this theory to develop a conceptual understanding of the research problem.

2.3.3 The conceptual framework

The conceptual framework used in this study is built on the innovation-diffusion theory proposed by (Rogers, 1995). The study employed a random utility framework in analysing the adoption of improved coffee variety. The adoption of improved coffee varieties can be influenced by the expected benefits (higher yields and profit). This study assumed that a smallholder coffee farmer is a rational producer and will, therefore, make a rational production decision of whether to adopt or not to adopt the high-yielding, disease resistance with good beverage quality coffee varieties. Considering the presence of improved and traditional coffee varieties, farm households have choices of planting only traditional varieties, only improved varieties or a combination of the two if doing so will maximize utility. These reasons are based on farmers' perceptions of what they think are the major factors that influence their decision of choice. Since farm households aim to make maximum profits from their choices by comparing the benefit provided to them by the various choices available; it is vital to understand how socio-economic characteristics, technology characteristics, and institutional factors influence smallholder farmers' adoption of improved coffee varieties in the study area as presented in Fig. 1.2.

2.4 Methodology

This section refers to the methodology used in this study as presented in chapter one.

2.4.1 Data analysis

The analysis involved descriptive statistics for quantitative data and content analysis for qualitative data. The qualitative data were broken down into the smallest meaningful units of information and/or themes and summarized to supplement important information concerning the objectives of the study. The collected quantitative data were coded, edited, and analysed using the Statistical Package for Social Sciences (SPSS) version 16 Computer software. Descriptive statistics such as mean, standard deviation, frequency, and percentages were computed. The inferential analyses were done using the t-test at a p-value of 0.05 level of significance to determine the association between the perception of improved coffee varieties and demographic/socio-economic variables.

2.4.1.1 Perception of smallholder farmers on improved coffee varieties

Smallholder farmers' perceptions of improved coffee varieties were gauged on a five-point Likert scale which consisted of 5 levels, strongly disagree, disagree, neutral, agree, and strongly agree, with scores 1, 2, 3, 4, and 5 respectively. Likert- scale type of interview items findings in a single score that represents the degree to which a person agrees or dis-agree with responding concerning the question asked (Bernard, 2006).

2.4.1.2 Factors influencing adoption of improved coffee varieties

To identify the determinants of adoption, the logistic regression model was employed because it is a suitable model to identify factors that influence the probability of adoption of improved technologies among farmers (Bushara *et al.,* 2018). The model was adapted from similar studies, for example, Bushara *et al*. (2018), Lugandu (2013) and Mariano *et al.* (2012). The binary model is motivated by the fact that, when faced with a decision regarding an innovation, a farmer either adopts or rejects the technology. The logistic regression model was chosen because of the discrete or partly-discrete nature of adoption decisions. Because not all coffee producers use improved varieties and because even those who have adopted the improved coffee varieties may not allocate all of their coffee farms to these varieties, then logistic regression becomes a suitable model for this study. There is widespread literature showing that farmer adoption decisions can be analysed using this model. The dependent variable for this study was the farmer being an adopter taking the values of 1 and 0 for non-adopters of improved coffee varieties. In this study, adopters of improved coffee varieties are defined as farmers with a minimum of 300 improved coffee trees grown on their farms while others were considered non-adopters. By considering this definition, the value of 1 indicates adopters while the value of 0 indicates non-adopters. Thus, the following simple regression model was analysed using STATA.

$$P_i = \frac{1}{1+e^z} = \frac{e^z}{1+e^z} \quad \text{.........................} (2.1)$$

Where: P_i is the probability that the i^{tch} farmer adopted the new varieties and that P_i is nonlinearly related to Z_i(i.e. X_i and β_s).

$Z_i = \beta_0 + \beta_i X_i + \cdots + \beta_n X_s$ and e represents the base of natural logarithms

Then, $(1 - P)$, the probability of non-adopters of improved coffee varieties is presented as:

$$1 - P_i = \frac{1}{1+e^z} \quad \text{.........................} (2.2)$$

Therefore, by dividing equation 2.1 by equation 2.2, the odds ratio in favour of adopting the improved variety was obtained as follows:

$$\frac{P_i}{1+e^z} = \frac{e^z/_{1+e^z}}{1/_{1+e^z}} = e^z \quad \text{.........................} (2.3)$$

Again, to estimate the logit model, the dependent variable was transformed by taking the natural log of Equation 2.3 as follows:

$$L_i = \left(In\frac{P_i}{1-P_i}\right) = Z_i + \beta_0 + \beta_i X_i + \cdots + \beta_n X_s \quad \text{.........................} (2.4)$$

Where: L_i is the log of the odds ratio, linear not only in the explanatory variables but also in the parameters. L is the logit, and hence it is the logit probability model. It is, thus, noted that the logistic model defined in Equation 2.4, is based on the logit Z_i which is the stimulus index. This verifies that Z_i ranges from $-\infty$ to ∞ + P_i ranges between 0 and 1.

Logistic Regression was developed using farm and farmer-specific characteristics. Since the variables are dichotomous, 1 is used if a farmer is likely to adopt improved coffee varieties and 0, otherwise. The dependent variable is the adoption of improved Arabica coffee varieties. The other variables in the model are expressed in equation 2.5. This analysis was carried out using the Stata, Second Edition assuming the absence of multicollinearity.

$$Y_1 = \beta_0 + \beta_1 Sex + \beta_2 Age + \beta_3 Edu + \beta_4 HHsize + \beta_5 Memb + \beta_6 Ext + \beta_7 Train + \beta_8 FS + \beta_9 Market + \beta_{10} Variety + \beta_{11} Inc + \varepsilon i$$

……………………………………………………………………………………………..… (2.5)

Where: Y_i =takes the value of 1 for adopters and 0 for non-adopters for the i^{tch} farmer; X_i =the explanatory variables which include;

β_1 Sex = Sex of respondents defined as a dummy variable. Male-headed households are expected to be better adopters than female household heads because female-headed households are hypothesized to have fewer resources and are less likely to have access to new information than male-headed households.

β_2 Age = Age in years; Age of household head either positively or negatively influences improved variety adoption. Older household heads have more experience in farming and so make better farming decisions. However, younger household heads may be more innovative and less risk-averse.

β_3 Edu = Level of education of the household head. This is a proxy for individuals' knowledge about new varieties. Better knowledge will positively influence the adoption.

β_4 HH size = Household size. A larger household provides more labour thus expected to positively influence adoption.

β_5 Member = membership of the primary cooperative. Membership in primary cooperatives may have better access to information which will positively influence adoption.

β_6E xt = Extension contact. Access to extension advice should findings in households making better farming decisions, including that of adopting an improved variety.

β_7T rain = Training on coffee farming. Access to farmer training on coffee farming is expected to positively influence farmers' adoption.

β_8 FS = Farm size (ha). It is the total land that a household had access to during the reference year. Farm size is a proxy for wealth. A larger landholding is expected to positively influence adoption.

β_9 Market = Access market information. Access to market information particularly on price influence farmer decision as to what to invest in or produce.

β_{10} Variety = Access information about coffee variety. Farmers who are in a better position to access information can make better farming decisions, including adopting an improved variety.

β_{11} Inc = Sources of income. Alternative sources of income can positively or negatively influence the adoption of technology. The higher the income the alternative available the more likely to be adopted or not and e = Error term: It is assumed the error term is independent and normally distributed with mean zero (0) and known variance (σ^2) β_0 = Intercept, β_1… β = Regression Coefficient.

2.5 Findings and Discussion

2.5.1 Socio-economic characteristics of respondents

The finding as presented in Table 2.1 showed the socio-economic characteristics of respondents in the study area. The descriptive analysis indicated that the average age of smallholder farmers in the study area is 49 years. The age of farmers was categorized into three categories for both adopters and non-adopters. The findings showed that 43 % of adopters and 41 % of non-adopters of improved coffee varieties were between 46 and 60 years. It was also found that 22 % of adopters and 30 % of non-adopters were in the age category of 36 and 45 years while 18 % of adopters and 17 % of non-adopter were in the age category of above 60 years whereas 16 % and 13 % for adopters and non-adopters were in the age category of 18 and 35 years. The findings imply that coffee farming in the study area is dominated by a middle-aged group active to perform agricultural activities with fewer youth participating in coffee farming. Youth have a perceived notion that, coffee farming is not profitable partly because of unstable coffee prices in the world market but also because of other activities such as avocado farming and doing business which is perceived to have relatively higher returns (BOT, 2019; ICO, 2018a).

The findings indicated that 75 % of adopters were male while 25 % were female. Similarly, 85 % of non-adopters were male and 15 % were female. The findings also show that the mean difference between the two groups of adopters and non-adopters is statistically significant (p=0.023). The findings provide evidence that coffee farming is dominated by males with few females participating in the coffee farming process. Females are less involved in coffee farming because they have systematically lower access to resources, such as land and information than males (ICO, 2018a; Imron *et al.*, 2019; Lyon, 2019; Seleman, 2017).

Likewise, the findings show that about 97 % of adopters and 96 % of non-adopters were married. The marital status of a household head can determine the level of adoption of improved coffee varieties in the study area since it can be associated with agricultural land ownership. However, there was no observable difference between adopting and non-adopting household heads in terms of their gender and marital status. The study conducted by Leavens and Anderson (2011) found that the marital status of the farmer implies land ownership because marriage affects the production process as it increases labour availability in the household while widows and unmarried females often suffer the consequences of land ownership.

Meanwhile, the findings show that 89 % of both respondents' adopters and non-adopters of improved coffee varieties have primary levels of education. The finding implies that the majority of smallholder farmers were literate enough to use the improved coffee varieties. The formal education status increases the probability of farmers adopting new technologies compared to farmers with no formal education and it has a positive and significant influence on adoption (Bushara *et al.*, 2018; Ghimire *et al.,* 2015; Mwakatwila, 2016; Udensi *et al.,* 2011).

The household size was categorized into three groups, where the majority 53 % of adopters and 51 % of non-adopters were in a group of 5-6 persons with the average number of 5 and 6 people per household respectively. The mean difference between the two groups is statistically significant (p=0.015). The findings imply that the number of family members in the household might influence farmers' decision of adopting. The findings are in line with the 2012 population and housing census, that the average household size in the study area is 5 to 6 members respectively (URT, 2013).

Likewise, the findings show that 62 % of adopters and 74 % of non-adopters of improved coffee varieties have other alternative sources of income than coffee which include crop farming, livestock keeping and business. The mean difference between the two groups of adopters and non-adopters was found to be statistically significant (p=0.016). This implies that ownership of different sources of income might influence farmers' decision to the adoption of improved coffee varieties.

Furthermore, the findings from descriptive statistics indicate that the average land size owned by adopters is 1.25 ha and non-adopter is 1.75 ha and their mean difference is statistically significant (p=0.003). The land size owned by farmers was categorized into five categories for both adopters and non-adopters and the findings show that the land planted for improved coffee varieties is small than the area planted for traditional coffee varieties.

Table 2.1: Socio-economic characteristics of respondents in the study area

Descriptions		Mbinga		Mbozi		All		t	p>t
		% of adopters	% of Non-adopters	% adopters	% of Non-adopters	% adopters	% of Non-adopters		
Age group of respondents	18 -35 years	18	11	14	14	16	13	-0.092	0.926
	36 - 45 years	16	30	31	29	22	30		
	46 - 60 years	47	35	39	45	43	41		
	>60 years	19	24	16	11	18	17		
Sex of respondent	Male	70	80	82	89	75	85	2.28	0.023
	Female	30	20	18	11	25	15		
Marital status	Married	97	99	98	96	97	96	0.414	0.679
	Single	1		2	1	2	1		
	Divorced	1	1		3	1	2		
Level of education in the category	Not attended school	1	1		5	1	3	-1.312	0.190
	Primary	93	95	84	85	89	89		
	Secondary	4	4	14	8	8	6		
	College	1		2	1	2	1		
	Adult education				2		1		
Household size grouped	1-2 persons	3	3	14	3	7	4	1.374	0.170
	3-4 persons	14	12		7	8	9		
	5-6 persons	56	55	47	48	53	51		
	Above 6 persons	27	29	39	43	32	36		
Other sources of income	Yes	70	75	49	74	62	74	2.421	0.016
	No	30	25	51	26	38	26		
Land size in the category	Less 0.5 ha	23	8	26	10	24	9	5.744	0.000
	0.5 - 0.99 ha	34	22	41	19	37	20		
	1-1.49 ha	22	26	20	28	21	28		
	1.5-1.99 ha	6	16	6	19	6	18		
	>= 2 ha	15	28	8	24	12	26		

2.5.2 Rate of adoption of improved coffee varieties by smallholder farmers

The findings as presented in Table 2.2 indicate that the overall rate of adoption of improved coffee varieties is 38 % which is higher than that reported by Mhando and Mdoe (2017) and TaCRI, (2017) (20 %). The possible explanation for the increase in the rate of adoption can be attributed to some reasons.

The reasons were the government directives of 2017/18 that require coffee seedlings multiplied by TaCRI and local government authorities to be distributed to farmers for free. The price of coffee seedlings from TaCRI-owned nurseries and nurseries owned by the district council before the government directives were 300 TZS per seedling. The government ordered these stakeholders to multiply and distribute coffee seedlings to farmers for free.

The increased capacity of TaCRI to produce compact seeds and the strengthening of farmer groups to multiply coffee seedlings using coffee seeds contribute to multiplying more coffee seedlings in a short period and time. Before compact seeds, the method used for coffee seedlings multiplications include clonal propagation and grafting methods. The seedlings multiplied through clonal and grafting methods were not highly preferred by the majority of stakeholders because it requires enough skill and knowledge to ensure that true-to-type coffee seedlings are produced (Magesa *et al.,* 2018).

The rate of adoption of technology is measured in terms of the number of persons who adopted that particular technology. However, the analysis shows that the rate of adoption in the Mbinga District is 44 % whereas in Mbozi District is 32 %. The high adoption rate in Mbinga District could be associated with the emphasis given by the Mbinga district council to promote coffee production and the adoption of improved coffee varieties. These findings comply with the theory of adoption of technology reported by Rogers (1995) that the adoption of technology is a process that requires time and resources and the theory of change.

Table 2.2: Rate of adoption of improved coffee varieties by smallholder farmers

District	Ward		Adopters		Non - adopters		Total	
		Village	Frequency	%	Frequency	%	Frequency	%
Mbozi	Igamba	Mwanda	6	12	33	31	39	25
		Itepula	2	4	13	12	15	10
	Ihanda	Hasketwa	8	16	7	7	15	10
		Masangula	14	29	28	26	42	27
	Isansa	Isansa	6	12	15	14	21	14
		Isangu	13	27	10	9	23	15
	Total		**49**	**32**	**106**	**68**	**155**	**100**
Mbinga	Kilimani	Sepukila	27	37	29	32	56	34
	Utiri	Utiri	17	23	30	33	47	28
	Luwaita	Luwaita	11	15	9	10	20	12
		Buruma	18	25	24	26	42	25
	Total		**73**	**44**	**92**	**56**	**165**	**100**
Grand total			**122**	**38**	**198**	**62**	**320**	**100**

2.5.3 Perception of smallholder farmers on improved coffee varieties

The findings as presented in fig. 2.1 reveal that 66 % and 55 % of respondents in the Mbozi and Mbinga Districts respectively agree that the improved coffee varieties are resistant to CBD and CLR. This implies that the performance of improved coffee varieties continues to show stability across the coffee ecosystem on the resistance of CBD and CLR. The CBD can quickly destroy 50 % to 80 % of the developing berries and CLR infection can cause severe leaf defoliation leading to the die-back of primary branches, followed by the death of the coffee tree (Mtenga, 2016).

Likewise, 52 % of respondents in Mbozi and 48 % in Mbinga Districts agree on the attribute of high yielding of the improved varieties. These findings are similar to what Kilambo *et al.* (2015) documented that the coffee growers in Hai, Rombo and Mbinga Districts evaluated the improved compact varieties using a “pair-wise and matrix ranking” as part of a participatory approach in selecting elite compact coffee hybrids and finds these varieties to be better than commercial variety N39. This may imply that respondents have more of a profit-maximization objective expressed by higher demand for yield to maximize income (Wale *et al.,* 2005).

Meanwhile, the findings show that 52 % of respondents in the Mbozi District and 41 % in the Mbinga District agreed on the attribute of early maturity of the improved coffee varieties as among the factors that motivate farmers to opt to plant these varieties. Improved coffee varieties take 18 months to mature and farmers can start getting the first harvest while the traditional coffee varieties take 36 months to mature (Kilambo *et al.,* 2015; Magesa *et al.,* 2018). This was anticipated to be an obstacle to adopting the improved coffee varieties but it was different. This is because farmers who adopted improved coffee varieties target to maximize productivity and profitability provided there are good markets for the produce (Wale *et al.,* 2005).

However, during the FGDs, adopters of these varieties in the study area have consigned about dying back of these varieties. According to Maro et al. (2014), dying back can be attributed to many factors including prolonged drought, pests and disease and also low use of fertilizer during the high crop season.

The findings from the Likert scale are in line with the theory of diffusion of innovation of technologies and the theory of change. These theories explain that the adoption of technology increases time after time if the community see the utility of adopting that particular innovation and how a given intervention, or set of interventions, is expected to lead to specific development change.

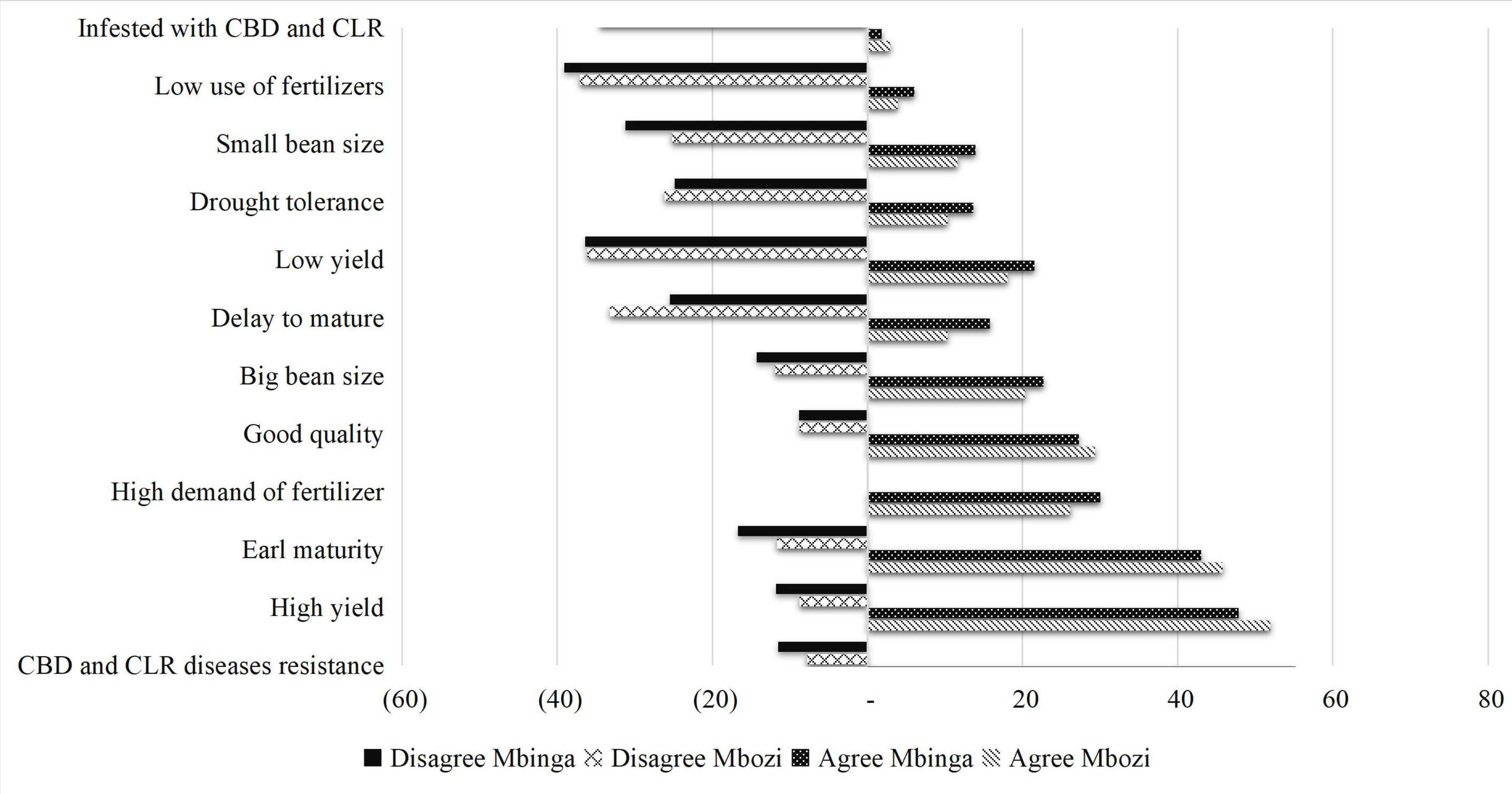

Figure 2.1: Perception of smallholder farmers on improved coffee varieties

2.5.4 Factors influencing adoption of improved coffee varieties

The results in Table 2.3 from the logistic regression model showed the statistically significant ($p<0.01$) that the number of contacts by extension officers influences the adoption of improved coffee varieties. This implies that the availability of extension services is an important aspect to influence the adoption of improved coffee varieties.

Access to extension services has been widely reported to influence the adoption of agricultural technologies (Ghimire *et al.,* 2015; Lugandu, 2013; Teferi *et al.,* 2015). Meanwhile, the findings show adoption of improved coffee varieties is also influenced by farmers be a membership in the primary cooperative (p=0.000). The findings imply that farmers' membership in cooperatives gets a chance to improve their social interactions and exchange of information among farmers which in turn enhances technology adoption (Mwakatwila, 2016).

Moreover, the result indicated that farmer access to improved varieties influences the likelihood of farmers adopting improved coffee varieties (p=0.000). These findings support Luzinda *et al.* (2018); Mmbando and Baiyegunhi, (2016) and Nyanga, (2012) who found that access to technology has a positive relationship with the adoption of technologies of that particular crop. During the FGDs, it was reported that the lack of improved coffee seedlings hinders farmers to adopt these varieties.

Nevertheless, the findings indicated that farmers' access to market information affects the adoption of improved coffee varieties (p=0.006). This implies that, if farmers have a positive perception about the varieties to meet the preferences of consumers, the adoption will increase so as they can produce more and sell in the market and vis versa. Lack of proper market information hinders the adoption of new technology because producers are willing to adopt technology that has market demand. Access to information about the improved coffee varieties (p=0.000) affects the adoption of improved coffee varieties. Different studies have reported that access to information may positively or negatively influence the adoption of that particular technology *(*Chagwiza *et al.,* 2016). This depends on the kind of induced information given to farmers and their capability to digest and understand that information to make proper action of adopting or not adopting.

During the FGDs, it was reported that the life span of improved coffee varieties is shorter than the traditional varieties, and the quality keeps some farmers in dilemma for deciding on whether to adopt or not. According to Maro *et al.* (2014), low use of fertilizers to productive coffee trees, the prolonged drought due to unreliable weather conditions, can cause die-back.

The land size (p=0.000) negatively influenced the adoption of improved coffee varieties. Possible explanation of this outcome is that, most of the farmers establish their farms with the new improved coffee varieties through clearing of the old coffee farm with traditional variates and or clearing forest and burning. This activity causes deforestation, land ruin, and depletion of soil nutrient as previously documented in TaCRI (2017). Meanwhile, with the rapid population growth, to increase crop output is less possible by land extension to fresh areas where the depletion of soil nutrients has either occurred leading to low crop productivity. Different studies have shown that land size has a positive or negative effect on the likelihood of farmers adopting improved technologies (Ghimire *et al.,* 2015; Lugandu, 2013; Teferi *et al.,* 2015).

During the FGDs it was reported that improved coffee varieties require more inputs such as labour and fertilizer application than traditional coffee varieties hence increasing the cost of production for large land sizes and low-income farmers to become difficult to afford hence high crop loss will happen because of poor management.

Table 2.3: Factors influencing the adoption of improved coffee varieties

Varieties	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Age of respondent (years)	0.015	0.022	0.700	0.482	-0.028	0.058
Sex of respondent (Dummy)	-0.052	0.050	-1.050	0.295	-0.151	0.046
Level of education of respondent (years)	0.011	0.011	1.020	0.308	-0.010	0.032
Household size (number)	0.031	0.026	1.210	0.228	-0.019	0.081
Income from other crops (TZS/year)	-0.116	0.089	-1.300	0.194	-0.292	0.059
Income from livestock ((TZS/year)	0.039	0.045	0.880	0.381	-0.049	0.128
Contact by extension officers (Number of Visits)	0.039	0.021	1.840	0.067	-0.003	0.080
Farmer training on GAPs (number)	0.051	0.061	0.830	0.408	-0.070	0.171
Member of primary cooperative (Dummy)	0.406	0.065	6.270	0.000***	0.279	0.534
Access to market information (Dummy)	-0.150	0.054	-2.780	0.006**	-0.257	-0.044
Access to improved coffee varieties (Number)	0.407	0.057	7.170	0.000***	0.296	0.519
Information about coffee varieties planted (Dummy)	-0.149	0.034	-4.340	0.000***	-0.216	-0.081
Total land size owned (ha)	-0.057	0.015	-3.670	0.000***	-0.087	-0.026
_cons	0.278	0.236	1.180	0.240	-0.186	0.743

*Significant difference p < .05, **highly significant p<.01, *** very highly significant p<.001

The findings in Table 2.4 indicated that the F-statistics of *F (13, 306)* = 54.2 was statistically significant (p=0.000) indicating a joint influence of the independent variables on the dependent variable and that the model existed. The R-squared was 0.542, implying that 54.2 % of the factors affecting the adoption of improved coffee varieties are explained by the factors combined from the STATA scores analysis.

Table 2.4: Summary of Logistic regression model

Source	SS	df	MS	F	Sign.
Model	40.880	13	3.145	27.8	<.000
Residual	34.608	306	0.113		
Total	75.488	319	0.237		

2.6 Conclusions and Recommendations

2.6.1 Conclusion

This study aimed at assessing perception and determining factors influencing the adoption of improved coffee varieties among smallholder farmers in the Mbinga and Mbozi Districts. It was noted that the rate of adoption is increasing in the study area notably due to the observed performance of these varieties under the farmers' management level. Both adopters and non-adopters of improved coffee varieties have a positive perception of attributes of improved varieties particularly having high yields, producing good beverage quality, and they are resistant to coffee leaf rust (CLR) and coffee berry disease (CBD). The factors that positively influence the adoption of improved coffee varieties include visits by extension officers, membership of primary cooperatives and access to improved coffee varieties while factors negatively affect the adoption of improved coffee varieties are access to market information, access information about coffee varieties planted by farmers and land size owned (ha). However, the lack of enough improved coffee seedlings hinders the majority of farmers to adopt the improved coffee varieties. Thus, based on the findings of this study the null hypothesis was rejected in favour of the alternative hypothesis that the government efforts of promoting and disseminating improved coffee varieties has positive impact on productivity and profitability among adopters and non-adopters of improved coffee varieties. The socio-economic characteristics, institutional factors and farm characteristics showed a significantly influence the rate of adoption of improved coffee varieties.

2.6.2 Recommendations

This study recommends that the coffee industry should strengthen extension services including capacity building to extension officers in coffee growing districts through training and also transport facilities to disseminate appropriate information to farmers. The government should provide support to improve logistics and infrastructure for coffee seedling multiplications and distributions to farmers to meet the demand. Meanwhile, TaCRI should develop a seed certification system that will guide and control the quality of coffee seeds and seedlings to avoid and minimize the risk of farmers collecting seeds and seedlings from unknown coffee varieties that are not recommended. These recommendations will contribute to an increase in the rate of adoption of improved coffee varieties hence increasing productivity and profitability, also will contribute to an increase in the rate of adoption of improved coffee varieties hence increasing productivity and profitability.

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CHAPTER THREE

MANUSCRIPT TWO

3.0. ASSESSMENT OF COFFEE YIELD GAP AMONG ADOPTERS AND NON-ADOPTERS OF IMPROVED COFFEE VARIETIES IN MBINGA AND MBOZI DISTRICTS [2]

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3.1 Abstract

Coffee productivity in Tanzania is still low despite having coffee varieties with the potential of producing more yields. This study aimed at understanding factors affecting coffee productivity and causing the yield gap among smallholders in the study area. The primary data were collected from 122 adopters and 198 non-adopters of improved coffee varieties using a semi-structured questionnaire. The descriptive statistics and Soil Analysis for Fertility Evaluation and Recommendation on Nutrient Application to Coffee (SAFERNAC) model were used to analyse the coffee yield gap while the linear regression (OLS) model was used to determine factors influencing coffee productivity. The findings revealed that 38 % of respondents adopted improved coffee varieties and 43 % of the total area under coffee has planted these varieties. The average fertilizer application for both adopters and non-adopter was below the recommended rate. Fungicide applications to control Coffee Berry Diseases (CBD) and Coffee Leaf Rust (CLR) were found to be below the recommended rates. The average coffee productivity attained by adopters is 1250 kg/ha and by non-adopters is 512 kg/ha. The descriptive analysis shows that the yield gap for adopters was 750 kg/ha equivalent to 38 % and for non-adopters 488 kg/ha equivalent to 49 %, implying that farmers gain less than the potential yield. Likewise, the farmers' actual yield was below the estimated yield with the SAFERNAC model. The main factors positively influencing coffee productivity were coffee variety planted (p=0.055), plant population (p=0.000), access extension services (p=0.008), fertilizer applications (p=0.001), pruning (p=0.003) and amount of fertilizer applied (p=0.001). The study concludes that the coffee productivity among adopters and non-adopters of improved coffee varieties is affected by observed agricultural practices such as use low use of fertilizer, improper control of coffee pests and diseases, poor pruning, weeding and the impacts associated with climate change. Therefore, the study recommends that government should strengthen extension services to ensure farmers access the right information on recommended fertilizers application rates and the use of fungicides. Also, farmers should implement recommended agricultural practices as per the type of coffee varieties planted, which means that farmers are required to know the line of coffee varieties planted because they have different management practices and it could

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contribute to increasing coffee productivity to attain the optimal level and minimize yield gap.

Keywords: Coffee, adopters and non-adopters, coffee varieties, the coffee yield gap

3.2 Introduction

The current world coffee demand is estimated to exceed production due to an increase in global coffee consumption (ICO, 2019a). An increase in coffee productivity is one of the thrusts aimed at transforming the economic growth and development of coffee producers in Tanzania (TCB, 2012a). In Tanzania, 90 % of coffee is produced by smallholder farmers with average productivity of 250 to 300 kg/ha for Arabica coffee and 450 kg/ha for Robusta coffee (BOT, 2017). Coffee yield from other countries such as Kenya stands at 302 kg/ha of clean coffee (ICO, 2019a), Ethiopia 802 kg/ha (Bickford, 2019), Rwanda 880 kg/ha (Nzeyimana, 2018) and Uganda 2100 kg/ha (ICO, 2019b) which is relatively higher than in Tanzania. In general, it can be argued that coffee yield from smallholder farmers in Tanzania is low despite Tanzania having coffee varieties with the potential of producing 2000 kg/ha for improved and 1000 kg/ha for traditional coffee varieties (Kilambo *et al.,* 2015). Progressive promotion of high-yielding coffee varieties and advocating the implementation of good agricultural practices (GAPs) such as proper selection of coffee seedlings. Planting space, weeding, control of coffee pests and diseases, pruning, fertilizer application, and control of soil moisture and soil erosion through mulching and planting coffee trees were expected to increase coffee yield among adopters and non-adopters of improved coffee varieties. Despite the higher yield in research trials empirical evidence on how the varieties are performing under farmers management is limited. The yield gap analysis method was used in this study to understand the yield gained by farmers against the average research yield and factors causing the coffee yield gap among smallholder farmers in the study area. The findings from this study will help researchers, policy makers and other stakeholders to come up with strategies that can be used to contribute to minimise the yield gap.

3.3 Theoretical, Empirical, and Conceptual Frameworks

3.3.1 Theoretical framework

Agricultural production is concerned primarily with economic theory as it relates to the producer of agricultural commodities (Debertin, 1986). The major concerns in agricultural production economics among other goals and objectives of the farm manager include a choice of outputs to be produced, and allocation of resources among outputs choices. The household production theory explains the relationship between inputs and outputs, which is the transformation of factor inputs into outputs (Muellbauer, 1974). This theory predicts that farm productivity will differ over farms using different levels and combinations of inputs. This theory considers a simplified view of the economy in which production output is determined by the amount of input involved and the amount of capital invested. The strategies for increasing coffee production in Tanzania include encouraging investment in the promotion of improved coffee varieties and farmer training on the implementation of good agricultural practices such as farm rehabilitation, application of fertilizers, control of coffee pests and diseases using recommended pesticides, and fungicides (TCB, 2012). Therefore, this theory is useful as the basic framework for understanding the causes of the yield resulting from utilizing the major inputs of coffee production in the study area.

3.3.2 The Empirical Framework

Different approaches such as field experiments (van Ittersum *et al.,* 2013), crop growth simulation models (Lu & Fan, 2013; van Bussel *et al*., 2015), socio-economic surveys (Tamene *et al.,* 2016), and precision agriculture (Schulthess *et al.,* 2013; Tittonell & Giller, 2013) have been used to assess farmers' yields and yield gaps between households. The field experiments approach is used to compare farmers' yield 'control' and research yield within the experimental plots (van Ittersum *et al.,* 2013). This approach does not set the optimum yields to the level attainable by farmers and the limited number of test locations makes it difficult to upscale to larger areas (Tittonell & Giller, 2013). Crop growth simulation models (Lu & Fan, 2013; van Bussel *et al.,* 2015), compare the potential yield with the actual yield but require intensive data for model input, calibration, and validation (van Ittersum *et al.,* 2013). Precision agriculture which is fast and accurate is used to measure the yield of plots in real time but it is more technology-intensive (Tittonell & Giller, 2013). The socio-economic survey captures yield harvested by smallholder farmers and corresponding agronomic/management practices depend much on farmers' memory and it is time-saving (Tamene *et al.,* 2016). Because this is a cross-sectional study that depends much on the data reported by farmers, this study, therefore, opts to use the socio-economic survey because the nature of data collected from the study area depends on farmers' records.

3.3.3 The Conceptual Framework

The conceptual framework developed in this study focuses on three main components which include the agronomic, socio-economic, and institutional factors that influence coffee yield as expressed in Fig. 1.2. Agronomic factors such as weeding, pest and disease control, coffee varieties planted, plant population, application of fertilizer, and farm expansion were analysed to determine their influence on coffee yield. The socio-economic factors such as level of education which was hypothesized to influence farmers' adoption and implementation of good agricultural practices were also considered as an important variable that might influence coffee yield. Institutional factors including access to extension services were among the key variables of analysis which in one way or another, influence coffee yield. It was hypothesized that the farmers who access extension services get a higher yield than their counterparts who do not access the service. From these sets of variables, the yield gap among smallholder farmers was determined and the factors influencing the level of coffee yield were analysed.

3.4 METHODOLOGY

This section refers to the methodology used in this study as presented in chapter one.

3.5 Data Analysis

The analysis involved descriptive statistics for quantitative data and content analysis for qualitative data. The qualitative data were broken down into the smallest meaningful units of information and/or themes and summarized to supplement important information concerning the objectives of the study. The collected quantitative data were coded, edited, and analysed using the Statistical Package for Social Sciences (SPSS) version 16 Computer software. Descriptive statistics such as mean, standard deviation, frequency, and percentages were computed. The inferential analyses were done using the t-test at a p-value of 0.05 level of significant to determine the association between the perception of improved coffee varieties and demographic/socioeconomic variables.

3.5.1 Coffee yield estimation among smallholder farmers

The surveyed data were subjected to descriptive and inferential analyses of a 5 percent level of significance. Data collected through farmer interviews were coded and analysed using the SPSS whereby descriptive statistics (i.e., frequencies, percentages, and means, minimum and maximum values of variables) were determined. The inputs such as fertilizer pesticides and fungicides used as reported by farmers recall were converted to standard unit conversion factors of which for this study was g/tree for fertilizer application, litre per ha for fungicide and pesticide application. The coffee yield reported by farmers' recall was converted to standard unit conversion factors which are kg/ha. The findings were compared using a t-test of difference in means to establish if there is any statistically significant (at 5 percent) difference between yield obtained by adopters and non-adopters of improved coffee varieties.

3.5.2 Yield gap analysis

The farmer Yield gap (Yg) can be computed as the difference between the maximum farmer yield attained and the estimated average yield under farmers' management or the difference between an average research yield (generally reported from on-farm research trials which are potential yield) and average yield under farmers management practices. Different studies such as Pushpa and Srivastava (2014) and Sadras (2015) different methods to compute yield depending on their objectives. The yield gap was then computed by taking the difference between the estimated national average research yield (Yr.) and the average farmer's yield obtained from the primary data collected from the study area under farmers' management practices (Yf). The research yields data was obtained from research records published by Tanzania Coffee Research Institute (TaCRI) reports. The average farmer yield was obtained from the primary data collected from January to April 2020 in the study area. Arithmetically the yield gap was expressed as follows:

$Y_g = Y_r - Y_f$ ………………………………………………………………..……………... (3.1)

Where:

Y_g =Yield gap (kg/ha), Y_r = research yield (kg/ha) and Y_f = the average farmers' yield (kg/ha).

This study also employed a Soil Analysis for Fertility Evaluation and Recommendation on Nutrient Application to Coffee (SAFERNAC) which is a yield simulation model used to predict the yield parchment considering soil properties such as Organic Carbon (OC), total nitrogen (N), available phosphorus (P) and exchangeable potassium (K) and pH water). This model was developed by the Tanzania Coffee Research Institute, Sokoine University of Agriculture, and the Wageningen University of Agriculture Netherlands (Maro, 2014).

3.5.3 Estimation of factors affecting coffee yield

The factors affecting coffee yield were investigated by regression analysis using the Ordinary Least Square (OLS) technique. This method has been widely used in yield gap studies to show specific factors influencing crop yields (Greene, 2003). The OLS technique was employed since the dependent variable was a continuous random variable and the independent variables were either continuous or categorical, taking into consideration regression modelling assumptions. The linkages among coffee productivity and its factors were modelled to establish the important policy variables. Generally, linear function, f(.), was specified as follows:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \cdots + \beta_{12} X_{12} + e$ ………………… (3.2)

Where:
Y = coffee yield of the i^{th} crop (kg/ha),
X_1 = Education level of the coffee farmer was categorized into literates and illiterates (+): We predicted a positive relationship between this variable and coffee yield since an educated farmer can evaluate the improved production practices and make informed technical and economical choices to increase adoption.

X_2 = Frequency of weeding of the coffee farm by the coffee farmer (+): Weeds normally compete with the coffee tree for water and nutrients (Maro, 2014; TaCRI, 2011). Therefore, the higher the weed control frequency, the better for the plant to develop and produce more output and yield.

X_3 = Fertilizer application. The fertilizer variable was assumed to be a dummy variable which takes the value 1 if the coffee farmer applied fertilizer to his/her farm, and otherwise takes the value 0 (+): In Tanzania, cultivation of coffee on a piece of land has been found to result in soil fertility decline due to soil nutrient mining (Maro, 2014; Robinson, 1961). Thus, applying fertilizer to such soils can replenish the depleted soil nutrients and hence, increase coffee output and yield.

X_4 = Frequency of spraying against coffee pests such as White coffee stem borer, mealy-bug, green scale, and snail by the coffee farmer (+); These pests attack the coffee trees by feeding on the succulent foliage and in extreme cases causing death, leading to a reduction in coffee output and yield. It has been recommended by Magina (2011) and TaCRI (2011) for farmers to spray against these pests with insecticides 4 times per annum to ensure the effective control of the pests. Therefore, it was posited that high spraying frequencies result in ineffective pest control, leading to output and yield increases.

X_5 = Frequency of spraying against Coffee Berry Diseases (CBD) and Coffee Leaf Rust (CLR) disease by the farmer (+); CBD and CLR disease can destroy more than half of the crop, particularly traditional varieties (Kilambo *et al.,* 2015; TaCRI, 2011). Thus, it was assumed that high spraying frequencies could lead to effective control of CBD and CLR, resulting in increased output and yield.

X_6 = Age of coffee tree (years) (-); The older the tree, the higher the probability that coffee output and productivity will decrease, causing discouragement in farm maintenance.

X_7 = Coffee variety planted by the coffee farmer. The coffee variety variable was scored by giving a value of 1 if the farmer planted an Improved variety, and a value of 0 if the farmer planted a traditional variety (+): Improved coffee variety, which is early-bearing and high-yielding and currently recommended to farmers, is an improved variety over the traditional variety. Thus, it is anticipated that a farmer planting improved coffee varieties could produce a higher coffee yield than those with traditional varieties.

X_8 = Plant population per ha (+): The number of coffee trees per unit area was assumed to positively influence yield because as an increase in plant population per unit area the management and resource allocations would contribute to increasing the coffee output.

X_9 = Frequency of extension visits by the extension officer (+): The more frequent the exposure of a farmer to extension information of new improved production practices, the more likely he/she can be convinced to adopt the appropriate technologies to increase yield.

X_{10} = Pruning coffee tree (+): It is anticipated that proper coffee pruning will contribute to an increase in coffee yield. Pruning is recommended three times a season (TaCRI, 2011).

X_{11} = Quantity of fungicides applied to coffee farms measured in kg/ha (+): It is hypothesized that the higher the number of fungicides applied by farmers with traditional coffee varieties, the more effective will be the control of CBD and CLR disease which tends to decrease coffee output and yield. The improved coffee varieties do not require fungicide applications because they are not infested by CBD or CLR.

X_{12} = Coffee farm expansion measured in ha (-): Coffee farm expansion for coffee production is predicted to be negatively related to yield as new coffee farms require a high number of inputs such as liming because, in the study area, the soil pH is low which require to be regulated by applying liming which could require extra financial resource.

X_{13} = Quantity of fertilizers applied to coffee farms measured in g/tree (+): It is hypothesized that the higher amount of fertilizers applied per tree as recommended, the more productivity gained from a coffee tree.

e = Error term: It is assumed the error term is independent and normally distributed with mean zero (0) and known variance (σ^2) β_0 = Intercept, $\beta_1 \ldots \beta$ = Regression Coefficient.

3.6 Findings and Discussion

3.6.1 Implementation of good agricultural practices among smallholder farmers

The finding as presented in Table 3.1 shows that all farmers weed their coffee farm three times per season. According to Maro (2014), TaCRI (2011) and Robinson (1961) weeding is required to be conducted three times per season to reduce nutrient and water competition between coffee trees and weeds. The findings show that 94 % of adopters and 91 % of non-adopters apply fertilizer three times per season. It is documented in different studies including Maro (2014) and Robinson (1961) that fertilizer application helps to replenish the depleted soil nutrients resulting in soil fertility decline due to soil nutrient mining.

Table 3.1: Coffee Farm Management Practices

Descriptions		Weeding	Fertilizer	Manure	Pesticides	Fungicides	Pruning
Mbinga District							
	n	73	70	59	71	40	18
	%	100	96	81	97	55	25
Adopters	Rate	3	3	1	2	3	1
	n	92	90	86	88	79	26
Non-adopter	%	100	98	93	96	86	28
	Rate	3	3	1	2	3	1
Mbozi District							
	n	49	45	43	45	34	17
	%	100	92	88	92	69	35
Adopters	Rate	3	3	1	2	3	1
	n	106	91	84	98	92	17
Non-adopter	%	100	86	79	92	87	16
	Rate	3	3	1	2	2	1
Overall Mbinga and Mbozi							
	n	122	115	102	116	74	114
Adopters (n=122)	%	100	94	84	95	61	93
	Rate	3	3	1	2	3	2
	n	198	181	170	186	171	165
Non-adopters (n=198)	%	100	91	86	94	86	83
	Rate	3	3	1	2	2	2
t		1.084	1.584	2.38	2.533	0.852	1.022
df		318	294	270	300	243	277
Sig.		0.279	0.114	0.018	0.012	0.395	0.307

The findings indicated that 84 % of adopters and 86 % of non-adopters apply manure once per season. It was noted that a few coffee farms were mixed with different cropping systems such as green manure crops like beans and others were mixed with banana. The mixing cropping farming system contributes to improving soil nutrients and fixing nitrogen (Maro, 2014).

The findings also showed that 95 % of adopters and 94 % of non-adopters apply pesticides to control coffee pests three and two times per season respectively to control major coffee pests in the study area. During the FGDs it was noted that the white coffee stem borer (WCSB), Antestia bugs, Mealybugs, green scales, berry moth, yellow-headed borer and thrips are major coffee pests in the study area. Magina (2011) and TaCRI (2011) documented that spraying against pests with insecticides can go up to four times per annum depending on the intensity of pest infestations.

Furthermore, the finding showed that 61 % of adopters and 86 % of non-adopters apply fungicides to control coffee-related diseases three and two times per season respectively. According to Kilambo *et al.* (2015) and TaCRI (2011), farmers with traditional coffee varieties are required to spray six to nine times per annum to ensure effective control of CBD and CLR. Moreover, the findings show that 93 % of adopters and 83 % of non-adopters pruned coffee trees two times a year (season). TaCRI (2011) asserted that pruning coffee trees is required to be carried out three times in a season to have a significant impact on coffee yield.

The findings as presented in Table 3.2 show that the overall average fertilizer application for adopters of improved coffee varieties is 140 g/tree with a high rate in the Mbinga district at 160 g/tree and Mbozi District at 129 g/tree. The findings also show that non-adopters of improved coffee varieties apply 111 g/tree on average of which Mbinga apply 89 g/tree and Mbozi applies 135 g/tree. The findings revealed no statistically significant difference in fertilizer application between adopters and non-adopters (p>0.05).

Table 3.2: Fertilizer used and rates of application

Descriptions		UREA	CAN	NPK	Yara Milla Java	SA	Average
Mbinga District							
Adopters (n=73)	n	8	29	13	15	13	52
	%	11	40	18	21	18	71
	g/tree	46	82	123	102	65	129
Non-adopters	n	6	30	16	22	28	74
(n=92)	%	7	33	17	24	30	80
	g/tree	55	76	38	67	69	89
Mbozi District							
Adopters (n=49)	n	4	9	4	14	6	29
	%	8	18	8	29	12	59
	g/tree	234	95	46	70	283	160
Non-adopters	n	7	36	8	18	24	67
(n=106)	%	7	34	8	17	23	63
	g/tree	55	82	18	63	186	135
Overall Mbinga and Mbozi District							
Adopters	n	12	38	29	19	17	81
(n=122)	%	10	31	24	16	14	66
	g/tree	109	85	87	134	104	140
Non-Adopters	n	13	66	40	52	24	141
(n=198)	%	7	33	20	26	12	71
	g/tree	55	79	65	123	31	111
t		0.912	0.277	1.062	0.119	2.334	0.938
Sign.		0.371	0.782	0.292	0.906	0.025	0.349

During the FGDs, it was reported that farmers lack capital and information on the rate of fertilizer recommended. TaCRI, (2011) documented that adopters of improved coffee varieties are required to apply UREA (90 - 175 g/tree), CAN (50 – 100 g/tree), NPK (90 – 175 g/tree), Yara Milla Java (110 – 215 g/tree) and SA (90 – 175 g/tree) whereas non-adopters apply UREA (90 – 120 g/tree), CAN (50 – 65 g/tree), NPK (90 – 120 g/tree), Yara Milla Java (110 – 145 g/tree) and SA (90 – 120 g/tree). There is a need to encourage farmers to use Integrated Soil Fertility Management Practices (ISFM) for soil organic matter enrichment as documented by Maro (2014).

The findings as presented in Table 3.3 show that smallholder farmers in the study area apply different types of pesticides and fungicides to control coffee pests and diseases. The findings showed that there is no statistically significant difference between the two groups in the amount of pesticide applied in the study area. According to Magina (2011) and TaCRI, (2011) spraying against pests with pesticides or insecticides is required when pests are identified in coffee farms. Coffee pests can be controlled by using integrated pests management (IPM) practices which combine cultural, biological and chemical control.

During the FGDs, it was reported that white coffee stem borer (WCSB), Antestia bugs, Mealybugs, green scales, berry moths, yellow-headed borers and thrips are major coffee pests in the study area. However, farmers lack information about the rate and frequency of pesticides and fungicides application while others lack the capital to purchase fungicides.

The findings further show that the number of fungicides applied by adopters of improved coffee varieties to control coffee diseases such as CBD and CLR was relatively lower than non-adopters. According to Kilambo *et al.* (2015) and TaCRI, (2011) control of CBD and CLR requires the application of 35 to 49 kg/ha of fungicide per annum with an average spray of 6 to 9 times because CBD may destroy 30 to 90 % of the crop and CLR can cause losses from 30 % to 50 % in coffee production if the weather conditions are favourable to its epidemics.

During the FGDs, it was reported that, farmer lack knowledge on how to differentiate symptoms of CLR and nutritional deficiency while others can not differentiate CBD and coffee berries infested with pests. These two challenges may lead farmers to apply fungicides or pesticides inappropriately.

Table 3.3: Pest and fungicide applications

	Mbinga				Mbozi				Overall					
	Non-adopters		Adopters		Adopters		Non-Adopter		Adopter		Non-Adopters			
Descriptions	**n**	**Kg/ltr/ha**	**n**	**Kg/ltr/ha**	**n**	**Kg/ltr/ha**	**n**	**Kg/ltr/ha**	**n**	**Kg/ltr/ha**	**n**	**Kg/ltr/ha**	**t**	**Sign.**
Pesticides														
Selecrone	3	2	22	2	3	1	15	2	6	2	37	2	-0.933	0.356
Dusban	14	2	17	1	11	1	37	1	25	1	54	1	0.786	0.434
Agrocron	5	3	9	3	3	2	1	1	10	3	10	2	0.392	0.700
Crush	2	2	2	2	1	1			4	2	2	2	0.453	0.674
Roundup	14	2	33	1	2	4	22	2	18	2	55	2	1.308	0.195
Fungicides														
Blue copper	20	2	34	5	20	3	42	5	40	3	76	5	-4.344	0.000
Red copper	6	1	18	2	3	1	14	4	9	1	32	3	-2.383	0.022
Belaton	6	1	13	1	3	1	11	1	9	1	24	1	-0.812	0.423
Xanthos	2	1	11	2	3	2	18	2	5	1	29	2	-0.696	0.491
Ninja	3	1	12	2	4	0	18	1	7	1	30	2	-1.8	0.081
SNOW PLUS	3	1	6	5	4	1	8	4	7	1	14	4	-2.295	0.033
SNOW VIL			3	1	3	1	4	3	3	1	7	2	-1.443	0.187
Quadric	10	2	8	2	9	1	24	2	19	1	32	2	-0.327	0.745
MPAVIL	1	2	1	7	1	1	3	5	2	1	4	5	-1.663	0.172
Twigafosi	3	1	8	3	1	1	4	3	4	1	12	3	-2.092	0.055
Santo	4	1			2	1	2	2	6	1	2	2	-2.739	0.034

3.6.2 Coffee yield analysis among adopters and non-adopters

The findings in Table 3.4 shows that, for the 2019/20 crop season, the average coffee yield for adopters is 1250 kg/ha of parchment relatively higher ($p<0.05$) than 512 kg/ha gained by non-adopters. The average yield analysis per tree shows that, the improved coffee varieties produce 1.21 kg/tree equivalent to 60 % of the average national research yield from these varieties whereas the average yield from traditional coffee varieties is 0.38 kg/tree equivalent to 38 % of the yield potential. The improved hybrid Arabica first-generation tall, second-generation tall and compact hybrids coffee varieties have different yield potentials with an average of 2 kg//tree or 2000 kg/ha while the traditional coffee varieties N39 and KP 423 are 1 kg/tree or 1000 kg/ha (Kilambo *et al.,* 2015; Maro, 2014). The yield attained by smallholder farmers can be associated with several factors including agricultural practices and the impact of climate change.

Table 3.4: Coffee yield attained by smallholder farmers

	Mbinga		Mbozi		All	
Descriptions	**Adopters**	**Non-adopters**	**Adopters**	**Non-adopters**	**Adopters**	**Non-adopters**
Plant population	2000	1330	2000	1330	2000	1330
Average yield (kg/tree)	1.29	0.37	1.12	0.38	1.21	0.38
Average yield (kg/ha)	1293	540	1186	488	1250	512
t		9.672		9.455		13.801
Sig.		0.000		0.000		0.000

3.6.3 The coffee yield gap analysis using farmer yield record

The yield gap was computed as the difference between the estimated national average research yield (Yr.) and the average farmer's yield obtained from the primary data collected from the study area for the 2019/20 crop season under farmer management practices (Yf). The average farmer's yield was used after noting that there were no clear outliers from the primary data otherwise the median could be used if the distribution of data values is skewed or when there are clear outliers. The overall findings as expressed in Table 3.5 shows that the yield gap of adopters of improved coffee varieties is 750 kg/ha equivalent to 38 % and non-adopters are 488 kg/ha equivalent to 49 %. The findings imply that the yield gained by smallholder farmers is below the potential yield under farm management practices. The possible reasons can be variations in management practices and the impact of climate change.

Poor farm management practices contribute to low yield (Tamene *et al.*, 2016; Mondal, 2011). However, during the FGDs we have noted other key factors that contribute to low coffee yield. For example, in the Mbozi district, it was reported that erratic rainfalls, increased temperature and prolonged drought affect coffee yield.

Likewise, in the Mbinga district, it was reported that an increase in a prolonged period of coldness and frost, affects coffee flowering and ripening on time hence fruits developed during this period don’t mature on time an abortion can occur. Craparo et al. (2015) reported that the increase in temperature in the coffee-growing regions in Tanzania including the southern highlands affects coffee yield.

In addition, the occurrence of new pests and diseases such as snails was reported in the Mbozi district and this caused yield loss and widened the yield gap. Jawo *et al.* (2022) reported that the climate changes pronounced in increasing temperature and rainfall variability will reduce the bio-climatic suitable areas, growth and yield of coffee and will induce the occurrence of pests and diseases.

Table 3.5: Yield gap estimated using farmer yield records from the study area

Descriptions	Mbinga		Mbozi		All	
	Adopters (n=73)	Non-adopters (n=92)	Adopters (n=49)	Non-adopters (n=106)	Adopters (n=122)	Non-adopters (n=198)
Mean	1293	540	1186	488	1250	512
Average research yield	2000	1000	2000	1000	2000	1000
Yield gap	707	460	814	512	750	488
% of yield gap	35	46	41	51	38	49

3.6.4 The coffee yield gap analysis using the SAFERNAC model

Soil fertility data from 36 geo-referenced points of Utiri (12), Kilimani (11), Ihanda (2), Igamba (5), and Isansa (6) in two districts were fed into the model under two distinct approaches – a combination of seven tons of organic (manure) and 80 kg/ha of inorganic (NPK) fertilizers. The finding is presented in fig. 3.1 indicated that the farmer's actual yield was below the estimated yield with the SAFERNAC model. The finding implies that there is no significant mean difference between the model and the farmer's yield except for Ihanda wards. The possible reason can be attributed to data variation which is based on farmers' memory rather than farmers' record. However, the analysis still shows the actual yield reported by farmers is lower than the yield simulated by the model.

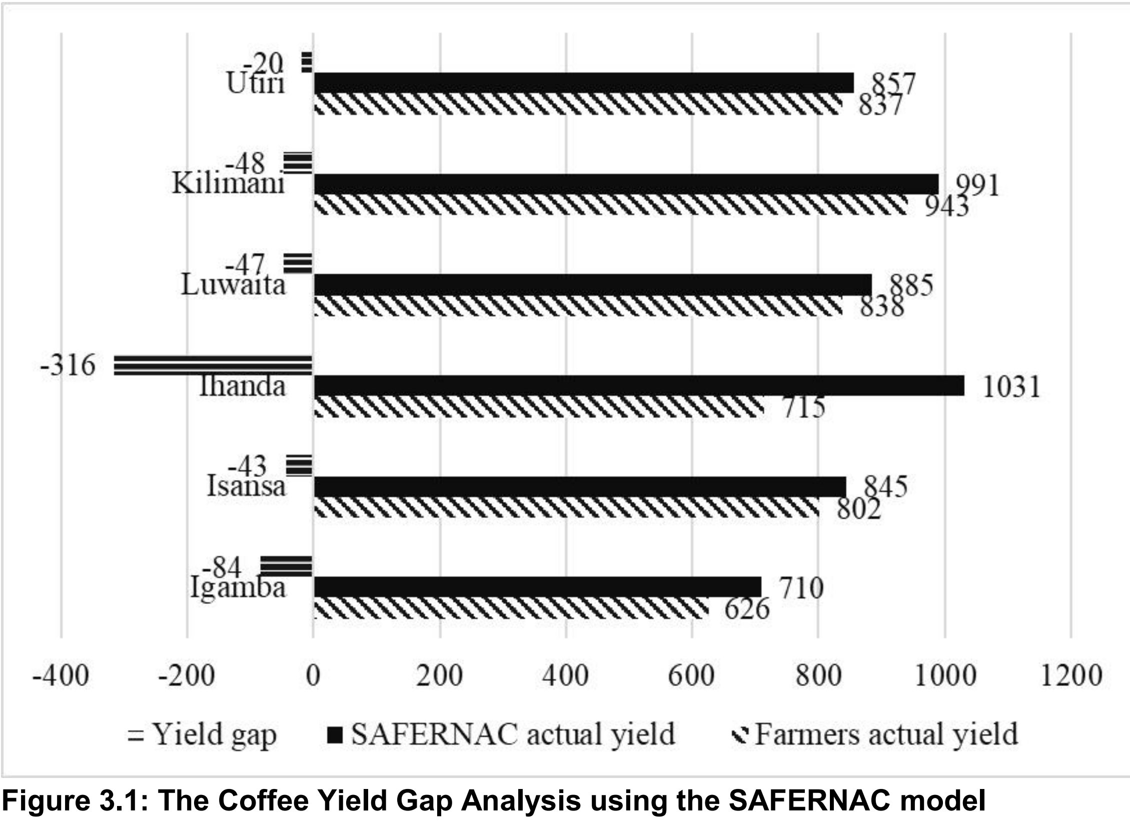

Figure 3.1: The Coffee Yield Gap Analysis using the SAFERNAC model

3.6.5 The factors affecting coffee yield among smallholder farmers

The findings in Table 3.6 show that there is a positive relationship ($p<0.05$) between coffee yield and the type of coffee varieties planted by respondents. The varieties were scored 1 for improved varieties and 0 for traditional varieties. Therefore, the improved coffee varieties produced high yields than traditional coffee varieties and this can be associated with the attributes of these varieties such as early-bearing, high-yielding, and resistance to coffee diseases like CBD and CLR for improved varieties as opposed traditional varieties (Kilambo *et al.,* 2015 and Mtenga, 2016).

Meanwhile, the findings show that the adequate number of plant populations per unit area influences coffee yield significantly ($p = 0.000$). According to TaCRI (2011), the average number of coffee plants per ha is 2000 plants of improved varieties planted in a space of 2 metres by 2.5 metres and 1330 plants for traditional coffee varieties planted in a space of 2.74 metres by 2.74 metres. Silveira *et al.* (2018), reported that reducing the spacing between rows and between plants in the row results in increased coffee yields. The number and distribution of plants are decisive to obtain high coffee yields and should be considered in the adoption of spacing for coffee crops. Coffee crops are highly influenced by the interaction genotype-environment. The yield reached by a given cultivar is related, in addition to other technical aspects, to the adopted spacing. These findings correspond with Wang *et al.* (2015) who reported the association between increased coffee tree density and coffee yield.

Furthermore, findings indicated that access to extension services influences coffee yield ($p=0.008$). Different scholars, Ghimire *et al.* (2015); Lugandu, (2013), and Teferi *et al.* (2015) documented that, farmer access to extension services helps in improving farm management practices hence increasing coffee yield.

Moreover, the finding revealed that the rate of fertilizer application and the amount of fertilizer applied have a significant influence on coffee yield ($p<0.05$). The application of fertilizers can contribute positively to increasing soil nutrients which have a direct impact on proper crop growth, yield, bean size cup quality, and eventually high price (Maro, 2014; Robinson, 1961). Thus, applying fertilizers to such soils can replenish the depleted soil nutrients and hence, increase coffee output and yield.

The findings also showed that coffee pruning ($p=0.003$) influences coffee yield. According to TaCRI, (2011), coffee pruning is recommended three times a season. The study conducted by Dufour *et al.* (2019) which makes a comparison between the average production of ripe berries on pruned and un-pruned coffee trees showed that pruning resulted in significantly higher yields over two years.

Furthermore, the expansion of the coffee farm (ha) shows a negative statistically significant ($p =0.012$) effect on coffee yield contrary to the theory where it was anticipated that the land expansion will contribute to an increase in coffee yield. This implies that, since the majority of smallholder farmers own smaller farms in the study area are more productive as they optimize more input, particularly labour, and hence the resulting output is larger. As opposed to a large land size where they require more inputs with the constraint of resources for farm management hence affecting coffee production. In addition, the large farm size requires substantiation of moisture control and irrigation to overcome the impact of climate change which requires more costs and hence affects productivity. The studies conducted by Minai et al. (2014); Wickramaarachchi and Weerahewa, (2018) found the land size to be negatively related to coffee and paddy productivity respectively.

Table 3.6: Linear regression model on factors affecting coffee yield

Coffee yield (kg/ha)	Measurements	Coef.	Std. Err.	t	P>t
Level of education	Years	-101.77	66.09	-1.540	0.125
Coffee variety planted	Dummy (1,0)	330.79	171.54	1.930	0.055*
Age of coffee tree	Years	12.90	14.40	0.900	0.371
Plant population	Tree/ha	0.23	0.02	11.140	0.000***
Access extension services	Number of visits	145.88	54.17	2.690	0.008**
Frequency weeding	Count/season	-31.26	40.68	-0.770	0.443
Fertilizer applications	Count/season	168.63	51.38	3.280	0.001***
Pest control	Count/season	6.21	5.18	1.200	0.232
Control coffee diseases	Count/season	-42.54	36.42	-1.170	0.244
Pruning	Count/season	238.34	77.73	3.070	0.003***
Fertilizer applied (g/tree)	g/tree	1.59	0.60	2.630	0.009**
Amount of fungicide applied	Kg/ha	-51.87	74.84	-0.690	0.489
Expansion of coffee farm	ha	-59.54	23.55	-2.530	0.012*
_cons		-867.46	349.32	-2.480	0.014

*Significant p < .05, **highly significant p<.01, *** very highly significant p<.001

The findings from Ordinary Least Square (OLS) regression analysis as presented in Table 3.7 indicated that the F-statistics of 34.02 was significant (P = 0.000), indicating a strong relationship between the independent variables and the dependent variables for respondents. The R squire was 0.7188 implying 71.88 % of coffee yield variations among smallholder farmers are explained by the factors combined.

Table 3.7: The descriptive summary of the factors included the OLS model

Source	SS	df	MS	F	Sign.
Model	56841779	13	4372445	34.02	<.000
Residual	22234872	173	128525.3		
Total	79076650	186	425143.3		

3.7 Conclusion and Recommendations

3.7.1 Conclusion

Coffee productivity in Tanzania is still low despite efforts to promote high-yielding and disease-resistant varieties adopted by farmers. This study aims at understanding factors affecting coffee productivity and causing the yield gap among smallholders in the study area using the yield gap analysis model.

The findings from this study show that the average yield gained by adopters and non-adopters of improved coffee varieties is below the average national research yield due to the observed poor implementation of recommended good agricultural practices and other socio-economic related factors, extension services and lack of updated skill and knowledge on coffee. The yield simulated by the SAFERNAC model shows that the actual yield was below the model and this can be due to the low use of fertilizer. Also, prolonged drought and infestation of insect pests affect coffee yield and lack of proper record keeping on yield. The regression analysis indicates that the coffee yield among smallholder farmers is positively influenced by plant population, access to extension services, fertilizer applications, and pruning. Meanwhile, the inverse relationship between land size and yield is observed.

3.7.2 Recommendations

Concerning the findings reported in this study, the recommendations, therefore, include: First the government to strengthen extension services to disseminate the right extension messages to farmers. The government also should ensure farmers' timely supply of inputs, research technologies and extension services as strategies to minimize yield gaps. The extension officers update farmers’ knowledge on the causes of yield gaps in crops and measures to minimize the gaps through training, the establishment of demonstration plots, conducting field visits and monitoring so that farmers achieve high yields. Likewise, farmers to invest in the implementation of good agricultural practices through the timely application of inputs, adoption of integrated soil fertility management practices (ISFM), integrated pests management practices (IPM) and supplementary irrigation as strategies to minimize yield gaps associated with climate change. Finally, there is a need to look at the profitability of coffee farming in the study area to understand if is profitable to adopt improved coffee varieties compared with traditional varieties. The implementation of these recommendations will contribute to motivating farmers to invest in coffee farming and gain high yield and profit.

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CHAPTER FOUR

MANUSCRIPT THREE

4.0. PROFITABILITY ANALYSIS OF COFFEE PRODUCTION AMONG ADOPTERS AND NON-ADOPTERS OF IMPROVED COFFEE VARIETIES IN MBINGA AND MBOZI DISTRICTS [3]

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4.1 Abstract
Smallholder farmers rise to consign regarding low returns from coffee production. There is limited empirical evidence on the economic benefit of improved coffee varieties adopted by smallholder farmers in the country. This study aims to test the hypothesis of whether it is profitable to adopt improved coffee varieties compared with traditional varieties. Data were collected from 320 smallholder coffee farmers both adopters 122 and 198 non-adopters of improved coffee varieties. The descriptive statistics, Gross Margin (GM), Benefit-Cost Ratio (BCR), the Break-even analysis for yield and price and the sensitivity of gross margin were used to compare profitability among adopters and non-adopters of high-yielding and diseases resistance coffee varieties in the study area. The gross margins for adopters were 5 451 666 TZS/ha statistically significantly higher ($p<0.000$) compared to 1 727 389 TZS/ha of non-adopters. Likewise, the BCR for adopters was 2.16 significantly ($p<0.000$) higher compared to 1.18 for non-adopters. Meanwhile, the break-even price for adopters was relatively low compared to non-adopters and the breakeven yield of adopters was relatively higher compared with non-adopter. The sensitivity analysis of the gross margin shows that the GM for adopters is less affected by a 15 % decrease in coffee price, a 25 % increase in operating costs and a 20 % decrease in coffee yield compared to non-adopters. The findings provide evidence that coffee farming using improved coffee varieties is profitable for adopters compared with non-adopters because of the high, Gross Margin (GM), Benefit-Cost Ratio (BCR), the Break-even analysis for yield and price and the sensitivity of the gross margin of adopters compared with non-adopters. It is, therefore, recommended that farmers should be encouraged to adopt the improved coffee varieties and implement good agricultural practices to increase productivity and profitability.

Keywords: Arabica, coffee, profitability, coffee varieties.

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4.2. Introduction

Coffee is among the important tropical valuable and traded commodities. The crop is produced in 70 countries in the world including 25 countries in Africa. Brazil is the leading coffee-producing country followed by Vietnam and Colombia. In 2018/19, Brazil produced 3.78 million tonnes (36.8 %) of the world's production and Vietnam contributed 18.2 %, and Colombia 8.1 %. In Africa, Ethiopia is the biggest coffee producer ranked 5th in the world with a production of 0.47 million tonnes followed by Uganda in the 8th position with 0.28 million tonnes and Côte d'Ivoire 13th with 0.14 million tons (Sänger, 2018). In Tanzania, for the past six years, coffee has been a primary agricultural export crop contributing 18 % of traditional cash crops earning after cashew nuts (36 %) and tobacco (27 %). Other crops include cotton (7 %), tea (6 %), sisal (3 %) and cloves (2 %) which collectively contribute lower than coffee (BOT, 2020). In Ethiopia coffee accounts for 34 % of the total value of agricultural products exported (Bickford, 2019), Kenya 5.5 % (ICO, 2019a), and Uganda 15 % (ICO, 2019b). Despite the importance of the crop in Tanzania, still coffee farmers claim low returns from coffee production. This is partly due to high costs associated with farm management, low productivity caused by the genetical capacities of coffee varieties, insect pest damage, disease damage, poor crop husbandry practices and low coffee quality which led to low prices in the market. Tanzanian government put efforts to address these challenges including promoting the adoption of high-yielding and disease resistant coffee varieties. Government support multiplications and distributions of improved coffee seedlings, training smallholder farmers on the implementation of good agricultural practices (GAPs) to increase productivity and quality and reduce taxations in the coffee sector to improve profitability (TaCRI, 2018). Despite these efforts, information on production costs as a determinant of farm profitability that compares the adopters and non-adopter of improved coffee varieties remains scanty. The lack of this information makes it difficult to tell whether the government's efforts are working or not. Different studies have been conducted in the coffee sector to assess various aspects including agricultural practices of coffee farming, production, marketing, and profitability (Jeremiah *et al.,* 2018; Kilambo *et al.,* 2015; Mhando and Mdoe, 2018; Mtenga, 2016; Otieno *et al.,* 2019). The findings from these studies have generalized or treated all farmers as having one coffee variety irrespective of the presence of improved and traditional coffee varieties planted by farmers. The objective of this study is to compare the profitability of coffee production among adopters and non-adopters of improved coffee varieties in the Mbinga and Mbozi Districts. The findings from this study will help researchers and other stakeholders in the coffee industry to understand the cost and profitability of coffee production for both adopters and non-adopters of improved coffee varieties.

4.3 Theoretical and conceptual frameworks

To better understand the subject matter, it is imperative to have some theoretical and conceptual frameworks about coffee husbandry. This will shed light on the industry that will benefit stakeholders including planners, government and smallholder coffee farmers.

4.3.1 Theoretical Framework

The major concern in coffee production among farmers is the minimization of cost(s) for a given level of output, and the maximization of revenue for a given level of inputs. However, some farmers incurred high costs of coffee production because they lack alternative means of minimizing the costs and maximizing profit. The literature suggests that farmers may be motivated to produce based on their attitude towards risk; the utility derived from production; and for-profit reasons (Huffman, 2011; Muellbauer, 1974). In Tanzania, coffee is a cash crop and it employs more than 450 000 families TCB (2016) who are the owner and managers of coffee farms. It is, therefore, safe to argue that profit maximization is the priority of the majority of coffee farmers. This study was guided by the theory of profit maximization (Muellbauer, 1974). Coffee producers invest in coffee production to get a certain output that minimizes costs and maximizes profit. Understanding the production costs and profitability of coffee production among adopters and non-adopters of improved coffee varieties is at the centre of the present study which aims to test the hypothesis on whether the government efforts of promoting and disseminating improved coffee varieties has positive impact on productivity and profitability among adopters and non-adopters of improved coffee varieties.

4.3.2 The Conceptual Framework

Achieving profitability in coffee production can be influenced by several factors including socio-economic, institutional and agronomic factors. At the core of this study is the assumption of producers' optimization behaviour in which they attempt to maximize some objective function subject to a set of constraints. The literature suggests that farmers may be motivated to produce based on their attitude towards risk; the utility derived from production; and for-profit reasons (Huffman, 2011; Muellbauer, 1974). It is assumed that farmers differ in their farm and physical characteristics. These characteristics including socio-economic, institutional factors and farm characteristics are expected to impact the profits through their impact on the volume of production, the price received per unit of a commodity and the cost structure as expressed in Fig. 1.1.

4.4 METHODOLOGY

This section refers to the methodology used in this study as presented in chapter one.

4.4.1 Data Analysis

The collected data were coded and analysed using Statistical Package for Social Sciences (SPSS) and MS Excel. The quantitative data were analysed using descriptive statistics to capture mean, frequency, and percentages. The t-test was used to test for the statistical significance of the variables at a 5 percent level of significance. The profitability of coffee production was analysed using the Gross Margin (GM), the Benefit-Cost Ratio (BCR) and the Break-even of coffee yield and price (ICC, 2019; Montagnon, 2017).

4.4.1.1 Profitability analysis of coffee production

The analysis of gross margin (GM), the Benefit-Cost Ratio (BCR) and the Break-even analysis, aimed at estimating the relative economic profitability of coffee production in the study area. The gross margin per hectare is important because it is a good measure for comparing the profitability of similar-sized farms and it also represents the bare minimum that a farm must generate to stay in business (Debertin, 1986). The advantage of using gross margin is that it does not involve tedious calculations and it is also more flexible in accommodating personal expectations and limitations of the given condition (Huffman, 2011). Likewise, it is the most common profitability criteria that farmers are familiar with and base their production decisions on using the gross margins allows for the most realistic baseline in our case which is also documented by Bonke *et al.*(2021). However, the gross margin is not a good measure of a farm's true profitability or a farm's long-term viability because cannot be used where varying capital input is needed for an enterprise (Heaslip *et al.,* 2013). The costs of equipment such as hand hoe, bush knife, pruning saw, secateurs, wheelbarrow, slasher, sprayer pump, and spade were assumed to last for ten years and therefore their total value was annualized by dividing them by ten as an approximation of their years of productive life. Since the productive assets may be used in other crops and activities outside of coffee, the cost is scaled by the fraction of the total farm area in coffee which is 50 %. Since no new assets were reported during the crop season of the reference year 2019/20, these costs are further scaled by 0.5 to roughly account for the likelihood that most productive assets are not new. Manure is recommended to be applied after every season but its economic value to the crop lasts for more than two seasons TaCRI (2011). This implies that the cost of manure was annualized by dividing it by three to get the real value.

Gross margin analysis

Gross margin analysis is the difference between the Total Revenue (TR) and the Total Variable Cost (TVC), that is:

$$GM = TR - TVC \quad (4.1)$$

Where: GM = Gross Margin (TZS/Ha), TR = Total Revenue ((Coffee Yield in kg x Price (TZS/kg)) and TVC = Total Variable Cost (TZS/ha)

The Benefit-Cost Ratio (BCR)

The benefit-cost ratio is the ratio between the sum of discounted net benefits of returns (R) and the sum of discounted cost (K), i.e., B = R/K. In costs benefit analysis (CBA), future benefits and costs are discounted relative to present benefits and costs to obtain their present values (PV). A cost or benefit that occurs in a year t is converted to its present value by dividing it by $(1 + r)t$, where r is the discount rate. The present value of the benefit, $PV(B)$, and the present value of costs, $PV(C)$, of the project, is represented mathematically as follows:

$$PV(B) = \sum_{t=1}^{t=n} \frac{B_t}{(1+r)^t} \quad (4.2)$$

$$PV(C) = \sum_{t=1}^{t=n} \frac{C_t}{(1+r)^t} \quad (4.3)$$

The decision rule is that we accept the project if the BCR ≥ 1 and when the cost and benefit streams are discounted. Thus, if BCR > 1 it implies that coffee production is profitable, if BCR < 1 it implies not profitable, and if BCR =1, the investment break even.

$$BCR = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+r)^t}} \quad (4.4)$$

Where: B_t = Benefits in each project year, *t,* C_t = Costs in each project year, *t,* n = Number of years to the end of the project (*n* ranges from 1 to 25) and r = Discount rate

Break-even analysis

Break-even analysis is the point where gross margin and total variable cost (TVC) are the same or when the sales of a farm are enough to cover the expenses (variable costs) of the farm. The goal of calculating a break-even price is to find out at what price a product would have to be sold in the marketplace to pay for its production. Break-even yield also shows at what production potential (yield per unit area) a product is economically feasible given the variable cost and price.

$$Break - even\ yield = \frac{TVC}{Sale\ price} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots(4.5)$$

$$Break - even\ price = \frac{TVC}{Total\ production} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.6)$$

4.4.1.2 Sensitivity analysis

Sensitivity analysis determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions. According to Khachatryan & Wei, (2022), sensitivity analysis is one way to assess uncertainty when building enterprise budgets. This study considers three uncertainty scenarios. The 15 % decrease in coffee prices, 25 % increase in operating variable costs due to increased price of fuel and inputs such as fertilizer and labour charges, and 20 % decrease in coffee yield as a cause of low farm management, the impact of climate change and yield variation along the year. In this study the gross margin (GM) was used as a dependent variable which is influenced by the sales price of the coffee produced, the yield harvested and sold to the market and the variable costs of production. The sensitivity is calculated to explore the impact of assumptions regarding the changes of these determinant factors on the gross margin.

4.5 Findings and Discussion

4.5.1 Costs analysis of coffee production

4.5.1.1 The establishment costs of coffee production

The findings as presented in Table 4.1 show that the average costs for establishing coffee farms by adopters of improved coffee varieties are 1 683 384 TZS/ha statistically significantly higher (p = 0.000) than 933 293 TZS/ha for non-adopters. The high cost for adopters was associated with plant population which contributed 21.1 % of the total costs followed by the cost of fertilizer which accounts for 19.6 % and costs of holing and manure 16.3 %. Meanwhile, the high costs for non-adopters were associated with costs of fertilizer that constitute 23.5 %, holing and manure 19.6 %. The findings imply that growing improved coffee varieties require relatively higher capital due to the increased number of man-days for performing farming activities such as holding, fertilizer application and manure application and coffee planting. Also, increased number of coffee seedlings, amount of fertilizer and manure required. Therefore, smallholder farmers can minimize the costs of establishing new coffee farms if they get subsidized seedlings and also use farmyard manure produced from their farms.

Table 4.1: **The establishment costs for coffee production (TZS/ha)**

	Overall			
Descriptions of costs	**Adopters**	**%**	**Non-Adopters**	**%**
Land preparations	207201.7	12.3	137801.4	14.8
Pegs preparations	137355.2	8.2	91349.36	9.8
Layout	53218.73	3.2	35393.62	3.8
Holing	274710.4	16.3	182698.7	19.6
Seedlings	354654.2	21.1	104494.4	11.2
Fertilizer for planting	329652.4	19.6	219238.5	23.5
Manure	274710.4	16.3	182698.7	19.6
Planting	51881.2	3.1	34504.08	3.7
Total establishment costs	**1683384**	**100.0**	**933292.9**	**100.0**

4.5.1.2 Operational variable costs coffee production

The findings presented in Table 4.2 indicates that the average cost of managing a coffee farm after being planted with improved varieties is 714 971 TZS/ha for adopters of improved coffee varieties relatively higher (p = 0.000) compared to 554 288 TZS/ha for non-adopters. The possible reason can be associated with differences in plant populations where adopters require more cost to buy inputs such as fertilizer and high labour costs to implement farm activities such as pruning and harvesting.

Table 4.2: Variable input cost in the 2019/20 coffee production season

Descriptions		Labour	Fertilizer	Pesticides	Fungicides	Average
Mbinga						
	n	73	52	27	31	73
Adopters	Costs (TZS/ha)	554685	148866	46221	44226	736709
	n	92	74	51	64	92
Non-adopters		384074	111092	49179	97093	601783
Mbozi						
	n	49	29	19	32	49
Adopters	Costs (TZS/ha)	515076	161230	40880	39589	682587
	n	106	68	58	78	106
Non-adopters	Costs (TZS/ha)	310047	122672	33447	98305	513067
Overall						
	n	122	81	46	63	122
Adopters	Costs (TZS/ha)	538776	153293	44015	41871	714971
	n	198	142	109	142	198
Non-adopters	Costs (TZS/ha)	344443	116637	40808	97759	554288
t		7.044	2.561	0.439	-4.676	4.494
Sig.		0.000	0.011	0.661	0.000	0.000

Labour costs

The findings as presented in Table 4.3 show that the labour costs for weeding and fungicide applications are relatively lower for adopters than non-adopters (p<0.000). The main reason is associated with plant population where the improved coffee varieties are planted in closer space than traditional coffee varieties hence, they suppress weeds. Likewise, the improved coffee varieties are fungicides free hence the application rates are low than non-adopters. According to TaCRI, (2011), the improved coffee varieties are not infested with CBD and CLR however they are infested with minor fungal diseases such as Fusarium (Kilambo *et al.,* 2015). The findings revealed that labour costs for harvesting was relatively higher and statistically significantly different for adopters than non-adopters of improved coffee varieties (p=0.000). The labour costs of fertilizer application and pruning were higher for adopters than non-adopters with no statistical evidence (p>0.05). This is due to the attribute of improved coffee varieties such as high yielding and genetic characteristics. Also, according to Robinson (1961) and TaCRI (2011) the age of coffee trees has a significant impact on the cost of pruning and canopy management. The analysis shows that the average age of improved coffee trees planted in the field was 10 years while the traditional coffee tree was 20 years.

Table 4.3: Labour cost analysis of coffee production in the 2019/20 crop season

Descriptions		Weeding	Fertilizer	Manure	Pesticides	Fungicides	Mulching	Pruning	Irrigation	Harvesting	Total costs
Mbinga											
Adopters	N	73	27	29	29	23	5	13	18	73	
	Mandays	16	4	4	2	5	4	15	1	86	
	Costs	117061	42963	44138	24074	53043	44000	146154	13333	388027	554685
Non-adopters	N	92	5	8	23	35	10	25	11	92	
	Mandays	28	3	5	2	16	5	12	1	36	
	Costs	227674	34000	49375	20870	155257	47000	120400	11818	161987	384074
Mbozi											
Adopters	N	49	18	12	12	10	5	15	19	49	
	Mandays	13	4	6	2	4	4	16	1	79	
	Costs	90833	37333	56667	22500	44000	38000	159333	17895	355892	515076
Non-adopters	N	106	20	13	26	32	6	30	19	106	
	Mandays	21	3	6	2	16	4	12	1	33	
	Costs	174385	33500	60000	19583	159469	40000	120667	13684	146377	310047
Overall											
Adopters	N	122	45	41	41	33	10	28	37	122	
	Mandays	15	4	5	2	5	4	15	1	83	
	Costs	105953	40952	47805	23590	50303	41000	153214	15676	375120	538776
Non-adopters	N	198	25	21	49	67	16	55	30	198	
	Mandays	24	3	6	2	16	4	12	1	34	
	Costs	203224	33667	55952	20213	157269	44375	120545	13000	153630	344443
t		-5.512	1.895	-1.103	1.877	-4.96	-0.336	3.87	1.139	13.801	7.044
Sig.		0.000	0.063	0.274	0.064	0.000	0.740	0.000	0.259	0.000	0.000

Costs of fertilizer used in coffee production

The findings as presented in Table 4.4 show different types of fertilizers applied by farmers in the study area for the 2019/20 crop season. The findings indicated that adopters of improved coffee varieties incurred relatively higher costs of fertilizer than non-adopters (p=0.011) and the possible reason is the number of plant populations which is high as opposed to traditional varieties. Maro (2014) and TaCRI (2011) documented that the adoption of improved varieties has more costs associated in terms of fertilizer applications. According to TaCRI (2011), farmers with improved coffee varieties are advised to apply a relatively high dose of different types of fertilizer because of the genetic characteristics of these varieties which include high yielding compared to traditional coffee varieties. Also, farmers are encouraged to adopt Integrated Soil Fertility Management Practices (ISFM) such as shed tree planting, mulching, inter-cropping, green manuring, and farmyard manure or composite which contribute to soil organic matter enrichment (Maro, 2014).

Costs for fungicides used in coffee production

The findings as presented in Table 4.5 show those adopters of improved coffee varieties incurred relatively lower costs for fungicides to control coffee diseases. According to Kilambo *et al.* (2013), fungicides are applied in coffee farms to control Coffee Berry Disease (CBD) and Coffee Leaf Rusts (CLR) which affect coffee productivity and quality, especially for traditional coffee varieties. Kilambo *et al.* (2015) and TaCRI (2011), documented that improved varieties are infested with scaly bark disease caused by *Fusarium lateritium* and root rot disease caused by *Armillaria mellea*. However, the impact of these two diseases is not high compared to CBD and CLR.

Table 4.4: The costs of fertilizer (TZS/ha) used by a farmer in the 2019/20 crop season

Descriptions		UREA	CAN	SA	NPK	YARA mila java	Booster (kg/ha)	Average
Mbinga								
	N	8	29	13	15	13	1	52
	Bag of 50kg/ha	1	2	2	2	2	5	
Adopters	Costs (TZS/ha)	65425	100412	76717	121148	113220	19277	148866
	N	6	30	16	22	28	6	74
	Bag of 50kg/ha	1	1	1	1	2	3	
Non-Adopters	Costs (TZS/ha)	90995	72066	39062	92852	99279	10879	111092
Mbozi								
	N	4	9	4	14	6	4	29
	Bag of 50kg/ha	3	2	1	2	3	2	
Adopters	Costs (TZS/ha)	172301	96235	46368	127821	179552	17024	161231
	N	7	36	8	18	24	5	68
	Bag of 50kg/ha	1.231	1.6666	0.683	1.4559	1.8375	1.2562	
Non-Adopters	Costs (TZS/ha)	79568	88846	30270	88991	112535	8289	122672
Overall								
	N	12	38	17	29	19	5	81
	Bag of 50kg/ha	1.67	1.95	1.67	2.12	2.13	2.91	
Adopters	Costs (TZS/ha)	101283	102321	69960	125009	137017	19210	153293
	N	13	66	24	40	52	11	142
	Bag of 50kg/ha	1.35	1.52	0.82	1.48	1.72	1.97	
Non-adopters	Costs (TZS/ha)	86271	80877	34533	90989	105567	11805	116637
t		0.645	1.413	3.025	2.562	0.845	1.233	2.561
Sig.		0.525	0.161	0.004	0.013	0.401	0.238	0.011

Table 4.5: The costs of fungicides used in the 2019/20 coffee production season

Descriptions		**Blue copper -** Oxychloride 50	**Red copper -** Cuprous Oxide 75	**Xanthos**	**Ninja**	**Snow plus**	**Snow viL**	**Quadric**	**Mpavil**	**Twigafosi**	**Santo**	**Karat**	**Average cost for Fungicide**
Mbinga													
	n	20.000	6.000	6.000	2.000	3.000	3.000		10.000	1.000	3.000	4.000	
	Kg/lrt/ha	2	1	1	1	1	1		2	2	1	1	
Adopters	Cost	12441	16875	17500	15000	21667	18500		26100	36000	16000	25000	44226
	n	34	18	13	11	12	6	3	8	1	8		
Non-	Kg/lrt/ha	5	2	1	2	2	5	1	2	7	3		
Adopters	Cost	28463	66778	45923	32273	51658	85833	30000	25250	126000	27750	.	97093
Mbozi													
	n	20	3	3	3	4	4	3	9	1	1	2	
	Kg/lrt/ha	3	1	1	2	0	1	1	1	1	1	1	
Adopters	Cost	33313	17533	20000	25000	8750	18125	12500	22111	9000	20000	20000	39589
	n	42	14	11	18	18	8	4	24	3	4	2	
Non-	Kg/lrt/ha	5	4	1	2	1	4	3	2	5	3	2	
Adopters	Cost	63023	109963	42091	26306	35656	73000	50500	25417	87000	41500	40000	98305
Overall													
	n	40	9	9	5	7	7	3	19	2	4	6	
	Kg/lrt/ha	3	1	1	1	1	1	1	1	1	1	1	
Adopters	Cost	30888	17094	18333	21000	14286	18286	12500	24211	22500	17000	23333	41871
	n	76	32	24	29	30	14	7	32	4	12	2	
Non-	Kg/lrt/ha	5	3	1	2	2	4	2	2	5	3	2	
Adopters	Cost	64895	85671	44167	28569	42057	78500	41714	25375	96750	32333	40000	97759
t		-4.587	-2.051	-2.638	-0.885	-2.415	-2.304	-1.754	-0.265	-1.663	-1.38	-2.739	-4.676
Sig.		0	0.047	0.013	0.383	0.021	0.033	0.117	0.792	0.172	0.189	0.034	0.000

Costs for pesticides used in coffee production

The findings as presented in Table 4.6 show that the mean difference between the cost of pesticides used in the 2019/20 crop season among adopters and non-adopters is not statistically significant. This is because farmers are required to apply pesticides when substantial numbers of pests are identified in the coffee farm. Also, they are encouraged to use Integrated Pest Management Practices (IPM) such as natural products like the use of bio-pesticides (botanicals) to minimize or reduce the use of industrial pesticides. Meanwhile, blanket application of pesticides is discouraged (Magina, 2011;TaCRI, 2011).

Table 4.6: The costs of pesticides used in the 2019/20 coffee production season

	Adopters				Non-adopters					
Descriptions	**n**	**Litres /ha**	**Unit costs**	**Total cost**	**n**	**Litres /ha**	**Unit costs**	**Total cost**	**t**	**Sig.**
Selecron Profenofos 500 EC	6	2	17667	29445	37	2	17243	39147	-0.862	0.394
Dusban (Chlorpyrifos)	25	1	16655	24476	54	1	23696	30089	0.767	0.445
Agrocron	10	3	25500	70635	10	2	28400	70347	0.058	0.954
Crush	4	2	22000	44000	2	2	24500	36750	0.233	0.828
Roundup	18	2	10278	20008	55	2	11846	18672	-0.037	0.971
Total cost	**46**			**44015**	**109**			**40808**	**0.439**	**0.661**

Costs of production at different growth stages

The findings as presented in Table 4.7, show that the establishment cost of coffee production is relatively higher than the operational costs. The main establishment costs are associated with labour costs for land preparation, holing, pegging, planting and weeding because coffee production in the study area is labour-intensive. Another part of the costs is associated with the cost of inputs such as seedlings, manure and fertilizer for planting.

Table 4.7: Cost and return analysis (TZS/ha)

Cost description	Farmer's category	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5+
Land preparations	Adopter	207,202					
	Non-Adopter	137,801					
Pegging	Adopter	137,355					
	Non-Adopter	91,349					
Layout	Adopter	53,219					
	Non-Adopter	35,394					
Holing	Adopter	274,710					
	Non-Adopter	182,699					
Seedlings	Adopter	354,654					
	Non-Adopter	104,494					
Fertilizer for planting	Adopter	329,652					
	Non-Adopter	219,238					
Manure	Adopter	274,710					
	Non-Adopter	182,699					
Planting	Adopter	51,881					
	Non-Adopter	34,504					
Hand weeding	Adopter	105,953	105,953	105,953	105,953	105,953	105,953
	Non-Adopter	203,224	203,224	203,224	203,224	203,224	203,224
Fertilizer applications	Adopter		12,286	20,476	30,714	40,952	40,952
	Non-Adopter		10,100	16,834	25,250	33,667	33,667
Manure applications	Adopter			14,342	23,903	35,854	47,805
	Non-Adopter			16,786	27,976	41,964	55,952
Pesticides applications	Adopter			7,077	11,795	17,693	23,590
	Non-Adopter			6,064	10,107	15,160	20,213
Fungicides applications	Adopter			15,091	25,152	37,727	50,303
	Non-Adopter			157,269	78,635	117,952	157,269
Mulching	Adopter			41,000	41,000	41,000	41,000
	Non-Adopter			44,375	44,375	44,375	44,375
Pruning	Adopter			-	76,607	114,911	153,214
	Non-Adopter			-	60,273	90,409	120,545
Irrigation	Adopter		15,676	15,676	15,676	15,676	15,676
	Non-Adopter		13,000	13,000	13,000	13,000	13,000
Cost for fertilizer	Adopter		45,988	76,647	114,970	153,293	153,293
	Non-Adopter		34,991	58,319	87,478	116,637	116,637
Cost for pesticides used	Adopter			22,008	33,011	44,015	44,015
	Non-Adopter			20,404	30,606	40,808	40,808
Cost of fungicides used	Adopter			12,561	20,936	31,403	41,871
	Non-Adopter			29,328	48,880	73,319	97,759
Harvesting	Adopter			187,560	281,340	375,120	375,120
	Non-Adopter			76,815	115,223	153,630	153,630
Total costs	Adopter	1,789,337	179,903	518,390	781,056	1,013,596	1,092,792
	Non-Adopter	1,191,403	261,315	642,416	745,025	944,145	1,057,079

The findings indicated in fig. 4.1 shows the trend of the operational costs for the first year of investment is relatively low as compared to the second year of establishment where the costs start to increase gradually up to the fifth year when the crop is fully matured. According to indicated that the establishment cost of coffee production accounts for 60 % of the total operating costs. Increase in cost of operational cost. The increased cost of operation is related to the increased amount of fertilizer requirement, pesticides and fungicides used to control coffee pests and diseases, and labour cost for pruning and harvesting. The study conducted by Samuel and Beza, (2019) reported similar results where they observed that, the costs of coffee production increases from stage I, II, III and IV due to increased management costs.

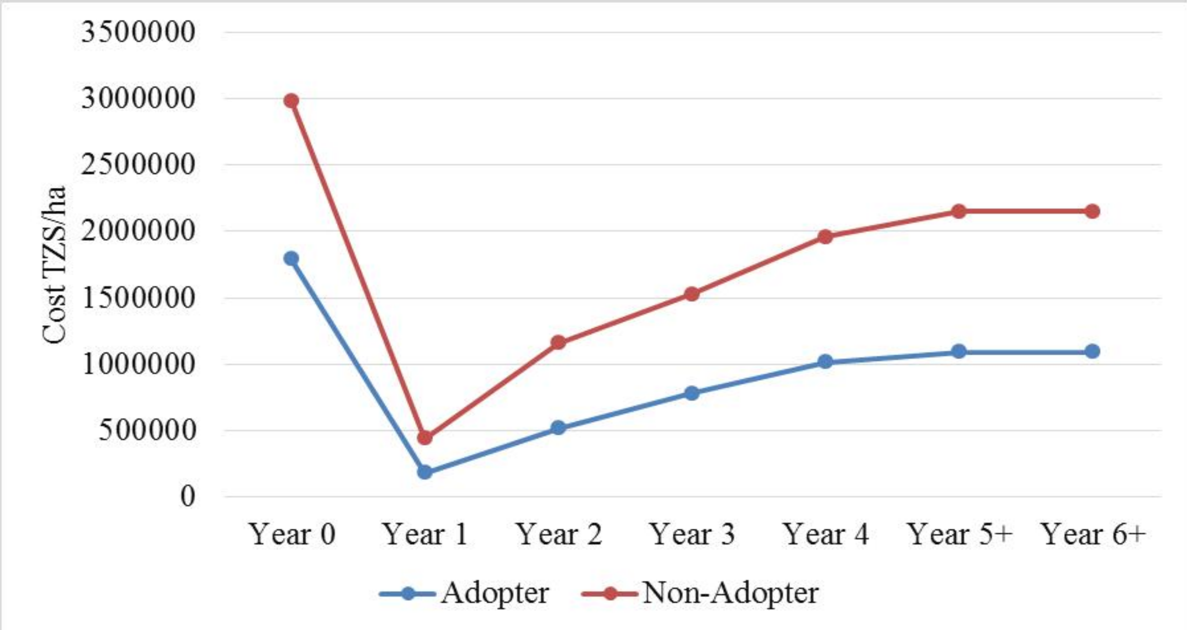

Figure 1.1: Costs of production at different growth stages

4.5.2 Profitability analysis of coffee production

4.5.2.1 Gross margin analysis

The findings as presented in Table 4.8 shows that the gross margin for adopters of improved coffee varieties for the 2019/20 crop season is 5 451 666 TZS/ha statistically significantly higher (p=0.000) than 1 727 389 TZS/ha for non-adopters. This can be significantly contributed to differences in plant population among adopters and non-adopters. The findings were also desegregated by districts and show that the gross margin for adopters in the Mbinga district was 5 692 063 TZS /ha relatively higher as compared to 5 319 339 TZS/ha in the Mbozi districts. Similarly, the gross margin for non-adopters in the Mbinga district was 1 848 415 TZS/ha relatively higher than 1 622 347 TZS/ha gained by smallholder farmers in the Mbozi district non-adopters. These findings provide evidence that the adoption of improved coffee varieties is more profitable in the study area. Our findings are similar to Samuel and Beza, (2019) in Jimma Zone Ethiopia who reported that adopters of improved coffee varieties get higher profits than non-adopters. Similar findings were documented by Montagnon (2017) where in this report they added that smallholder farmers who adopted improved coffee varieties need to have substantial capital hence profit must be high to cover the costs.

Table 4.8: Profitability analysis

Descriptions	Mbinga Adopters (n=73)	Mbinga Non-Adopters (n=92)	Mbozi Adopters (n=49)	Mbozi Non-adopters (n=106)	Overall Adopters (n=122)	Overall Non-adopters (n=198)
Average yield (kg/ha)	1293	540	1219	488	1250	512
Average yield (Kg/tree)	1.29	0.37	1.12	0.38	1.21	0.38
Price TZS/kg	6278	6278	6278	6278	6278	6278
Revenue (TZS/ha)	8120120	3389847	682587	513067	7850021	3214970
TVC (TZS/ha)	2428057	1541432	2336883	1440843	2398355	1487581
TVC (TZS/kg)	2415	3020	2511	3374	2549	3384
GM (TZS/kg)	3863	2538	3766	2904	3729	2894
GM (TZS/ha)	**5692063**	**1848415**	**5319339**	**1622347**	**5451666**	**1727389**
Std. Deviation	4207280	1240531	4163744	1107937	4211181	1173845
Std. Error Mean	492425	129334	607346	107612	381262	83421
t-test		8.324		8.517		11.736
Sign		0.000		0.000		0.000

4.5.2.2 Benefit-cost ratio analysis

The findings provided in Table 4.9 show that the BCR for adopters was 2.16 and for non-adopters was 1.18. The analysis by districts wises shows that the BCR for adopters in the Mbinga district is 2.23 and for non-adopters was 1.22 whereas the BCR in the Mbozi district was 2.14 for adopters and 1.15 for non-adopters. The findings imply that, for every TZS value invested in coffee production, a profit was realized for both adopters and non-adopters. However, the BCR analysis results reveal that coffee production is more viable for adopters than non-adopters because of the high BCR realised. According to Gittinger (1982), projects with BCR equal to or higher than 1 are considered and accepted to be economically viable because they indicate the project's capacity to cover the investment and operating expenditures.

Table 4.9: Benefit-cost ratio analysis

District	Descriptions	n	BCR	t	P>t.
Mbinga	Adopters	73	2.23	5.677	0.000
	Non-Adopters	92	1.22		
Mbozi	Adopters	47	2.14	5.58	0.000
	Non-Adopters	106	1.15		
Overall	Adopters	122	2.16	7.813	0.000
	Non-Adopters	198	1.18		

4.5.2.3 Break even yield and price analysis

The findings as presented in Table 4.10 shows that the overall break-even yield for adopters of improved coffee varieties is 382 kg/ha relatively higher than 237 kg/ha for non-adopter. This implies that the adopter of improved coffee varieties is required to gain a high yield to cover its costs of coffee production as compared to non-adopters. The break-even yield in the Mbinga district is 387 kg/ha for adopters relatively higher than 246 kg/ha for non-adopters and in the Mbozi district is 372 kg/ha for adopters higher than 230 kg/ha for non-adopters. These findings imply that the requirement to cover the cost of marketing is higher for adopters as compared to non-adopters.

Meanwhile, the overall break-even price for adopters was 2549 TZS/kg and 3384 TZS/kg for non-adopters. In the Mbinga district the break-even price for adopters is 2415 TZS/kg and for non-adopters is 3395 TZS/kg whereas in the Mbozi district is 2511 TZS/kg and 3374 TZS/kg for adopters and non-adopters respectively. The findings imply that, for any changes in coffee yield or price, adopters of improved coffee varieties will be on the better side of gaining as compared to non-adopters. This can be attributed to the fact that the improved coffee varieties have higher productivity than traditional varieties which are prone to infestation of CBD and CLR hence low productivity and profitability as early documented by Kilambo *et al.* (2015).

Table 4.10: Break-even analysis for smallholder coffee farmers

	Mbinga		**Mbozi**		**Overall**	
Descriptions	**Adopters**	**Non-adopters**	**Adopters**	**Non-adopters**	**Adopters**	**Non-adopters**
Break-even Price	2415	3395	2511	3374	2549	3384
Break-even Yield	387	246	372	230	382	237

4.5.3 Sensitivity analysis

The findings from the sensitivity analysis of gross margin as presented in Table 4.11 for the three scenarios indicate that the variability of the gross margin is high for all farmers resulting from changes in coffee yield if decreases by 20 % assumed followed by 25 % changes to the average costs per hectare. This implies that an increase in production is mainly caused by an increase in coffee production revenues. Therefore, the sensitivity of the gross margin is higher concerning the average yield and costs per hectare. The risks shown that might affect the gross margin are related to the decrease in coffee price and the increase in the variable costs holding the yield remain constant. These situations can make coffee producers non-profitable.

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Table 4.11: Sensitivity analysis of Gross Margins

Description	Original value		15 % decrease in coffee price		25 % increase in operating costs		20 % decrease in coffee yield	
	Adopter	Non-adopter	Adopter	Non-adopter	Adopter	Non-adopter	Adopter	Non-adopter
Yield (Kg/ha)	1250	512	1250	512	1250	512	1000	410
Price (TZS/kg)	6278	6278	5336	5336	6278	6278	6278	6278
Revenue (TZS/ha)	7850021	3214970	6670375	2732186	7847500	3214336	6278000	2571469
TVC (TZS/ha)	2398355	1487581	2398355	1487581	2997944	1859476	2997944	1859476
GM (TZS/ha)	5451666	1727389	4272020	1244605	4849556	1354860	3280056	711993
BCR (%)	2.16	1.18	1.78	0.84	1.62	0.73	1.09	0.38
Break-even price (TZS/kg)	2549	3384	1919	2905	2398	3632	2998	4540
Break-even yield (Kg/ha)	382	237	449	279	478	296	478	296
% change in GM			21.64	27.95	11.04	21.57	39.83	58.78

4.6 CONCLUSIONS AND RECOMMENDATIONS

4.6.1 Conclusion

This study aimed to test the hypothesis on whether the government efforts of promoting and disseminating improved coffee varieties has positive impact on productivity and profitability among adopters and non-adopters of improved coffee varieties. Based on the findings of this study, the adopters of high-yielding coffee varieties, disease resistance and good beverage quality gain higher profit compared to non-adopters. This is because the GM for adopters were relatively higher compared to non-adopters and showed a statistically significant difference (p=0.000), and the BCR for adopters was also statistically significant higher (p=0.000) compared to non-adopters. Meanwhile, the break-even price for adopters was relatively low compared to non-adopters and the break-even yield of adopters was relatively higher compared with non-adopter. Finally, the sensitivity analysis in all scenarios shows that the GM for adopters was less affected by a 15 % decrease in coffee price, a 25 % increase in operating costs and a 20 % decrease in coffee yield as compared to non-adopters. This implies that the government's efforts to promote the adoption of improved coffee varieties have a significant contribution to improving smallholder coffee farmers' profitability. Therefore, it can be concluded that coffee production in the study area is more profitable for adopters of improved coffee varieties as compared to non-adopters.

4.6.2 Recommendations

Given the significant contribution of improved coffee varieties on profitability and its economically viable among smallholder farmers who adopted these varieties in the study area, the following recommendations were made: Farmers are encouraged to improve implementations of good agricultural practices to increase coffee yield which has a high risk to affect profit margin if the yield decline. The coffee stakeholders should support the effort of dissemination of high-yielding, disease-resistant coffee varieties to farmers. Likewise, efforts to promote the adoption of good agricultural practices will contribute to mitigating climate change and minimise the cost of production. Meanwhile, capacity building for farmers through training on good agricultural practices and patterning coffee production is crucial. These recommendations will ultimately help farmers increase the productivity of quality coffee that can fetch a high price in the market hence improving household profitability.

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CHAPTER FIVE

5.0 GENRAL SUMMARRY, CONCLUSIONS AND RECOMMENDATIONS

This chapter provides general summary, concluding remarks drawn from the thesis, recommendations based on findings of the study, and highlights contributions the thesis makes to the existing body of knowledge.

5.1 General Summary

This study was conducted in Mbinga and Mbozi districts of Ruvuma and Songwe regions respectively. These two districts were selected based on production shares which was 50 % of Arabica coffee in Tanzania and with potential land for expansion suitable for coffee production. In this area, coffee is an important crop, which serves as source of cash. Tanzania coffee research institute (TaCRI) has developed and released 19 Arabica coffee hybrids coffee varieties and four Robusta varieties distributed in the study areas. These varieties combine high-yielding and good beverage quality with resistance to coffee leaf rust (CLR) and coffee berry disease (CBD) for Arabica and coffee wilt disease (CWD) for Robusta were disseminated to farmers. However, adoption of improved coffee varieties and factors influencing adoption of improved coffee varieties, effect of improved coffee varieties on productivity and profitability were not well studied in the study area. The general objective of this study was to provide empirical evidence on factor affecting adoption of improved coffee varieties, farmers perception of these varieties over the traditional varieties and how coffee varieties influence coffee productivity and profitability among smallholder farmers. For this study, a total of 320 respondents (122 adopters and 198 non-adopters) were interviewed using structured instrument. The findings from the descriptive statistics revealed that 38 % of respondents adopted improved coffee varieties and 43 % of the total area under coffee has planted these varieties. The findings from the Likert scale and the chi-square test revealed that smallholder coffee farmers consider improved coffee varieties to have high yields, good beverage quality, and disease resistance. The findings from the logistic regression model showed that the coefficient of visits by extension officers (0.039), membership of primary cooperative (0.406) and access to improved coffee varieties (0.407) influence farmers' adoption decision of improved coffee varieties positively. However, factors such as access to market information (0.150), access information about coffee varieties (0.149) and total land size owned (ha) (0.057) had a negative coefficient influence on the adoption of improved coffee varieties. The study showed the average coffee productivity for adopters is 1250 kg/ha relatively higher compared to non-adopters 512 kg/ha. The yield gap of adopters of improved coffee varieties is 750 kg/ha equivalent to 38 % and non-adopters are 488 kg/ha equivalent to 49 %. The farmer's actual yield was below the estimated yield with the SAFERNAC model. The regression analysis indicated that the coffee yield among smallholder farmers is positively influenced by several factors including, coffee variety planted, plant population, access extension services, fertilizer applications, pruning, and amount of fertilizer applied (g/tree). The findings of this study show that the average variable costs of coffee production for adopters was relatively higher compared to non-adopters with statistically significance difference of p=0.000. The GM for adopters was relatively higher compared to non-adopters and the BCR for adopters was also higher compared to non-adopters both of them GM and BCR with significantly significance different of p=0.000 respectively. Meanwhile, the break-even price for adopters was relatively low compared to non-adopters and the break-even yield of adopters was relatively higher compared with that of non-adopter. Finally, the sensitivity analysis showed that the GM for adopters were less affected by a 15 % decrease in coffee price, a 25 % increase in operating costs and a 20 % decrease in coffee yield compared to non-adopters.

5.2 Contributions to the Existing Body of Knowledge

Low coffee production, productivity and profitability mainly caused by old coffee trees coupled with lack of skill and knowledge proper farming practices and mitigation of climate change are main constraint facing smallholder farmers. Previous studies have shown that adoption of improved varieties can play an important role in alleviating some of these problems. However, in most studies, much attention has been given to the understanding of the determinants of adoption without analysing their effect on the productivity and profitability of farmers. This chapter contributes to the empirical literature in this area by examining the factors influencing adoption of improved coffee varieties, effect of improved coffee varieties on productivity and profitability among smallholder farmers in Mbinga and Mbozi district using farm household survey data collected from a sample of 320 households.

5.2.1 Practical implications

Overall, the practical implications of this study are based on empirical findings that illustrate the economic potential of improved high-yielding disease resistance with good beverage quality coffee varieties against the traditional low-yielding and susceptible CBD and CLR coffee varieties. This is important since innovations require an assessment of their technical feasibility to provide the technical basis for their adoption. The thesis investigated the economic potential in terms of farmers' perception and the likelihood of farmers adopting, yield performance under farmers' management and economic viability.

5.2.2 Perception and adoption of improved coffee varieties

The first contribution of this study to knowledge is the use of real exploratory data from adopters and non-adopters of improved coffee varieties to generate ex-ante information for the adoption of these varieties using the adoption and Diffusion of innovation theory. This theory explains why adoption is required for a technology to be adopted. In line with the theory of change which allow those involved in agricultural systems research, development, extension and policy to make quantitative predictions about the adoption outcomes for new farming practices. Its application in this study will serve as a key reference to researchers wishing to quantitatively assess the likelihood of adoption of new technologies. In addition, the results of this showed that the trends of adoption are in line with existing adoption theory including that of Rogers' adoption of innovation require time.

As in most adoption studies, it was found that the decision to adopt is a function of household characteristics, institutional factors and farm characteristics. Specifically, the number of visits by extension officers, membership of primary cooperative and access to coffee seedlings of the improved coffee varieties increases the likelihood of farm households adopting these varieties. On the other hand, the likert scale analysis showed that farmers have positive perceptions of the attributes of the improved coffee varieties.

5.2.3 Production and productivity of improved coffee varieties

Despite the importance of coffee to the Tanzanian economy, its production is below expected yield levels. Yields for many years has remained about half the economically attainable yields recorded from Tanzania Coffee Research Institute (TaCRI). The findings from this study showed that the adoption of improved coffee varieties has a significant contribution in the increase in production, productivity. The empirical findings from this study has showed that, smallholder farmers who have adopted improved coffee varieties in combination of implementation of good agricultural practices gain 62 % of economically attainable yields of these varieties which is higher than 51 % gained by non-adopters. The findings implies that, adoption of improved coffee varieties in combination with the implementation of good agricultural practices is aligned with the Household Production theory.

5.2.4 Profitability analysis of improved coffee varieties

The analysis of profitability using the gross margin approach based on data collected from farmers who have only grown improved coffee varieties and those only grown traditional coffee varieties provides empirical evidence of the economic potential of improved coffee varieties against the traditional coffee varieties. Moreover, this analysis is good to provide the first impression of the key variables' costs, price and yield enough for the farmer to get profit from coffee production. However, sensitivity analysis of gross margin concerning the changes of the key variables such as a decrease in price, yield and increase in costs of production were considered towards farmers' attitude on risk considered growing improved coffee varieties is more beneficial relative to existing traditional coffee varieties and hence they are likely to spend additional capital despite on agricultural inputs and labour costs and probably loses which may occur due to risks. Form the findings of this study, coffee farming is profitable, and it is observed that adopters gain higher profit compared to non-adopters. These empirical findings align this study with the theory of profit maximization.

5.3 Conclusions

The adoption studies that evaluated factors leading to adoption decision of different improved technologies among farmers mainly focus in improving farmers yield and profitability. It is believed that with these technologies, farmers can make positive changes for themselves as well as the agricultural sector. In this study the hypothesised variables of adoption of improved coffee varieties based on theoretical and empirical frameworks of previous studies were tested. It was found that, adopters and non-adopters of improved coffee varieties have positive perception about the attributes of improved coffee varieties over the traditional coffee varieties. The adoption of improved coffee varieties is influenced by number of visits by extension officers, membership of primary cooperative and access to improved coffee varieties. The adoption of improved coffee varieties has relatively increased coffee yield per hectare. However the yield gap among adopters and non-adopters is still high. Moreover the total income of adopters is relative higher than that of non-adopters of improved coffee varieties. In general these revealed that adoption of improved coffee varieties has significantly increased yield (productivity), coffee revenue as well as total income of the farmers. Therefore, empirically the null hypothesis was rejected in favour of the alternative hypothesis that the government efforts of promoting and disseminating improved coffee varieties has positive impact on productivity and profitability among adopters and non-adopters of improved coffee varieties.

5.4 Recommendations

Based on the empirical findings reported in this research, the following recommendations were made:

Firstly, the government should provide support to coffee research and development to improve infrastructure and other necessary logistics for coffee seedling multiplications to meet the demand. This will help to farmers avoid and minimize the risk of farmers collecting seeds and seedlings from unknown coffee varieties.

Secondly, TaCRI in collaboration with the Ministry of Agriculture, the Tanzania Coffee Board (TCB) and private sector to multiply, disseminate and promote use of improved coffee varieties. This can be achieved through the establishment of demonstration plots and conducting farmers exchange field visits to update farmers' knowledge and monitoring and ensure farmers access to seedlings which hence contribute to an increase in the rate of adoption of improved coffee varieties.

Thirdly, the government to strengthen coffee extension services through capacity building to extension officers in the sector so as to improve their capability to disseminate the right extension messages to farmers. This will contribute to increase adoption of improved coffee varieties and implementations of agricultural practices hence minimize the coffee yield gap among smallholder farmers. The yield gap can be minimized by encouraging farms to improve their farm management practices including proper use of fertilizer, pruning and soil moisture conservations.

Fourthly, the LGAs in coffee growing zones in collaboration with other stakeholders such as NGOs, AMCOS, and coffee traders should be mobilized to support government efforts of coffee seedlings multiplications and extension services to farmers in order to increase coffee production and quality.

Lastly, given the significant contribution of improved coffee varieties on profitability among smallholder farmers who adopted these coffee varieties in the study area, non-adopters of the improved coffee varieties should be encouraged to adopt improved coffee varieties and invest on the implementation of good agricultural practices. This will help farmers to minimise the cost of production associated with the use of fungicides to control coffee pests and diseases hence increase productivity and profitability.

These recommendations will ultimately help farmers increase the productivity of quality coffee that can fetch a high price in the market hence improve coffee profitability which ultimately contribute toward transformation of coffee industry to better economic growth and prosperity.

5.5 Area for Further Research

It is critical for researchers to disseminate the coffee varieties per line as each line has its attributes hence different requirements in terms of input application and level of productivity. Undertake this information will increase the farmers' management based on the line of coffee planted and increase performance in terms of yield and profitability.

APPENDICES

Appendix 1: A questionnaire

SECTION A: IDENTIFICATION

S/N	Particulars	Information
i.	Questionnaire number	
ii.	Date	
iii.	Region	
iv.	District	
v.	Ward	
vi.	Village	
vii.	Longitude	
viii.	Latitude	
ix.	Altitude	
x.	Name of enumerator	
xi.	Mobile Nº of enumerator:	

Provide the farmer with information about the questionnaire
Respondent's Name & Contact Normally Household Head (HH)
Note: It is mandatory that the respondent is informed about the interview and agrees to it. Otherwise arrange to pass by again if logistically feasible, otherwise, drop the respondent.

SECTION B: HOUSEHOLD CHARACTERISTICS
Respondent name: ________________________________Mobile Nº.: ____________________

1. Age of respondent (years): __________
2. Sex of respondent (tick answer): a. Male ______b. Female
3. Marital status respondent: a. Married b. Single c. Divorced, d. Separated, e. Single parent, f. Widow, g. Others (specify)_______________
4. Level of education of respondent (tick answer): a. Primary, b. Secondary, c. College d. University e. Adult f. None, g. Others (specify) ______________
5. Household size: _____________
   Household compositions

Descriptions	Male	Female
<18 years		
18-35 years		
36 – 45 years		
46 - 60 years		
>60 years		

6. What are the major sources of your household income?
   a. ____
   b. ____
   c. ____

7. What are the food/cash crops you grow in your farm apart from coffee farming?
   a. ____
   b. ____
   c. ____
   d. ____
8. What are the livestock do you keep/rear?
   a. ____
   b. ____
   c. ____
   d. ____
9. What is the total size of your farmland under agriculture (size in acre)? _______
10. Total land owned (acre) ____________
11. Total land rented (acre) _____________

SECTION C: COFFEE PRODUCTION

12. How long have you been practicing coffee farming? (Years) _______________
13. What is the area under coffee on your farm? (Acres) ________________
14. What type of training on coffee farming practices did you attend?

S/N	Type of training	Respond (✓)	
		Yes	No
i.	Multiplication of the improved coffee seedlings		
ii.	Field layout for planting improved or traditional coffee		
iii.	Application of weed management strategies		
iv.	Pruning of coffee tree to maintain the growth vigor of the coffee plant		
v.	Application of Integrated Pest Management (IPM) strategies in the control of coffee insect pests		
vi.	Application of cultural management strategies for control of Coffee Berry Disease & Coffee Leaf Rust		
vii.	Identification of the symptoms of soil fertility deficient and proper fertilizer application		
viii.	Application of fertilizers and organic manures for improved production and quality		
ix.	Application of mulch to preserve soil moisture conservation		
x.	Planting shed trees		
xi.	Rain water harvesting for irrigation		
xii.	Timely and selective picking of red-ripe cherry		
xiii.	Coffee post-harvest handling and marketing		

15. Do you have access to extension services? a. Yes b. No
16. How many times extension officers visited your farm in the last crop season______?
17. What type of coffee varieties do you have? a. Improved b. Traditional
18. How many number of improved coffee trees do you have in your farm? .__________
19. How many number of traditional coffee trees do you have in your farm? .__________

20. Total number of coffee tree owned ___________________?

21. If you planted improved coffee varieties, where did you get them?

Source of seedlings	Number of seedlings	Year planted	Comment if any
TaCRI nurseries			
Farmer groups nurseries			
Cooperative nurseries			
District council			
NGOs			
Others			

22. Did you establish new coffee farm in recent two crop seasons (2017/18 and 2018/19)?

a. Yes b. No

23. If Yes, complete the table below

Year	Number of improved varieties	Number of traditional varieties
2017		
2018		
2019		

24. What is the cost encored to establish new coffee farm?

S/N	Description	Unit	No of unit	Total cost
i.	Uprooting/farm preparations	Man-days		
ii.	Slashing	Man-days		
iii.	Peges preparation	Man-days		
iv.	Lay-out	Man-days		
v.	Hollings	Man-days		
vi.	Refiling Manure	Man-days		
vii.	Seedlings	seed		
viii.	Fertilizer for planting (DAP/Minjingu) g/tree	gms		
ix.	Manure for planting	Tins		
x.	Labour for Plantings	Man-days		

SECTION D: PERCEPTION OF FARMERS ON IMPROVED COFFEE VARIETIES

25. Who persuade or motivate you to plant improved coffee varieties?
    a. Neighbours b. Extension officer c. Relative d. Politician
26. Is there any advantage considered when adopting improved coffee varieties? a. Yes b. No
27. If Yes, which are they? (Select from the table below).
28. If Yes, indicate among of the following attributes

S/N	Description	Level (✓)			Comments
		High	Moderate	Low	
i.	Has higher output quantity				
ii.	Has better quality				
iii.	Resistance to Pest				
iv.	Resistance to diseases				
v.	Has lower production cost				
vi.	Early Maturity				
vii.	Easy to manage				
viii.	Stable to weather changes				
ix.	Uses lower chemical fertilizers				
x.	Uses lower pesticides				
xi.	Uses lower herbicides				

29. Where did you get the information about improved coffee varieties? a. TaCRI sub-stations b. Farmers in the village c. Farmers in the other village d. Extension officers e. Cooperative union f. Mass media g. NGOs
30. If you don't have planted improved coffee varieties, what are the major reasons for not planting the improved coffee varieties?

S/N	Description	Rank (1 to 8)
i.	Lack of seedlings	
ii.	Lack of capital	
iii.	Lack of land	
iv.	Lack of information	
v	Drought	
vi	Traditional varieties are better than improved	
vii	Improved coffee varieties are expensive to manage	
viii	Input intensive which I cannot afford	

31. If you planted improved coffee varieties, what factors affect the yield of the improved coffee varieties?

S/N	Factors affecting coffee yield	Respond (✓)

		1	2	3	4	5
1	Infestation of coffee pests					
2	Infestation of coffee diseases					
3	Low use of fertilizer					
4	High price of agro inputs					
5	Lack of farm implements					
6	Unreliable rainfall					
7	Shortage of labour					

Note: 1= Strong disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strong agree

32. If you planted improved coffee varieties, what do you think are the factors affect the profitability of the improved coffee varieties?

S/N	**Factors affecting coffee profitability**	**Respond (✓)**				
		1	**2**	**3**	**4**	**5**
1	Delay in payment					
2	Low price of coffee in the market					
3	Low production					
4	Unreliable market					
5	Price fluctuation					
6	Low quality					

Note: 1= Strong disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strong agree

33. How do you perceive about the yield you gain from your coffee farm last crop season?

S/N	**Perceived yield gained from coffee production**	**Respond (✓)**	
		Yes	**No**
i.	Very low		
ii.	Low		
iii.	Moderate		
iv.	High		
v.	Very high		

34. What is the trend of coffee production in your area?

a. Increasing b. Decreasing c. Remain the same

35. If the trend of coffee production in your farm is increasing, Why?

S/N	**Reason for decreasing in coffee production**	**Respond (✓)**	
		Yes	**No**
i.	Improved varieties		
ii.	Good price		
iii.	Access to extension services		
iv.	Good weather conditions		

36. If the trend of coffee production in your farm is decreasing, Why?

S/N	**Reason for decreasing in coffee production**	**Respond (✓)**	
		Yes	**No**

i.	Low price		
ii.	Unreliable market		
iii.	Low use of fertilizer		
iv.	Coffee pest		
vi.	Coffee diseases		
vii.	High price of farm inputs		
viii.	Unreliable rainfall		

SECTION E: AGRICULTURAL PRACTICES

37. What type of agricultural practices do you practice?

S/N	**Agricultural practices**	**Practice (✓)**		**Frequency per year**	**Type of Labour**		**№ of days**	**Acre**	**Labour Cost**
		Yes	**No**		*H	*F			
i.	Weeding								
ii.	Apply fertilizer								
iii.	Apply manure								
iv.	Apply pesticides								
v.	Apply agrochemicals								
vi.	Apply mulch								
vii.	Pruning								
viii.	Irrigate coffee								

*Note: *H= Hired labour *F= Family labour*

37.A. What is amount of Roundup used for weeding ___________

37. B. What is the unit cost for Roundup ___________

37. C. What is the total cost for Roundup used __________________

38. List kind amount and costs of manure you use in the last crop season 2018/19

Name of compost or manure	**Amount used** □ **Bag** □ **liter** □ **gm** □**kg** □ **tin**	**Application** □**tree** □**acre**	**Total cost**

39. List the name of fertilizer amount and costs encored during last season 2018/19

Name of fertilizer	**Amount used** □ **Bag** □ **liter** □ **gm** □**kg** □ **tin**	**Application** □**tree** □**acre**	**Total cost**

40. List the name of pesticide amount and cost encored during last crop season 2018/19

Name of pesticides	**Amount used** □ **Bag** □ **liter** □ **gm** □**kg** □	**Application** □**tree** □**acre**	**Total cost**

	tin		

41. List the names of agrochemicals used in the last crop season 2018/19 amount and its costs

Name of agrochemicals	Amount used □ liter □ gm □kg □ tin	Application □tree □acre	Total cost

SECTION F: COFFEE HARVEST &MARKETING

S/N	Descriptions	Crop season 2018/19		
		Unit	Unit cost	Total cost
42.	What is the cost of harvesting cherry coffee in TZS?			
43.	What is the cost of processing cherry to parchment coffee and drying in TZS			

44. How many kilogram of parchment coffee harvested and sold in the last crop season of 2018/19?

S/N	Descriptions	2018/19
i.	Kilogram of parchment coffee harvested	
ii.	Kilogram of parchment coffee Sold to Cooperative	
iii.	Kilogram of parchment coffee Sold to Private buyer	
iv.	Price of coffee offered by Cooperative	
v.	Price of coffee offered by Private buyer	

Note: ** Name the buyer if is Co-operative ____________ or Private _____________

SECTION G: CAPITAL ASSETS

45. Which of the following items do you own? *(Multiple answers possible)*

Asset	Respond (✓)	
	Yes	No
Scissor		
Knapsack sprayer		
Hand hoe		
Bush knife		
Pruning saw		
Harvesting buckets/bags		
Pulper		
Drying chicken match		
Wheel barrow		
Others* _______________		

SECTION H: OTHER SOURCES OF HOUSEHOLD INCOME

46. How much do you get per year from Employment _______________?

47. How much do you get per year from Business _______________?
    i. How much do you get per year from Sale of Livestock and livestock products such as cow Milk _____________
    ii. Sales of cattle ______________
    iii. Sale of manure _______________
    iv. Sale of goat ________________
    v. Sale of Cow meat ____________
    vi. Sale of goat meat _____________
    vii. Sale of hen/chicken __________
    viii. Sale of eggs _______________
    ix. Sale of pig __________________
    x. Sale of pig meat _____________
    xi. Other specify ________________

48. How much do you get per year from Sales of agricultural products such as
    i. Maize_____________
    ii. Rice ________________
    iii. Can sugar _______________
    iv. Cassava ____________________
    v. Irish Potatoes ________________
    vi. Sweet potatoes ______________
    vii. Tomatoes _______________
    viii. Firewood _______________
    ix. Other specify________________

57. How much do you get per year from Sale of other sources such as
    i. Charcoal _____________________
    ii. Sale of Local brew _________________
    iii. Sale of fruits___________________
    iv. Sale of coffee seedlings___________________
    v. Sales of fruits seedlings___________________
    vi. Sale of trees___________________
    vii. Sale of timber___________________
    viii. Others (Specify) ___________________

THANK YOU VERY MUCH FOR YOUR COOPERATION

Check list questions to guide focus group discussion in the study area

A: Background information

1. Questionnaire number: ________________ Date: _____________________________
2. Region: ________________________ 3. District: _____________________________
4. Ward __________________________ 5. Village: ______________________________

6. Name/ position of participants:

S/N	Name of participants	Sex	Age	Position
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				

B: Specific area of discussion ***(Enumerator please use flip chart to write the all responses from the discussion and before posting them in this questionnaire)***

1. Do you know the improved coffee varieties developed by TaCRI and disseminated to farmers in your area? a. Yes b. No. If Yes,
2. What do you say about these varieties in terms of yield?
3. Are there any problems among the farmers using the improved coffee varieties? a. Yes b. No
4. If yes, please state the problems
5. For farmers with improved coffee varieties, are there any improvements in yield and income? a. Yes b. No If yes, please specify
6. Are there any social benefits attributed to the use of improved coffee varieties? a. Yes b. No. If Yes Please specify the benefits
7. Do you think the improved coffee varieties have higher demand in this area? a. Yes b. No If Yes, please give reasons for the answer in the question above

a. If farmers need extension support for coffee, do they get support/help? a. Yes b. No. If yes, please explain who assists them and how?

8. Please suggest ways of improving the dissemination of improved coffee varieties to farmers in your area

THANK YOU VERY MUCH FOR YOUR COOPERATION

Appendix 2: Trend of coffee price

Year	New York Price	Auction Price ($/50kg)	$/kg	Exchange rate	TZS/kg
2009/2010	138.17	161.38	3.2276	1475	4761
2010/2011	216.95	235.31	4.7062	1611.5	7584
2011/2012	239.3	255.12	5.1024	1602.1	8175
2012/2013	168	157.54	3.1508	1603.5	5052
2013/2014	123.25	131.61	2.6322	1749	4604
2014/2015	188.18	201.59	4.0318	2160.7	8712
2015/2016	122.97	131.49	2.6298	2214.4	5823
2016/2017	154.85	161.61	3.2322	2240.5	7242
2017/2018	128.75	142.55	2.851	2303.5	6567
2018/2019	108.61	111.36	2.2272	2297	5116
2019/2020	106	117	2.34	2316.6	5421
Total					69056
Price index					6278

Sources: TCB 2020

Appendix 3: Data set for computing yield gap using SAFERNAC model

PROFILE_NO	X	Y	Z	DISTRICT	DIVISION	WARD	OC_G_KG	N_G_KG	BRAY_1_P	K_MMOL_KG	PH_WATER	YBASE	YORG	YINORG	YCOMBI
TNS55	35.0604	-10.9132	1451	Mbinga	Mbinga Mjini	Uteri	34.30	2.50	48.000	8.30	6.57	467.48	623.00	842.36	844.71
TNS56	35.0573	-10.8824	1571	Mbinga	Mbinga Mjini	Uteri	25.60	1.50	1.000	6.20	5.81	487.46	694.99	1062.93	1039.99
TNS57	35.0600	-10.8663	1482	Mbinga	Mbinga Mjini	Uteri	25.70	1.30	34.000	3.00	5.56	387.85	608.93	894.20	948.66
TNS58	35.0775	-10.8526	1410	Mbinga	Mbinga Mjini	Uteri	39.70	1.90	40.500	2.50	5.47	279.96	630.42	772.80	891.41
TNS59	35.0575	-10.8322	1405	Mbinga	Mbinga Mjini	Uteri	36.80	1.80	22.000	4.20	5.53	412.80	691.51	874.00	968.57
TNS60	35.0729	-10.8947	1408	Mbinga	Mbinga Mjini	Uteri	32.60	1.70	23.000	2.10	5.88	278.21	557.37	733.83	828.27
TNS61	35.0389	-10.9034	1297	Mbinga	Mbinga Mjini	Uteri	37.20	1.80	17.000	2.40	5.29	277.98	557.80	726.31	815.17
TNS62	35.0118	-10.8837	1367	Mbinga	Mbinga Mjini	Uteri	43.70	2.40	13.000	2.60	5.28	262.72	582.53	716.33	805.94
TNS63	34.9871	-10.8859	1386	Mbinga	Mbinga Mjini	Uteri	38.40	2.00	4.000	3.90	5.51	364.33	618.48	788.20	847.33
TNS64	35.0283	-10.8407	1494	Mbinga	Mbinga Mjini	Uteri	38.30	2.20	7.000	4.80	5.67	386.78	571.72	773.53	795.55
TNS65	35.0109	-10.9152	1369	Mbinga	Mbinga Mjini	Uteri	28.50	1.80	2.500	10.40	5.47	444.26	593.83	837.62	822.02
TNS66	34.9809	-10.9208	1317	Mbinga	Mbinga Mjini	Uteri	31.70	1.80	2.000	2.20	5.91	251.40	457.11	651.03	674.63
TNS67	35.0606	-10.9753	1371	Mbinga	Mbinga Mjini	Kilim ani	44.10	2.40	0.000	5.60	5.46	416.66	631.41	823.22	851.89
TNS68	35.0416	-10.9741	1510	Mbinga	Mbinga Mjini	Kilim ani	39.70	2.60	2.000	7.50	5.63	547.36	750.85	948.75	977.03
TNS69	35.0407	-10.9919	1367	Mbinga	Mbinga Mjini	Kilim ani	18.50	1.00	9.000	3.10	5.85	371.98	588.63	924.76	938.67
TNS70	35.0259	-11.0137	1152	Mbinga	Mbinga Mjini	Kilim ani	44.00	3.00	36.000	4.10	5.91	378.57	685.21	819.17	907.33
TNS71	34.9913	-10.9943	1553	Mbinga	Mbinga Mjini	Kilim ani	22.40	1.50	7.000	10.80	5.64	517.21	710.94	1049.77	1031.15
TNS72	34.9706	-10.9857	1366	Mbinga	Mbinga Mjini	Kilim ani	16.00	0.90	18.000	7.10	5.71	327.85	557.74	1034.79	971.97
TNS73	34.9875	-11.0277	1286	Mbinga	Mbinga Mjini	Kilim ani	18.60	1.30	26.000	7.10	5.58	469.24	675.91	1086.82	1041.25
TNS74	34.9963	-11.0422	1279	Mbinga	Mbinga Mjini	Kilim ani	35.50	2.00	29.500	4.00	5.68	389.03	624.00	811.17	861.81
TNS75	35.0991	-10.9335	1258	Mbinga	Mbinga Mjini	Kilim ani	17.80	1.40	10.000	12.80	5.54	628.11	837.77	1294.13	1229.91
TNS76	35.1062	-10.9763	1134	Mbinga	Mbinga Mjini	Kilim ani	13.40	1.00	38.000	6.20	6.32	336.86	569.81	1066.42	997.23
TNS77	35.1357	-10.9822	1087	Mbinga	Mbinga Mjini	Kilim ani	25.50	1.70	30.000	10.80	5.38	585.27	773.71	1107.50	1093.79
TNS175	32.8235	-9.1572	1589	Mbozi	Vwawa	Ihanda	18.20	1.10	6.500	9.20	4.81	298.70	451.92	734.05	703.87
TNS176	32.8695	-9.1707	1589	Mbozi	Vwawa	Ihanda	27.80	1.50	4.000	16.20	5.26	714.71	939.27	1424.00	1358.26
TNS190	32.9110	-8.8912	1517	Mbozi	Iambi	Igamba	25.80	1.30	4.000	11.60	5.89	477.50	657.47	910.60	893.55
TNS191	32.9413	-8.9380	1504	Mbozi	Iambi	Igamba	13.70	0.70	8.000	9.80	6.17	233.09	386.12	681.05	643.85
TNS192	32.9070	-8.9657	1613	Mbozi	Iambi	Igamba	23.30	1.10	1.500	10.10	5.83	362.96	513.85	774.84	751.54
TNS193	32.9170	-9.0263	1498	Mbozi	Iambi	Igamba	5.80	0.60	2.000	5.10	5.73	210.72	372.51	669.26	630.85
TNS194	32.9659	-8.9762	1494	Mbozi	Iambi	Igamba	11.70	0.50	5.000	5.40	5.84	190.90	381.48	658.49	630.56
TNS195	32.9716	-8.9150	1426	Mbozi	Iambi	Insansa	9.90	1.20	2.500	17.90	6.01	460.03	675.69	1080.31	1036.61
TNS196	33.0235	-8.9173	1335	Mbozi	Iambi	Insansa	16.90	1.40	18.000	22.80	5.96	316.26	468.48	759.01	722.49
TNS197	32.9926	-8.8206	1521	Mbozi	Iambi	Insansa	26.90	1.50	2.000	17.30	5.98	448.01	598.14	866.25	839.48
TNS198	32.9180	-8.8039	1553	Mbozi	Iambi	Insansa	23.70	1.20	2.000	19.40	6.02	395.87	548.57	836.36	803.57
TNS199	32.8580	-8.8634	1624	Mbozi	Iambi	Insansa	19.10	1.10	2.000	11.80	6.10	306.63	459.34	746.81	714.45
TNS200	32.8927	-8.8660	1624	Mbozi	Iambi	Insansa	17.40	0.80	2.000	14.30	5.58	323.54	544.39	985.37	954.43