RELATIONAL AGENCY, TECHNOLOGY AND TECHNICAL EFFICIENCY IN KENYAN COFFEE FARMING: A STOCHASTIC PRODUCTION FRONTIER APPROACH

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Abstract

RELATIONAL AGENCY, TECHNOLOGY AND TECHNICAL EFFICIENCY IN KENYAN COFFEE FARMING: A STOCHASTIC PRODUCTION FRONTIER APPROACH

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This study aimed to investigate the relationship between technology, technical efficiency, and the population of coffee farmers guided by activity theory, economics, and the acceptability of technology model. It examined the existence of relational agency in coffee farming; compared the rates of technology adoption among young and post-youth coffee farmers; connections between these variables among coffee farmers; and determine the output yield of central Kenyan coffee farmers.

Data was analysed using the log-likelihood linear regression function on the stochastic frontier while being summarised using descriptive statistics. Using simple random and stratified sampling with a structural questionnaire. The sample size was 384 responses selected from a target population of 304,600. A descriptive across-sectional research approach was adopted. The study's null hypothesis, that agency relationships and technology have a favourable impact on technical efficiency, was put to the test using inferential statistics. The data was determined to be reliable with a KMO rating of 0.642 > 0.5. The Estimation method for the study was the ordinary least squares.

The study found that agency networks significantly affect productivity and improved efficiency on farmers who get visit from extension officer with TE with mean of 0.52, confirming the support of activity theory that coffee research institution should develop modern cultivars which were less reliant to fungicides. It concluded that coffee production can be

increased by improving the inputs use and subsequently technical efficiency to increase farmers' experience.

This informs best practices by government and management corporations in incorporating reforms and agency relationships in coffee farming. It enriches the economics' production theory by showing synergy in production filling the gap in agency relationships studies. It recommends the government to promote farm investments that enhance access to credit and future research on the technical efficiency of large estate for coffee growers. It also recommends government policies on allocation of financial resources to support coffee producers by providing subsidy programmes for sustainable technology improvements, incentive programmes and creating institutional platforms for farmers to explore both local and international coffee markets. This will allow them to access information on the market and environmental conditions, and bargaining powers on the pricing and product marketing.

Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where stated otherwise by reference or acknowledgment, the work presented is entirely my own.

AI Acknowledgment

I acknowledge that I have not used any AI tools to create, proofread or produce any text or ideas related to any draft or final versions of the thesis.

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Dedication

I dedicate this project to my dad, Joseph Crispin Mwangi who has motivated me to soar high.

Acknowledgments

Special thanks to God Almighty for the strength he has enriched me with life to this moment, the good times, the challenges, and the opportunities you have presented, I am incredibly grateful.

To the entire faculty of UNICAF University, the supervisor Dr. Ben and university management, I thank you for the opportunity and equipping me with knowledge.

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List of Abbreviations

AERC	African Economic Research Consortium
AFA	Agriculture and Food Authority
CBK	Coffee Board of Kenya
CC	Cultivation Cost
CD	Coffee Directorate
CDF	Coffee Development Fund
CES	Constant Elasticity Substitution
CFA	Confirmatory Factor Analysis
CRF	Coffee Research Foundation
CRI	Coffee Research Institute
CSO	Central Statistical Office
CT	Cultivation Technology
DEA	Data Envelop Analysis
DF	Distance Functions
EE	Economic Efficiency
EFA	Exploratory Factor Analysis
FADN	European Farm Accountancy Data
FAO	Food and Agriculture Organization
FC	Fertiliser Cost
FFS	Farmer Field School

FGPA	Field Programmable Gate Array
FQ	Fertiliser Quantity
FS	Farm Size
GDP	Gross Domestic Product
GIS	Geographic Information System
GM	Genetically Modified
GoK	Government of Kenya
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HHS	Household Size
IC	Irrigation Cost
ICA	International Coffee Agreement
ICO	International Coffee Organization
IFC	International Finance Corporation
IRS	Increasing Returns to Scale
IT	Irrigation Technology
IV	Instrumental Variable
KALRO	Kenya Agricultural and Livestock Research Organisation
KARI	Kenya Agricultural Research Institute
KBS	Kenya Bureau of Statistics
KCCE	Kenya Co-Operative Coffee Exporters

KCPA	Kenya Coffee Producers Association
KCPTA	Kenya Coffee Producers and Traders Association
KCTA	Kenya Coffee Traders Association
KEBS	Kenya Bureau of Standards
KMO	Kaiser Meyer Olkin
KNBS	Kenya National Bureau of Statistics
KPCU	Kenya Planters Co-operative Union
MAD	Minimum Absolute Deviation
MCQs	Multiple-Choice Questions
MDG	Millennium Development Goal
MLE	Maximum Likelihood Estimation
MoA	Ministry of Agriculture
MSV	Marginal Shadow Value
M	Metric Tonnes
NAAIAP	National Accelerated Agricultural Input Programme
NACOSTI	National Commission for Science, Technology, and Innovation
NALEP	National Agriculture and Livestock Extension Programme
NCE	Nairobi Coffee Exchange
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental organisations
NGRDI	Normalized Green–Red Difference Index

NIB	National Irrigation Board
NIE	New Institutional Economics
NIRS	Non-Increasing Returns to Scale
OLS	Ordinary Least Squares SE Scale Efficiency
PC	Pesticide Cost
PCA	Principal Component Analysis
PEOU	Perceived Ease of Use
PQ	Pesticide Quantity
PRC	Pruning Cost
PRT	Pruning Technology
PU	Perceived Usefulness
PWM	Pulse Width Modulation
RFID	Radio-Frequency Identification
SACCO	Savings and Credit Cooperative Organisation or Society
SC	Spraying Cost
SDGs	Sustainable Development Goal
SF	Stochastic Frontier
SFA	Stochastic Frontier Approach
SMS	Short Message Service
SPF	Stochastic Production Frontier
SPF	Stochastic Production Frontier

SRA	Strategy for Revitalizing Agriculture
ST	Spraying Technology
TAC	Transactional Arrangements for Coffee
TAM	Technology Acceptance Model
TCE	Transaction Cost Economics
TE	Technical Efficiency
UAV	Unmanned Aerial Vehicle
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
VMD	Volume Median Diameter
WC	Weeding Cost
WSN	Wireless Sensor Network
WT	Weeding Technology
WTO	World Trade Organization

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CHAPTER 1: INTRODUCTION

Background and Context

Agriculture is perceived as the thrust force for the economic revitalisation of the Sub-Saharan Africa (SSA) in the efforts towards of the sustainable development goals (SDGs) realisation by 2030 (Ademola et al., 2018). To eliminate poverty, agribusiness offers an avenue for the substantial number of youths (about eleven million) who enter the labour market every year in Africa (Food Agriculture Organization [FAO], 2018). Policy interventions at the national and regional levels should be geared towards ensuring that there is an end to conflict and diseases to enable the household to focus on the productive units in farming. The externality effect of agriculture is a healthy nation, commercial agro-industries development, and foreign exchange earnings (Ademola et al., 2018). Therefore, agriculture cannot be ignored as it accounts for 70% of employment in SSA (World Bank, 1998).

Globally, there is a demand for food for a current populace of 7.5 billion irrespective of their economic activity; this poses a challenge for production (Organisation for Economic Co-operation and Development [OECD], 2019). In rural agriculture, millions of people use agriculture as their economic backbone for food production and cash crops for exports. Furthermore, agriculture occupies 40% of the land surface and affects biodiversity (OECD, 2019). This makes the production factor constrained since the expansion of land for agriculture will cripple natural resources such as forestry land. To tame the challenge, there is a need for a concerted effort to be innovative, have a concern for the environment, implore on sustainable development, and extending of strategy intercession for the urban food production (Gore, 2018).

Given the restricted access of small-scale farmers to agricultural land, technology, and marketplaces, it is critical to examine efficiency gains via current innovations and the utilisation of existing commodities and solutions. In certain cases, improvements in productivity utilising current innovations with improved input distribution or contemporary innovations with accessible inputs may contribute more to socioeconomic and ecological durability than technical change. Total factor productivity has plateaued even in the most developed countries accounting for a range of 1% to 3%, which shows there is a less budgetary allocation in agriculture (OECD, 2019). Rural agriculture is mostly subsistence in nature and for commodity exports. Side lining the agricultural sector is abating food crises, rural people's vulnerability, and detrimental to the SDG goals realisation. Against this backdrop, this paper explores in detail how technology and relational agency impact TE on smallholder farmers.

In Nepal, agricultural farms are quite diversified, with just a tiny percentage being commercialised, while the vast majority still function on subsistence levels, particularly in rural regions. Informal institutional structures in subsistence farming are inefficient due to a lack of precise information, (Lamichhane, 2022). Farmers confront severe market rivalry in commercial settings, prompting them to make more effective judgments in employing technology to its maximum capacity. As a result, local informal institutions have an impact on production decisions. However, such a framework does not have a dynamic atmosphere, which might result in increasing production inefficiencies. The drive for better health and environmental awareness in agriculture in Nepal increases organic food output- a lucrative source of income for rural areas.

The Brazilian agricultural industry has evolved from a conventional agricultural structure with little use of new innovations to a world agricultural leadership. That shift happened when the country shifted away from imported replacement strategies that favoured local industrial growth at the cost of farming and toward market-focused regulatory changes (Tittonell, 2020). These changes included increased accessibility to international commerce and expenditures, as well as the employment of modern technology, which resulted in a new growth trajectory. Most successful farms have embraced agricultural research advantages the fastest, expanding the production gap between these ranches and typical farms (Bastos & Marion, 2021).

While a sharp drop in production prices for coffee has put significant strain on growers in Costa Rica and other supplier economies throughout the world (Babin, 2020; Kebebe, 2019). Moving to specialist marketplaces, where the pressure on prices was lesser, was a potential response. Experience, accounting, and the quantity of adult family occupants are among the distinctive characteristics identified to have a substantial influence in the specialty coffee business. Cooperative participation results in improved farm-level effectiveness for traditional coffee growers. They make regulatory proposals to help producers enhance their farming efficiency and ability to deal with the impacts of the coffee disaster (Xi et al., 2021). These policy initiatives comprise the supply of accountancy technique services for extension, the establishment of revenue possibilities in rural regions, and the promotion of farmer-owned organisations (Altieri & Nicholls, 2020).

Developing countries have placed significant emphasis on the adoption of modern technology (Chan et al., 2018). Agriculture's ability to flourish, however, depends not just on the level of technology used, but also on how effectively it is used. The potential contribution of efficiency to overall output growth has been examined in several earlier studies, with a particular emphasis on production efficiency (Wu et al., 2020). Agricultural farms exhibit substantial heterogeneity, with only a few being commercially oriented while many remain subsistence based. The lack of information in subsistence farming leads to high efficiency costs within informal institutional arrangements. Contrarily, commercial farming, which is characterised by market competition, pushes farmers to make more wise choices regarding the best use of the available technologies. As a result, local informal institutions frequently have an impact on manufacturing decisions. However, the lack of a competitive environment in this system causes increasing production inefficiency. The idea of a "production frontier" fit with how technology is typically portrayed, specifically through a production function (Gkypali et al., 2019)

Over 716 million individuals live in Africa's 25 coffee-producing nations, and coffee is a significant product when it comes to both export profits and generating revenue for smallholder growers in a number of those nations (ICO, 2015). Producing coffee on smallholder fields on 4.5 million Km2 of land provided a living for around 33 million Africans. Its farming, extraction, trade, shipping, and distribution employ many people across all producing nations (Mohammed et al., 2013). Coffee is farmed mostly on subsistence lands/farms in Africa, with restricted and scattered ownership of land, restricted access to supplies, and poor pricing. It is grown in a variety of ways, the most common of which involves combining crops with additional crops and trees for shade (Taye, 2010). Nevertheless, its growth is hampered by factors such as declining productivity of land, shrinking per capita ownership of land, economic flaws, and climatic unpredictability and change (Tessema et al., 2015).

Apart from a few mineral resource-rich African nations, coffee is the most significant source of agricultural commodity exports, which, for most African nations, exports are the main source of foreign cash. Coffee is one of these commodities that is exported in its unprocessed form (Amoro & Shen, 2013). That means little value addition in the production. In Sub-Saharan Africa, production takes place for almost 57 countries Kenya included trade in essential linkage of the coffee chain as an export product. Another aspect is that agriculture—the largest industry in Sub-Saharan Africa—is supported by 75% of the region's workforce. Additionally, the industry helps agro-manufacturing businesses by providing raw materials (World Bank, 2008). Dramé-Yayé et al. (2011) draw attention to the fact that over time, support for this sector has decreased and African nations have not been able to increase their ability to supply exports (United Nations Conference on Trade and Development [UNCTAD], 2008). Kandiero and Randa (2004) posits that trade opportunities are hampered by a failure to increase export supply capacity while Mayer and Fajarnes (2005) contend that deliberate efforts should be made to increase exports to promote economic growth.

Coffee output in Africa was anticipated at 18.7 million 60kg sacks in the 2020-2021 coffee year, maintaining the preceding/previous annual volume. The African context contains more than 10 nations with Ethiopia generating 7.7 million bags, accounting for forty-one percent of total production, being followed by Uganda generating 4.9 million bags, Ivory Coast (2.2 million bags - twelve percent), Tanzania (900 thousand bags - five percent), and Kenya (844 thousand bags, with about four percent) are in the top five. Other African nations are anticipated to produce 2.2 million bags, which accounts for just 12 percent of total African output (ICO, 2020). The harvest of 18.7 million bags has stabilised from 2019 to 2020. This African production volume corresponds to 11% of world production, which is estimated at 169.6 million bags for the 2020-2021 coffee year (ICO, 2021).

In Cote d'Ivoire's, the coffee outcomes are at a mean percentage of TE for CCR and BCC models are 36% and 47%, indicating the need for considerable gains in productivity and/or cost reductions utilising current technologies. It is recommended that government agencies give official farmer organisations and associations and farmer capability development top priority (Joachim et al., 2003). Mengo et al. (2015) reports that in Zimbabwe following the fast-track land reform in 2000 that the usage of inorganic fertilisers, the number of seeds, labour, and the size of the planted area are related to enhanced maize production. The government and private sector initiatives should be implemented to facilitate access to productive resources and enhance agricultural extension services to enhance TE. Similarly, in South Africa farmers have significant TE but if they improved their efficiency, they could be able to reallocate some irrigation water to meet other needs. The relationship between numerous farm/farmer characteristics and water sub-vector efficiency shows that several farmer characteristics significantly affect the sub-vector efficiency for water (Speelmanna et al., 2007).

Ethiopia is known to be the origin and starting point for the diversity of Arabica coffee bean species. It has the most diverse types of Coffee Arabica compared to anywhere else in the world, leading botanical experts, and researchers to conclude that the origin, diversity, and expansion of the coffee plant are all centred in Ethiopia (Taye, 2013). About 15% of Ethiopia's population earns their living from coffee, which is important to the country's economy, their livelihoods are from it, either directly or indirectly. Coffee is also Ethiopia's primary export product, accounting for 25% of the country's total export revenue (Abu & Teddy, 2013). Ethiopia is not only a significant producer or exporter of coffee, but it is also the world's second-largest consumer of the beverage after Brazil (Kuma et al., 2016). Despite small-scale producers contributing more than 95% of Ethiopia's coffee production, traditional farming practices remain prevalent. Coffee is cultivated in four main industrial structures in Ethiopia: According to the United States Agency for International Development (USAID), 2010: "forest coffee (8–10%), semi-forest coffee (30–35%), cottage or garden coffee (50–57%), and modern coffee estate, United Nations Development Programme [UNDP], 2012; Taye, 2013). They are controlled by wealthy individuals or the state.

To improve productivity, it is necessary to implement effective measures that can increase farm-level efficiency and address factors that hinder productivity. Nevertheless, despite these challenges, Ethiopia's total coffee production has been steadily increasing from around 180 million tonnes in 1993 to over 471 million tonnes in 2021, owing to improved farm-level efficiency. Additionally, the coffee-growing area in Ethiopia has more than doubled since 1993, with further increases observed in 2022 (ICO Report 2021). Inadequate coffee farm management systems, socioeconomic variables of farmers, different farming techniques, the proliferation of Khat crops at the expense of coffee farms, and climate change are all factors that contribute to this reduced output (Taye et al., 2011; Abu Tefera, 2016). Therefore, to improve productivity, it is crucial to develop effective measures that can enhance farm-level efficiency and address factors that hinder productivity. Despite these challenges, Ethiopia's total coffee production has been steadily increasing, from around 180 million tonnes in 1993 to over 471 million tonnes in 2021, due to improved farm-level efficiency. Additionally, the coffee-growing area in Ethiopia has more than doubled since 1993, with further increases observed in 2022 (ICO Report 2021).

Kenya has an economically active population of 22.3 million people, which accounts for forty-four percent of the Kenyan population as per the Kenyan government's census in 2019

(Kenya National Bureau of Statistics [KNBS], 2019). Agriculture has a role to play in ensuring there is an adequate food supply. Agri-sector, therefore, serves as a bridge to reduce the already existing dependency rate at sixty-four percent, which constrains the income for the active population. Households engage in subsistence farming to supplement the food budget (Karanja, 2002).

The intensity in agriculture has also led to self-employment initiatives and agro-industries (KNBS, 2020). The land is a fixed resource for farming. Arable land for farming is an area of eighteen percent of the total land area in Kenya (KNBS, 2019). It is worth noting that this resource is fixed and is not optimally utilised (USAID, 2020). Besides, the variability of the climate has affected the agricultural sector negatively (Ochieng et al., 2016). Adopting the best practices in land management and environmental planning is key to improving human welfare, ecology, and sustainable farming (Mulinge et al., 2016). Moreover, the GDP for the Kenyan government is supported by the agricultural sector by more than thirty-three percent (USAID, 2020; KNBS, 2020). The sector, therefore, provides a drive for the economic prosperity of the nation.

Coffee is a core agricultural product in Kenya (Minai, 2017). In 1935, smallholder coffee farming in pre-independence Kenya commenced in Meru and Kisii after the gazettement of the Devonshire white paper of 1923, which allowed Africans to farm the crop (Minai, 2017; Karanja & Nyoro, 2005). In the post-independence era, coffee is widely grown by over 478,936 farmers (KNBS, 2019) on a small scale since the large-scale accounts for slightly over 1,000 farmers. The processing of coffee on a small scale is done through the cooperatives. Small-scale processors comprise about 64 percent of the total coffee produced in Kenya, while the estates account for only 36 percent.

Since Kenya attained independence in 1963, coffee was the first product earning the country foreign exchange, prior to tourism topping the market in 1989 (Karanja, 2002). Adopting the new coffee-cultivars and modernisation in coffee varieties contributed to the commodity being the premier crop in dollar inflows, but the yields are still low (Asayehegn et al., 2019; Thuku, 2013). The small-scale farmers' population has significantly reduced by twenty-one percent from over 600,000 in the year 2000 to 478,936 farmers in 2019 (KNBS, 2020). However, the government effort through the distribution of free coffee seedlings has led to an increase of 1.5 percent growth in the acreage under cooperatives as per table 1 below (KNBS, 2020; Waitathu, 2018).

Table 1

Production and Average Yield of Coffee by Grower 2014-2019

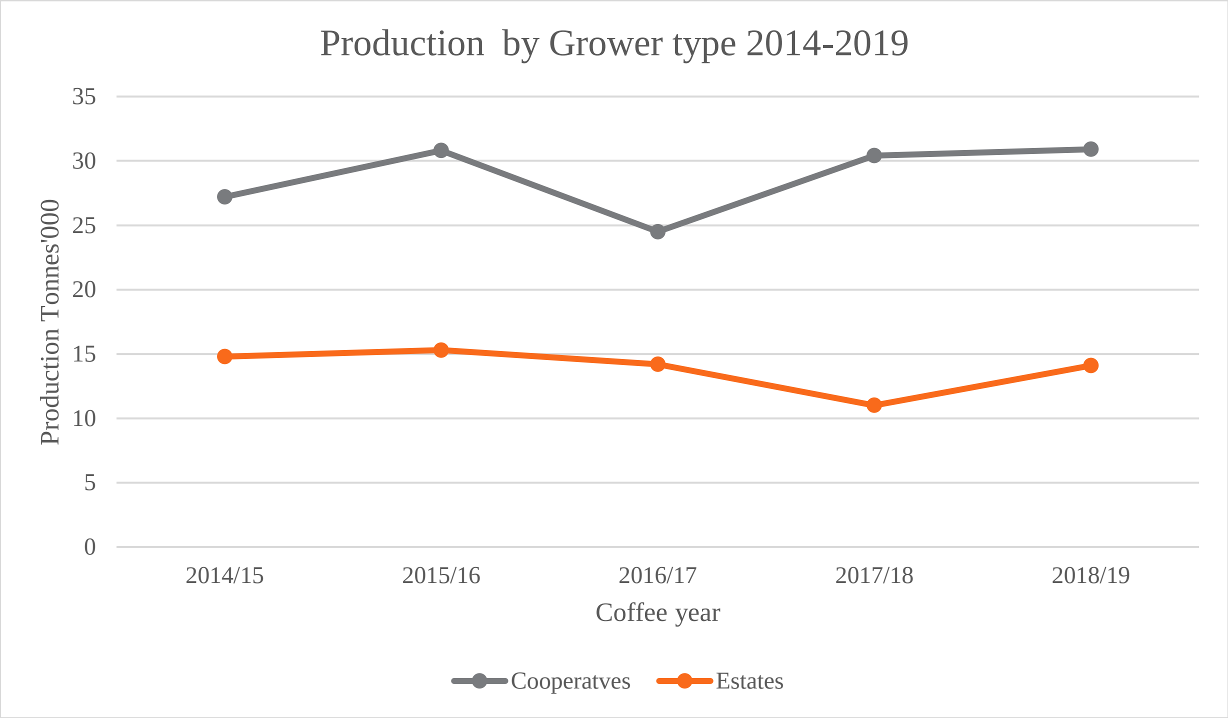
	2014/1	2015/16	2016/17	2017/18	2018/19
Hectares '000					
Cooperatives	87.8	88.2	88.8	89.5	90.8
Estates	25.7	25.8	25.9	26.1	25.4
Total	113.5	114	114.7	115.6	116.2
Production (Tonnes)'000					
Cooperatives	27.2	30.8	24.5	30.4	30.9
Estates	14.8	15.3	14.2	11	14.1
Total	42	46.1	38.7	41.4	45
Average/yield (Kg/ha)					
Cooperatives*	309.8	349.2	275.9	339.7	340.3
Estates*	575.9	593.0	548.3	421.5	555.1
	370.0	404.4	337.4	358.1	387.3

Derived numbers from the computations per the source document. Source: KNBS (2020)

The production has also slightly increased despite the large-scale farms abandoning the produce farming in favour of real estate development more so for the counties that neighbour Nairobi, the capital city of Kenya (KNBS, 2020) as shown in figure 1.

Figure 1

Production Trend for the Coffee by Grower Type for the Last Five Years



Data source: Kenya national bureau of statistics (2020)

The global trade and equilibrium of payment in 2019 reported a decline of 2.9 as the value of exports settled at Kenyan shillings (KES) 596.7 billion (US $5.97 billion) against the imports of KES 1,806 billion (US $ 18.06 billion) leading to a current deficit account (KNBS, 2020). Coffee, tea, and horticulture are the major agricultural commodities for the export market, as set out in Table 2 below. In terms of export revenues, coffee, which is the study's focus, was in fourth place in 2019 behind horticulture, tea, and fashion (KNBS, 2020). To bridge the gap and achieve equilibrium, the commodity crops farming is an area of great emphasis for the Kenyan government as we move to full eradication of poverty in all its forms by 2030.

Table 2

Quantities of Principal Domestic Exports, 2015-2019

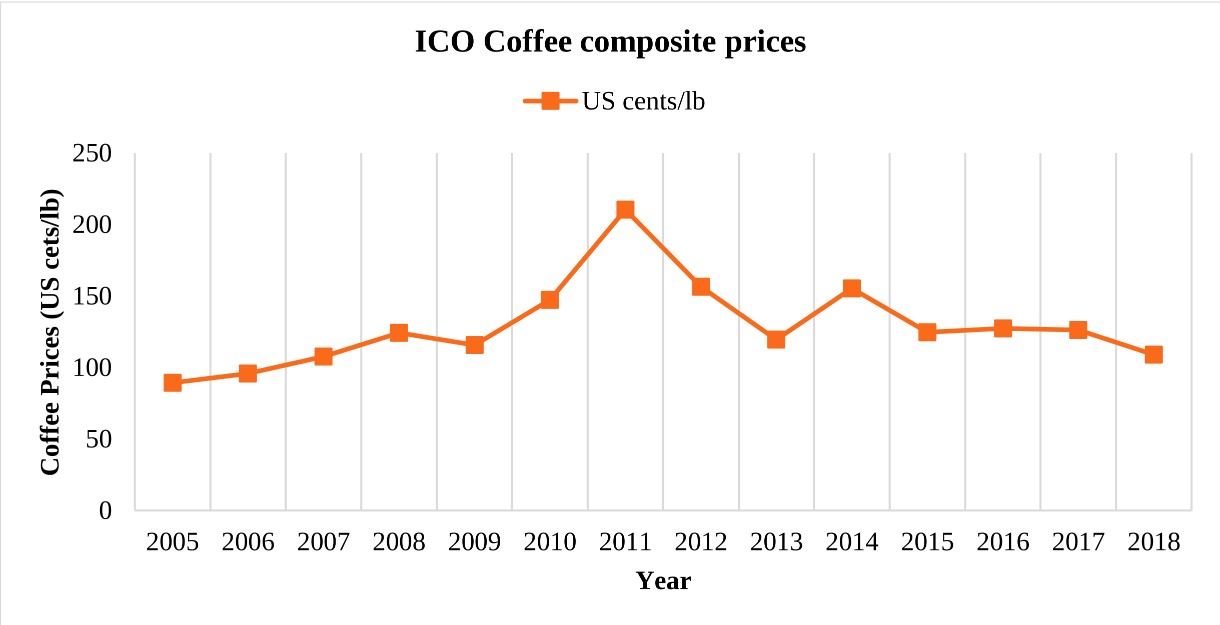
Year	Coffee Tonne	Tea Tonne	Horticulture Tonne
2015	43,600	420,527	443,076
2016	45,303	479,969	501,573
2017	43,469	467,032	457,201
2018	44,679	501,785	497,416
2019	48,735	475,502	467,602

Source: KNBS (2020)

The coffee production has been oscillating for the last five years without showing any trajectory increase, as shown in Figure 1 above. This is consistent with other studies done (Asayehegn et al., 2019; Thuku, 2013). Estates, some of them can produce at optimum at 2,000 metric tonnes per hectare (Eaagads, 2019). The coffee production price has been depressing more so in the period ending 2018 due to overproduction in the south American markets, as in.

Figure 2

Average Price of coffee in the New York Coffee Exchange



Source: ICO (2019)

Studies indicate that farmers are price responsive, and Kenya controls the sector through Coffee Directorate (CD) (Barjolle et al., 2017). Depressed prices have variable returns to the farmers, thus impacting on input utilisation. Recent studies allude that on yield management, small scale coffee farmers are less efficient at 54 percent (Kamau et al., 2017). Also, other recommendations on this subsector incline to the adoption of modern technology (Kamau et al., 2017), management of farms (Wambua et al., 2019; Kamau et al., 2017; Rijsbergen, 2016), training farmers (Ngweyo et al., 2015) and agency relationship for certifications (Muriithi et al., 2018).

The necessity to increase productivity and production growth in the agricultural sector, particularly among small-scale producers, is emphasised by the consensus for sustainable economic development. Productivity growth can only be attained by technological innovation, more effective application of currently available technology, or a mix of both. Small farms provide a variety of advantages, such as lowering unemployment, advancing income equality, and effectively generating demand for other economic sectors (Poudel et al., 2012). While significant technological advancements have been made through the green revolution in the past few decades, there is still room to improve productivity by better utilising existing technology. New agricultural technology has only had limited success in many developing nations. Therefore, if farmers are not making beneficial use of the current technology, it might be more cost-effective to concentrate on encouraging them to increase efficiency rather than introducing new ones. This approach is particularly suitable for resource-poor and marginalised farming conditions in countries where governments struggle to improve productivity despite implementing periodic plans and programs. Conducting such studies can provide valuable insights and contribute to the formulation of long-term production plans for high-value cash crops (Pemsl et al., 2022).

Based on the preceding, coffee farming has a paramount role in macro-economic and micro-economic level for the Kenyan government. There is limited data on agency management costs on coffee farming and its impact on TE. The concerns identified form the basis for this study on the agency relationships for the smallholder's farmers.

Statement of the Problem

Agriculture is a thrust force for Kenya's economic development, contributing more than a third in the gross domestic product (KNBS, 2020). Coffee commodity boom in 1977 through 1989 supported the rural families for they had safety, esteem needs to be met, and better access to social amenities. The collapse of the coffee subsector from 1989 due to controlled and untimely reforms led to government dependence on basic amenities for the rural community (Koss, 2024). In Kenya, coffee farming is a leading export earner alongside tea, horticulture, apparel of clothing, and accessories, which collectively account for 62% of the total domestic earnings (KNBS, 2019). It is an income-generating venture for rural-based families that alleviates poverty and hunger in line with global sustainable development goals. According to a study by Kundu and Ngigi (2018), cash payout from the agency due to a poor relationship led farmers to delay applying for agricultural inputs, consequently leading to low yield. Thus, there must be a good relationship between farmers and coffee agents, which can be identified as stronger and more yield, technological improvement, and TE. The observed agency relationship has its initiative from activity theory, which advances the subjects' interactive nature. Further, TE is an impetus of the “frontier” function approach. In the quest to improve growth in the agricultural sector, TE in farming households must be improved substantially.

Consequently, this will be recognised in farmers' socio-economic improvement and access to farm inputs.

Agricultural engineering is the ideal type of TE because it allows for the lowest production costs imaginable. A farmer applies a new technique that boosts crop yield and reduces waste thereby offer growers and farmers with precise forecasting, data driven decision making among others. These changes positively impacted on the bottom line of farmers which led to the improved food products at reasonable prices. These technologies may include irrigation, fertilisers, high yielding variety of seeds, insecticides/pesticides, farm machineries and financial institutions.

Unfortunately, small-scale growers and coffee farmers in Murang'a County confront a variety of difficulties, such as inadequate farming methods, subpar inputs, and restricted access to information, loans, and markets. New problems like climate change, altered pest and disease patterns, and demographic changes further exacerbate these problems. Traditional methods, such as boosting the use of pesticides and fertilisers and offering training on appropriate agricultural practises, fall short of closing the productivity disparities brought on by these problems.

The following passage examines different studies conducted on smallholder farming in Kenya, Ghana, and Rwanda. Ogada's (2013) research in Kenya found that a two-pronged approach is necessary to enhance the adoption of smallholder farm technology. Kamau et al. (2017) identified several significant factors of TE in smallholder coffee cultivation in Kenya, including farm size, coffee variety, financing availability, farmers' age, and household size. Al-Hassan's (2012) study in Ghana revealed that TE on smallholder rice farms is influenced by loan availability, family size, and non-farm employment. Education and the use of contemporary inputs are crucial factors that influence TE in the rice production in northern Ghana, according to Donko et al. (2013). The research by Mbogo (2019) in Kenya demonstrated that farmers who grow their crops in greenhouses are more technically proficient than those who do so in open fields, and that TE may be raised by more effective resource and technology use. Finally, Narcisse's (2017) study in Rwanda demonstrated that effective resource and technology utilisation can boost output in smallholder maize production.

The following passage discusses the limited research on TE in the field of agriculture. In a study on improving agricultural production in Rwanda, Ngong'a and Hong (2021) found that farms that grow hybrid maize varieties exhibit better values of TE, technological difference proportion, and meta-frontier TE than farms growing OPVs and indigenous maize varieties. The study also revealed that farmers exhibit significant differences in their technological and managerial capabilities. Meanwhile, Yetagesu (2022) conducted research on the variables affecting TE among smallholder coffee producers in Jimma zone, Southwest Ethiopia. The study discovered that the mean TE was 74.27 percent, indicating that smallholder farmers produce about 25.73 percent less than the frontier level of production overall.

Based on the above review, none has done a study on relational agency, technology, and TE in Kenyan coffee farming. With the active theory guiding this study with collaborative nature of the value of the actors, this study therefore will fulfill the gap by investigating relational agency, technology, and TE in Kenyan coffee farming in Central County.

Purpose of the Study, Research Aims and Objectives

Purpose of the Study

This study investigated TE among coffee farmers following the adoption of constructed relationships and technology by adopting a stochastic production frontier. Coffee exports lead to dollar inflows to the economy to alleviate poverty (KNBS, 2019); it is imperative to implore several ways to boost productions amidst glaring evidence of low yields. This will be identified by how coffee farmers adapt and utilise technology, variations in disease-resistant measures, and best coffee farming practices. A review of the study research questions dictates for a quantitative approach (Nyagaka et al., 2010).

By emphasising the difficulties faced by coffee producers in Murang'a in efficiently using resources and technology, this study attempted to close a research gap. By addressing these issues, farmers can improve their TE, resulting in higher yields and better-quality products. The use of stochastic production frontiers can also bring economies of scale benefits, reducing production costs per unit and increasing competitiveness for growers. This will enable farmers to operate in a wider market framework, reducing risks and losses and allowing them to participate in various market platforms and explore new markets with greater potential. Moreover, by improving the quality of their produce, farmers can secure higher farm prices, leading to increased productivity.

When quantifying technical inefficiency, the production frontier, a sort of production function, is employed to describe technology. Any departure from this boundary is viewed as an indication of technological inefficiency. A corporation is considered inefficient if its output falls short of the frontier. The degree to which a corporation is below the manufacturing frontier reveals its TE. According to Färe et al. (1985), production is technically efficient if it takes place outside of the set of production possibilities and technically inefficient if it happens inside the set.

Stochastic frontier frameworks are useful for assessing technical inefficiencies in industrial processes. These frameworks assume that given a particular set of inputs, production units like enterprises, regions, or countries may produce as much as they possibly can using a similar technology. These production units may experience inefficiencies because of a variety of circumstances, such as structural problems or market flaws, which prevent them from producing as much as they could.

The goal was also to evaluate Economic Efficiency (EE), which is broken down into two parts: TE and EE (Farrell, 1957). The capacity to create the greatest quantity of output from a given and achievable technology is referred to as TE, whereas EE aims to employ inputs in the optimal proportion in relation to their pricing (Coelli et al., 2005). The input-oriented method determines the extent to which a corporation can cut its inputs without negatively impacting its output. whereas the output-oriented method assesses how much a business can increase its output without changing its input levels. The efficient frontier can be categorised as either output-oriented or input-oriented.

Research Aims

The research goal is treasured as the ultimate desired outcome (Lee & Bong, 2019). Besides, the advocacy on goals theory is to have specific goals which are time bound (Locke & Latham, 1990). Adaptability of the subject to the constructs of the preferred actions leads to the achievement of the goal. The present study, based on the achievement goal theory, aims at deepening the understanding of the agency relationships' effect on TE. The findings of this study will be used to illustrate how technology and relational ideas have affected the coffee-growing sector. Another objective of the study is to use a stochastic frontier production function to estimate the level of TE among coffee-producing farms in the Githunguri division of Kenya.

It is impossible to overstate the importance of assessing TE given the country's dependence on the coffee industry. The necessity of looking into TE is further mandated by the downturn in the coffee industry sector. In addition, Vision 2030 predicts that Kenya would become a middle-income nation by 2030. Making ensuring that the GDP grows by at least 10% by 2025 is one method to make the vision a success. As a result, to produce broad-based economic growth, growth must be increased across the board, including the coffee industry. If the production and efficiency of the coffee business do not increase further, this goal cannot be achieved.

The study investigated the impact of relational agency, technological adoption, and TE in the dialect of how it impacts Kenyan farmers and their farming endeavour through the adoption of the frontier approach.

Research Objectives

i. To explore the existence of relational agency in coffee farming in central Kenya by November 15, 2020.

ii. To compare the levels of technology adoption by young and post-youth coffee farmers in central Kenya by November 20, 2020.

iii. To explore the relationship between coffee farmers in Central Kenya regarding the use of technology, the size of the farm, productivity, and agency by November 30, 2020.

iv. To identify the production yield of coffee farmers in Central Kenya by November 30, 2020.

v. To formulate recommendations to coffee farmers in Central Kenya to increase efficiency in coffee production by December 12, 2020.

Nature and Significance of the Study

Nature of the study

The study utilised a quantitative approach, including a revere for qualitative analysis. This study adopted the correlational research method (Williams, 2007). Correlation is the inference statistics for the variables pattern determination (Creswell, 2002). Leedy and Ormrod (2001) argued that it is paramount for the researcher to gauge the nature and extent of the inferences drawn from the test statistics.

Further, the study used a causal-comparative research design (Williams, 2007). To help the researcher find the causal-effect links between the variables under study, this is crucial. It will also allow easy validation of the research questions resulting from the provision of statistics herein (Nyagaka et al., 2010).

Data was collected using a structured questionnaire (Bee & Murdock, 2016). The questionnaire will follow through on the study's model to capture details such as socio-economic aspects of farmers, size of land, inputs utilised, intervention services, and yield per annum. Data captured were cross-sectional for a definite time (Belotti et al., 2013). The validity of the questionnaire was tested accordingly, and the enumerators partaking in research shall be subjected to training. The questionnaire was organised in the right structure to capture the questions identified for this research and to achieve its purpose.

The data were analysed using the Stochastic Frontier (SF) model, which has gained popularity since the works of Aigner et al. (1977). Progressive studies have led to the improvement of the model (Green, 2012). Unlike in the Data Envelop Analysis (DEA), the error term's existence as a predictor of inefficiency makes the model a better estimator of TE (Yohannis et al., 2020). The logarithmic function was examined using to fully address the research concerns of the study, the SF cross Stata software command (Belotti, 2013) to generate the variable vector estimates as well the technical inefficiency as explained by the exogenous variables (relational agency).

Model 1
Stochastic Frontier Model

$\ln Y^*i = \beta0+\beta1\ln M1 + \beta2\ln M2+\beta3\ln M3+\beta4\ln M4+\beta5\ln M5 + \beta6\ln M6+ \varepsilon i$

where Y*i is the technical efficiency estimate of the coffee output.

M1 is access to technology (tractor for agricultural mechanisation services);

M2 is the total number of labours in Coffee farming;

M3 is the educational status of respondents

M4 is the number of managing consultants (extension visits); and

M5 is the sex of the farmer (a dummy variable, 1 for males and 0 for females); M6 is the amount of credit received during the cropping season (in KES); εi is the error term; and βi is a vector of parameters to be estimated.

Descriptive statistics was used in the study to analyse the socioeconomic characteristics of the data sample, including mean and standard deviation for categorical and continuous variables. This analysis provided a response to research questions that measure data dispersal (Misra et al., 2019; Kamau et al., 2017). The variables were tested for significance using inferential statistics, and a $P>0.05$ value will indicate acceptance of the null hypothesis (Misra et al., 2019). Regression analysis was conducted to test the relationship between variables and identify outliers, as well as determine the predictor variable's influence on the criterion value through significance testing (Mugenda & Mugenda, 2003). Research questions three and four were analysed using regression analysis.

Significance of the Study

The agricultural sector ranks third in the Kenyan economy, the inefficiencies in this sector are depicted on the primary producing units, the coffee subsector (Varga, 2020). The present study will contribute to management and business through advisory. The study demonstrated how relational agency contributes to better yields and best practices. Besides, the study aimed to fill the gap identified by Kundu and Ngigi (2018) and offer a recommendation on agency networks. Strong agency through activity theory yields better returns. All actors (stakeholders) in the production (Coffee sub-sector) should work coordinated to ensure all desired outcomes are attained. Kamau et al. (2017) concluded that improving farming practices enhances efficiency as their study recorded a 54.4% score. Completing this study will demystify this, showing how accredited professional management coffee agents add to TE (Thuku et al., 2013).

The study contributed to the economic theory of production through substantive statistical tests to demonstrate the importance of relational agencies in agriculture and how it affects coffee production. This study addressed the existing gap on lack of study on relational agency and TE in coffee farming by offering a report on the interplay of the economic theory. Besides, the stochastic frontier analysis was tested to affirm the importance of this model, alluded by Aigner et al. (1977) in the determination of TE. Further the study will contribute to the academia by filling the gap on the lack of agency costs studies in developing and African countries Kenya on relational agency and TE.

The government and corporates in coffee management shall benefit from the research findings on how to manage the small farms. The study shall aid in policy formulation as the government existing reforms towards liberalisation have done little to improve coffee production (Asayehegn et al., 2019; Karanja & Nyoro, 2005; Thuku et al., 2013). This will help with government policy intervention and management of agency relationships through cooperative movements (Thuku et al., 2013). Besides, the SF analysis model of study will contribute to academia on how exogenous variable relational agency affects the technical inefficiency in coffee farming.

Measuring efficiency was critical for determining the causes of technological efficiency disparities and developing public and private measures to enhance performance. Identifying the sources of inefficiency might aid in the supervision and monitoring of manufacturing units' performance. Furthermore, this sort of production assisted farmers in reducing or eliminating environmental and social problems while also increasing farming management techniques and abilities to satisfy programme criteria. Farmers were able to produce better quality coffee with price premiums, enhanced market access, and increased on-farm efficiency or production consequently.

Many studies have investigated the TE of agricultural sectors, including analysing factors that affect TE among coffee farmers in Cote d'Ivoire (Nyemeck, 2003), calculating TE in Tanzanian sugarcane output, and evaluating TE in Kenya's maize production (Ashimogo, 2005). Few research, meanwhile, have used the stochastic frontier approach to investigate TE among coffee producers in Kenya's Murang'a County. Further focus is required to lower production costs by boosting TE given the difficult policy environment and scant research on TE in coffee growing (Kibaara, 2005). It is essential to evaluate existing TE levels to find any production losses that can be attributed to inefficiencies brought on by variations in socioeconomic traits and management techniques.

Since many coffee farmers in Central province of Kenya depend on their crop for a living, underemployment has been a problem in the past due to a decline in coffee production, low crop prices, and low worker productivity that led to the closure of several factors. The cost of coffee inputs is being subsidised by the Kenyan government, but this has not stopped the drop in coffee production. To improve the welfare of the coffee sector, it is necessary to look at alternative methods of growing coffee production. One strategy to boost coffee production is to identify sources of inefficiency. In this regard, efficiency measurements must be used to ascertain the greatest amount of coffee that can be produced given a particular quantity. It is crucial to conduct research on the elements that affect TE during the coffee-making process. Numerous researches on TE have been conducted, but none have examined the coffee industry in Kenya's Murang'a County. This study will help decision-makers increase their understanding of and adopt novel coffee production techniques.

Most small-scale coffee farmers have switched from their primary crop of coffee to other farm ventures like dairy, horticulture, and more importantly, subsistence farming, as a method of alternative farming. Others who were fortunate enough have ventured off the farm and started small and medium-sized businesses or looked for temporary work elsewhere. Because of this, coffee has been ignored. Some people now intercrop all kinds of crops, and in severe circumstances, they uproot the crops to invest in real estate or carry out other farming operations. Due to this, there has been a decline in the area under the crop and low coffee production, this study will be significant as it will assist other scholars to find new ways of better farm practices.

This study therefore fills the gap and adds value to the existing body of evidence on TE in coffee farming in Central province of Kenya.

Research Questions and Research Hypothesis

General Research Question

What is the impact of relational agency, technology on technical efficiency in Kenyan Coffee farming?

Research Questions

RQ1 How do relational agencies (Agro-management services, extension officers, marketing agents) improve technical efficiency in coffee farming in central Kenya?

RQ2 What is the difference in technology use (improved cultivars, mechanised, bio-inputs) between young coffee and post-youth coffee farmers?

RQ3 What is the association between agency networks (management entity, extension, and certification bodies), technology use (mechanised, improved variety), farm size, and productivity among coffee farmers in Central Kenya?

RQ4 What is the production produce of coffee farmers in Central Kenya?

Hypotheses

The hypothesis for the other research questions is formulated below.

H1o: Existence of agency networks (Coffee management agents, marketing agents, and extension) positively affects technical efficiency in coffee farming in central Kenya.

H1a: The presence of agency networks (Coffee management agents, marketing agents, and extension) has a negative effect on technical efficiency in coffee farming in central Kenya.

H2o: Young farmers use improved cultivars, bio inputs and mechanised implements than the post youth farmers.

H2a: Both young farmers and post youth farmers use improved cultivars, bio inputs and mechanised implements.

H3o: There is no relationship between technology use, farm size, agency networks, and productivity among coffee farmers in Central Kenya.

H3a: There is a relationship between technology use, farm size, agency networks, and productivity among coffee farmers in Central Kenya.

H4o: Production yield of coffee farmers in Central Kenya is greater than zero.

H4a: Production yield of coffee farmers in Central Kenya is less than zero.

CHAPTER 2: LITERATURE REVIEW

Introduction

Production theory has updated literature on TE in agricultural production. This study section explores how the activity theory, production theory of economics and the technology acceptance model underpins the study. The relational agency is explained by the activity, whereas the TE is part of production efficiency and technology is discussed under the technology acceptance model. Besides, the literature review is well documented under the subtopic themes to document the empirical and theoretical literature on the topic. The subthemes discussed in this section are, coffee production in Kenya, TE, relational agency, technology in coffee farming, and land reforms in Kenyan coffee farming. The subthemes are because of detailed research dating back to the year 2015 when I started my journey as a coffee management reporting accountant.

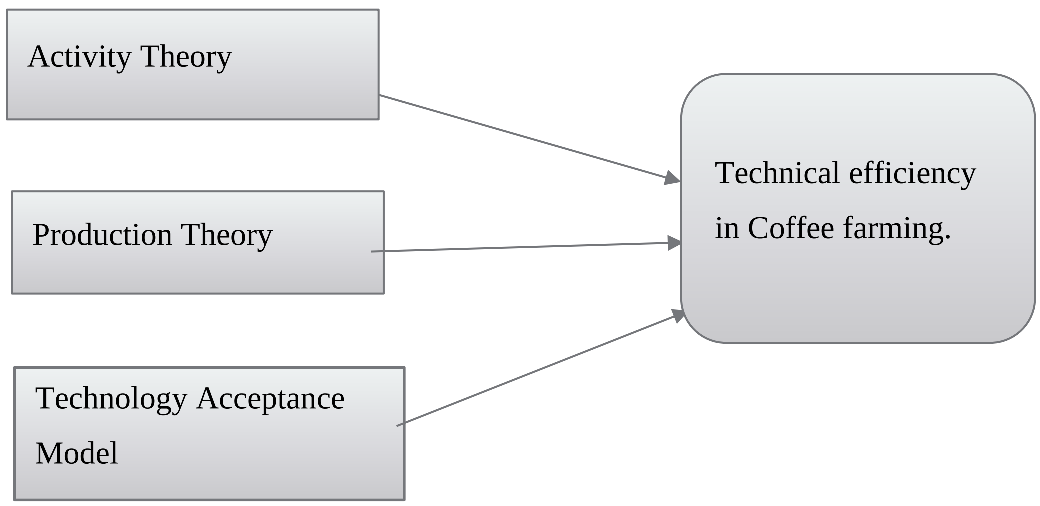
The keywords used in the literature review search were Agriculture, Activity theory, Agency theory, Coffee, Technology, Relational agency, TE, Collaborative Agency, Production function, Allocative efficiency, EE, Land reforms, Climate change and Smart agriculture. The search engines used in the study were Google Scholar, Microsoft Academics, ResearchGate, Connecting repositories, ProQuest database and Semantic scholar.

Theoretical Framework

The study adopted three theories to expound the concept of relational agency, technology, and TE in Kenya coffee farming. The theories were Activity Theory; Production Theory, also known as the frontier function approach, and Technology Acceptance Model. The activity theory relates to the relational agency in Kenyan coffee farming, while the second and third models detail the technology and TE aspect. The study adopts activity theory as it first provides a framework to analyse actions in a meaningful way in a collaborative environment. Secondly, it allows individual engagements to be intentionally embedded in the organisation to produce the desired results (Kitteringham & Fennelly, 2020). Third, activity theory is sequential in activity building and breaks down the steps for ease of implementation. The relational agency is derived from the activity theory that explains the collaborative nature of the value actors in coffee farming. Besides, production theory lays the underpinning model for efficiency and input combination to achieve the best output. Whilst the technology acceptance model exuberates the acceptance, adoption, and diffusion of improved ways of doing tasks. Figure 3 below illustrates how the three theories link up together. All these three theories are discussed in subsequent sections.

Figure 3

An Illustration of the Theoretical Framework



Activity Theory

It was Vygotsky who first developed activity theory in the 1920s. It was later advanced by his student Engestrom (Daniels et al., 2018). Vygotsky related human thinking to their actions. He stated that action precedes thinking and that it is through activity that an individual produces a solution. Initially, the theory involved interactions of three things: subject, object, and tool. The subject is the person undertaking the action. The object is the action itself, while the tool is the device that facilitates the activity (Cole et al., 2018).

Furthermore, Engestrom added two sets of analyses on the original theory developed by Vygotsky. The first addition is the rules, while the second pertains to the division of labour. The rules explain why and how individuals engage in activity after being conditioned. The division of labour details how work is shared among the subjects involved (Bozalek, 2016). Thus, the two additions create a new environment known as the community that holds the workers and the activity groups. Engestrom showed the relationship between object, subject, community, tool, rules, and division of labour (Daniels et al., 2018).

Activity theory considered the use of technology as tools that intercede social activity. These tools incorporate instruments, symbols, language, machines, and PCs (Bozalek, 2016). The connection between a person and their condition is considered throughout the part of the community. Rules intervene in the subject-community relationship. The division of labour intercedes the object-community association. Since tools fused into the social framework are made and altered by people during the improvement of the activity itself, technology is used to showcase changes at each stage for future generations to use (Nunez, 2015).

Therefore, activity theory describes how individuals cooperate in undertaking a task with the help of technology (Kaptelinin & Nardi, 2019). The theory has traversed modern society where machines do a lot of tasks, but human contribution is always there. The industrial sector particularly manifests its operation through this theory. If there is an activity conducted by individuals, society's produce is always guaranteed (Cole et al., 2018).

Numerous researchers perceived this theory as being comprehensively wealthy as far as seeing how individuals do things and the help of modern tools in such complex and dynamic conditions. In their context, method engineering from an activity theory perspective was differentiated through a collective of actors following different rules and activities. Together, they helped guide further improvements in work processes to realize better results. They concluded that activity theory worked well with method engineering, which was beneficial as a theoretical exercise and a practical tool (Karlsson& Wistrand, 2017).

The interaction between several variables in the Kenyan coffee producing sector was demonstrated in this study using the activity theory. More precisely, this study hypothesizes that the existence of agency networks (Coffee management agents, marketing agents, and extension) positively affects TE in coffee farming in central Kenya. It will thus determine the subjects in the sector. Agro-management services, extension officers, marketing agents, young and post-youthful farmers, will fall under this category. The activities carried out by all the stakeholders involved will be outlined, hence fulfilling the object element. The other key component that will be investigated is the tools that facilitate smooth operations in the sector.

Are there rules put in place in the Kenyan coffee farming. This question will be answered by looking at how the rules are set, who sets them, and who. It will also investigate how the relationship between the subject and the community is affected by the set rules. The interplay between the object and the community, the Kenyan coffee farming sector, and their connection through labour division will also be explored in this study.

The interaction between several variables in the Kenyan coffee producing sector is demonstrated using the activity theory. More precisely, this study hypothesises that the existence of agency networks (Coffee management agents, marketing agents, and extension) positively affects TE in coffee farming in central Kenya. It thus determines the subjects in the sector. Agro-management services, extension officers, marketing agents, young and post-youthful farmers, fall under this category. The activities carried out by all the stakeholders involved were outlined, hence fulfilling the object element. The other key component that will be investigated is the tools that facilitate smooth operations in the sector.

Production Theory and Frontier Function Approach

The economic production theory suggests, as demonstrated by Cohen et al. (2019), that owners or business entities typically decide the amount of a product to be manufactured as well as the quantity of raw materials and other production factors devoted to the development process based on a set of principles derived from various internal and external environmental factors. The proprietors or business entities represent the farmers and coffee business ventures, respectively, when comparing this theory to the overall hypothesis of this research.

To determine TE, Battese & Coelli (1989) introduced the stochastic frontier approach (Raa & Greene, 2019). According to O'Donnell (2018), TE is a measurement of how successfully inputs are converted into the desired outputs through the interaction of technology and opportune economic circumstances. Therefore, it is common to have two producers with similar technology and inputs producing varying outputs. TE is realized when the producer can achieve the highest output with minimal inputs. As a result, TE can be either input- or output-oriented. When producing TE that is input-oriented, the producer makes sure that the fewest possible inputs are used. An output-oriented TE ensures the highest output is realized from the available inputs. However, to factor in the external shocks, the error term is introduced (Aigner et al.,1977, Raa & Greene, 2019). The TE error is also introduced to cater for ununiformed producers' frontier output.

To cater for random shocks such as weather changes, bad economy among others that may affect production. A component to show that shock is added denoted with $\exp\{v_i\}$. The stochastic production frontier therefore changes to:

$y_i = f(x_i; \beta). TEi. \exp\{v_i\}$

TE_i can also be rewritten as $TE_i = \exp\{-u_i\}$, where $ui \geq 0$, for *TE_i to be greater or equal to 1*. The equation becomes:

$y_i = f(x_i; \beta). \exp\{-u_i\}. \exp\{v_i\}$

further, on assumption that $f(x_i, \beta)$ takes the log-linear Cobb–Douglas form, the equation changes to:

ln $y_i = \beta_0 + \sum \beta_n$ lnxni + vi - ui {\displaystyle \ln y_{i}=\beta _{0}+\sum \limits _{n}{\beta _{n}\ln x_{ni}+v_{i}-u_{i}}}

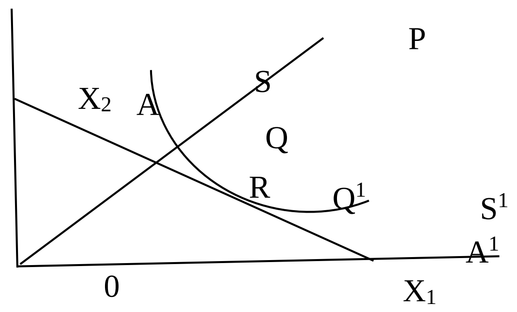
v_i and u_i are the error terms with v_i as the "noise" component, and u_i as the non-negative technical inefficiency component.

Also, Kumbhakar & Lovell used SFA to examine the "cost" and "profit" efficiency. The "Cost frontier" approach measured how far the firm was from full-cost minimization. The non-negative cost-inefficiency component was added instead of being subtracted in the stochastic specification (Padmavathi et al., 2019). Baltas similarly used SFA in microdata of consumer demand to benchmark consumption and segment consumers. A stochastic frontier model was estimated in a two-stage approach, and subsequently, deviations from the frontier were regressed on consumer characteristics (Padmavathi et al., 2019).

When considering the performance of a farm, it is assumed the best practice frontier is stochastic. This study will, therefore, utilize the model to determine the TE of Kenya coffee farming. The study will take an input-oriented approach as shown in figure 4 below. This model was coined by Farrel which empirically consents for an approximation of Technical and allocative efficiency (Kamau et. al., 2017). It considered the following socio-economic aspects; the land size, coffee cultivars, inputs utilized, intervention services, and yield per annum. The study also factors in the exogenous factors caused by economic disruptions, weather variations, and natural catastrophes.

Figure 4

An illustration of Technical Efficiency



Source; Kamau, et. al., (2017)

On the figure above point, P represents a level of input combination that the firm is observed to use to produce an output. The axis is the combination of the inputs, X_1 and X_2. Isoquant SS^1 represents the efficiency level for the two inputs. Any production along the isoquant is efficient, point Q and Q^1 are both efficient. The factor prices combination is represented by line AA^1. To produce the same level of output, the level of the input can either be at point Q or point P. At point Q we are using a lower level of inputs, thus total inputs 0Q, while P is using more inputs level denoted as 0P. The ratio 0Q/0P represents TE.

Utilising the stochastic frontier method and a production function-based approach, research on technical and allocative efficiency on a representative sample of New England milk producers on Cobb-Douglas discovered, mean of thirty percent economic inefficiency. Nevertheless, the research found a minimal variation in 83 percent average TE and 84.6 percent average allocative efficiency (Bravo & Riege, 1991). Cattle fields had technical effectiveness ratings of sixty-nine percent when utilizing data envelope analysis (Lansik & Backman, 2002). Yet, as Coelli et al. (2002) point out, the efficiency scores derived by various approaches only evaluate the comparative effectiveness within the population being studied. Coelli et al. (2002) discovered, for instance, that the size of the farm was a criterion that had a considerable impact on effectiveness. On a selected number of Ecuadorian milk producers, Barleiy et al. (1989) assessed scientific, allocative, as well as financial effectiveness and discovered an advantageous association between the size of the farm and technical effectiveness. Small to medium-sized farmlands were shown to be equally allocative effective as big agricultural land, compared to the New England research (Barleiy et al., 1989).

Technology Acceptance Model (TAM)

The model based on Technology aimed at predicting user acceptance while outlining potential issues before the user interaction with the technology. It borrows from the principles of the Theory of Reasoned Action, which explains social intents and the real conduct of new technology adoptees (Aubertetal., 2017). The concepts revolve around perceived ease of use (PEOU) and perceived usefulness (PU) in a model. These elements refer to users' perceptions and beliefs about technology. PU relates to how much a user thinks that using technology would improve job performance and productivity, while PEOU relates to how easy the user thinks it is to use the technology (Davis, 2020).

An extension of TAM to TAM2 indicates that TAM2 model brings about cognitive and social influence process as a method to measure the PEOU and PU. The model specifies how new users could be persuaded to use the latest technology (Venkatesh & Davis, 2015). The TAM2 model brought about cognitive and social influence process as a method to measure the PEOU and PU. They showed that TAM2 explained 52% of the variance in PEOU a particular technology while accounting for 60% of the variance in PU (Venkatesh & Davis, 2015). In another research TAM was extended to the Unified Theory of Acceptance and Use of Technology (UTAUT). The researchers concluded that the UTAUT model outperforms other acceptance models based on the value of an adjusted R2. The model specified how new users could be persuaded to use the latest technology (Venkatesh & Davis, 2015).

In a study done in the Ugandan Mt. Elgon region, Sebatta et al. (2020) examined the chance of transitioning to Arabica coffee-banana management techniques. Assessing the TE of four Arabica coffee-banana production systems and identifying the factors affecting farmers' acceptance of new practises were the study's main goals. The intensification paths were then organised to form a TE gradient after the study produced a production function to determine TE. To find out what motivates farmers to switch between systems, an ordered logit model was used. According to the study, farmers could only produce 50% of the maximum potential Arabica coffee output, which indicates a significant gap between actual and potential yields. The lowest efficiency was linked to fertiliser use. To increase the efficiency and sustainability of Arabica coffee production in the region, the study suggested that farmers adopt a low-input-low-output pathway and use improved coffee genotypes, manure, and labour intensification, particularly in the conventional and mild agroecological higher TE clusters.

Nguyen et al. examined smallholder farmers' increasing involvement in sustainable coffee farming in Vietnam in 2019. To compare the financial impacts of conventional versus sustainable coffee production on farmers' welfare, they employed stochastic frontier and cost-benefit models. Their study involved 316 smallholder farmers in Dak Lak. The researchers also conducted key informant interviews and field observations to explain various farming strategies. The study's conclusions indicate that economic incentives had a major role in farmers' decisions to engage in sustainable coffee production. Environmentally friendly agriculture was more profitable than traditional farming, despite minor variances in production efficiency. Increased agricultural knowledge, education, and group efforts, according to the authors, may help to mitigate the detrimental consequences of small-scale production on sustainably farmed coffee farmers. For the sector's long-term growth, they advocated pesticide control, increasing shade coffee, and eliminating excessive fertilising, over-irrigation, and unproductive coffee varietals.

Numerous researches, including those by Ho et al. (2014), Priyanath et al. (2018) and Ho et al. (2014) have used SFA to disentangle the effects of stochastic factors on inefficiency. Due to their simplicity in estimate and interpretation, the half-normal and truncated normal distributions are often utilised (Hong & Yabe, 2015). This method will be used in this study to compare the economic performance of conventional and sustainable coffee cultivation in Vietnam and to conduct a cost-benefit analysis. The report also addresses the key concerns about farmers' compliance with sustainable farming laws. The premise is that coffee growers are rational in selecting the most beneficial cultivation strategy. However, increases in farmers' welfare may range dramatically across the two agricultural systems due to differences in production intensities, yields, production costs, and coffee prices (Bacon, 2005; Daviron &

Ponte, 2005). The study's goal is to help authorities promote and preserve sustainable coffee cultivation in Vietnam.

Additionally, Yousafzai et al. (2017) conducted a meta-analysis and found three major factors attributable to the wider TAM adoption. The study did a meta-analysis of the research on TAM in the last fifteen years indicates a high correlation for the "field setting" concerning PU, PEOU, and the intention to use different technologies. The most-reported limitation concerning TAM is related to the self-reported usages. Additionally, since TAM is utilised in the prediction of behavioural intention concerning coffee.

Relational Agencies in Improvement of Technical Efficiency in Coffee Farming

Coffee Farming in Kenya

The commercial structure of this crop has called for in-depth academic investigation of a range of subjects pertaining to its production in the nation (Barjolle et al., 2017; Kamau et al., 2017; Muriithi et al., 2018; Ngweyo et al., 2015; Van Rijsbergen 2016; Wambua et al., 2019). This section will review relevant literature to understand the cultivation of coffee in the country. Specific themes that fall within the focus of this research's questions will be examined and used to make a concise conceptual framework to guide the preceding steps of data collection and analysis.

The Government of Nepal aims to achieve rapid agricultural growth by promoting cash crops like coffee. In the region, shade coffee cultivation, particularly the Arabica variety, combined with marketable intercrops, is a prevalent farming method (Poudel et al., 2012). Shade crops, which consist of multipurpose tree species, provide additional income for farmers. Intercropping is the practise of growing two or more crops concurrently on the same piece of land while using different row configurations. This method has a few benefits, such as better environmental factor utilisation, increased yields, soil protection, and social betterment. It's essential to use the available resources wisely if you want to increase output in small-scale farming operations. The production process is significantly influenced by variable inputs such as seeds, fertilizers, capital, labor, and managerial skills (Poudel et al., 2012). Production economics is concerned with optimization, which implies efficiency. Efficiency measurement is crucial since it results in significant resource savings. The estimation of efficiency metrics is possible using both parametric and nonparametric methods. Data envelopment analysis (DEA), a nonparametric technique, does not impose any parametric limitations on technology and does not need a particular functional form for production linkages. This nonparametric method is thought to be more adaptable for figuring out efficiency.

Most of the scholarly literature featured in this review illuminates the value that coffee presents to the Kenyan economy. Kamau et al. (2017) recognise coffee cultivation as a pivotal contributor to the Kenyan economy. They indicate that coffee farming has led to the employment of more than 6 million people in Kenya, both directly and indirectly. A significant portion of the people employed through coffee farming work in marketing relation operations meant to ensure that this crop's products are consumed both locally and globally. This point is also supported by Ndirangu (2016), whose study examines the history of coffee rearing in the country. In his review, showcases how the cultivation of this crop has revolutionised rural farmers' economic status in central Kenya.

The tending of Coffee in Kenya is traced back to the colonial days at the turn of the 20th century (Minai, 2017). Ndirangu (2016) explains that coffee farming was introduced in the country by European settlers, who had come to leverage the untapped agricultural potential abundant in pre-colonial Kenya. Little traces of the crop were noticeable in select parts of the country during the late 1890s and early 1900s. White settler farmers who were already familiar with coffee cultivation brought their expertise into Kenya during pre-colonial times. Ndirangu (2016) indicates that foreign coffee farmers' expertise was noted in the selection of ideal locations equipped with fertile soils and other climatic conditions that support the nourishment of this crop. The study also illuminates the political forces that shaped the cultivation of coffee in the country. Most notably, native African farmers were prohibited from cultivating coffee, given the immense economic rewards associated with this activity. However, over time, the liberation revolutions and anti-colonialism rhetoric gained traction, and by the early 1950s, select native farmers in Kenya were allowed to farm coffee. Since then, native farmers embraced coffee farming, and the popularity of this crop as the preferred economic activity was well pronounced long after attaining independence (Ndirangu, 2016).

The positive impact that coffee farming has had on Kenyans is well documented. As illustrated by Kamau et al. (2017), coffee farming is in the top four foreign currency earners. The study further shows that coffee farming contributed more than $108 million to the Kenyan economy in 2011 through foreign earnings in 2011. The cultivation of this crop has gradually been intertwined into the Kenyan culture. Since the end of colonialism and the institutionalisation of laws that allow local farmers to plant coffee, more and more Kenyans have taken up coffee farming. Kamau et al. (2017) estimate that more than 700,000 subsistence farmers in the country cultivate coffee. This trend is unique to sub-Saharan African countries that practice coffee farming. Dürr (2016) indicates that large-scale farmers contribute to most of the coffee production in developed countries. On the other hand, in most sub-Saharan African countries, small-scale producers are responsible for most of the coffee produced in this region. By proving that more than 85% of the nation's total coffee crop is produced by small-scale coffee growers, Kamau et al. (2017) reaffirm this argument. Since small-scale coffee farmers are the foundation of this business in the nation, many academics who have studied the development of coffee farming in the nation concur that more work needs to be done to increase their productivity.

According to Okech (2019), coffee is the leading tropical commodity in global trade, primarily produced by small-scale farmers. The effectiveness of the organisations established by these farmers greatly influences the economic benefits they receive from coffee production and marketing. In Kenya's coffee sector, Producer Institutional Arrangements are mainly comprised of cooperatives, with nearly all coffee farmers being cooperative members. This is because farmers with fewer than five acres are required by law to join a cooperative. In all producer arrangements, the study discovered a strong association between the institutional frameworks for producers and the financial gains for farmers. The study demonstrated the importance of farmer agency in determining the link between institutional frameworks and economic benefits, with Certified Coffee Cooperatives having the biggest influence, followed by Coffee Estates, and Non-certified Coffee Cooperatives coming in last. The study concluded that the farmer agency worked best in Certified Coffee Cooperatives. While certification had advantages, it also had difficulties with acquisition and upkeep. These results are consistent with the theories applied and show the value of institutions, which is emphasised by the New Institutional Economic theory. The report also highlights how transaction expenses have a big impact on the financial rewards that farmers obtain.

Several legislation and regulations were gradually put into effect to liberalise Kenya's coffee industry. In 1991, for example, the Kenya Planters Cooperative Union and the Coffee

Research Foundation lost their financial assistance because of these efforts (Wanzala et al., 2022). The cooperative farmers' land area was decreased from ten acres to five acres in 1996. In 1999, upstream procedures underwent additional deregulation, allowing growers to pick their preferred mills, pulping facilities, and marketing partners. In 2001, the Central Bank of Kenya (CBK) was only given limited regulatory authority, and in 2006, direct sales and the privatisation of the coffee auction were both permitted. As a result, cooperatives have the choice to either hire a professional miller or mill their own coffee privately at the factory level. Cooperatives and estates have the option of promoting their coffee either directly or through a marketing agent (Anania et al, 2019). Marketing agents are responsible for overseeing the sale program, determining the quantities and qualities offered at auctions, providing growers with samples before the auction, acting as growers' representatives while the auction is taking place, and managing the collection and distribution of exporters' revenues after the final sales. Through dealers, coffee delivered to the Nairobi Coffee Exchange's primary auction is sold. A small portion of the coffee is locally roasted and can be exported as individual lots or combined into greater volumes of consistently high-quality coffee.

There are now more players and options available thanks to the liberalisation of the coffee industry. As a result, adjustments were made to the institutional framework of farmer-participated producer institutional arrangements because of the laws and regulations controlling the coffee sector (Wanzala et al., 2022). Small-scale coffee farmers are still required by law to be members of cooperatives even though the institutional environment has altered. Considering that most coffee growers are small-scale farmers, research institutions is essential to comprehending the sector's economic performance. The goal of institutional arrangements is to facilitate production and help farmers achieve their primary objective of attaining economic benefits from their activities (Jaffee, 2012). Whether in cooperatives or estates, farmers share the goal of economic benefit. This study fills in the gaps in the existing literature by conducting a comparative analysis of several producer institutional arrangements in the coffee sector and examining the role of farmer agency within the context of these institutional arrangements.

The failure to consider institutional frameworks has resulted in underwhelming outcomes of development interventions. By include additional parties in the coffee supply chain and giving small-scale farmers more options, the institutional framework of the coffee business was changed because of liberalisation (Kamau et al., 2019). Small-scale farmers were expected to benefit from cheaper costs and better pricing because of competition among millers, marketers, and buyers. Farmers now have more options, but their capacity to make use of these opportunities depends on the institutional frameworks in place. According to the literature, the idea of empowerment emphasises the fact that giving farmers options does not necessarily make them more powerful. Not only must one have options, but one must also be able to use and gain from them.

The institutional structure of coffee cooperatives has been the subject of numerous researches on areas that either empower or disempower farmers (Makinde, 2024). These problems include inadequate coffee tree kinds and farming practises, considerable indebtedness, management issues, access to information and productive resources, farmers' negotiating strength, a lack of economic advantages and many supply chain members (Minot & Sawyer, 2016). Other factors include interference from politics in the management of the coffee society, an increase in coffee theft as a result of liberalised marketing, fragmented cooperative unions limit economies of scale and create instability brought on by an increase in cherry hawking, a lack of government support, including ineffective marketing efforts, high operational costs in farmer-serving organisations, difficulties with making poor investment judgements and repaying World Bank loans.

Proposed recommendations in the literature to address these challenges consist of several measures. Firstly, it is suggested to enhance information dissemination regarding the various institutions within the coffee sector and evaluate if different institutional arrangements can perform the same or more vital functions in a more efficient and cost-effective manner (Jaffee, 2012). Additionally, efforts should be made to promote competition, curb corruption, and reform governance structures. Improving communication channels between cooperatives and buyers, as well as providing information on cooperatives, is also recommended. In addition, it is important to address the problems brought on by liberalisation, such as the lack of management ability and the lowered access to loans and agricultural inputs. Government assistance in cooperative capacity building and the creation of public-private partnerships can be helpful in the near term (Meissner, 2019). Moreover, farmers' cooperatives should be developed as a means of vertical integration for the farmers. In terms of coffee marketing, there are two main methods: direct sales and auctions at the Nairobi Coffee Exchange, although it offers higher prices, typically has a longer payment duration compared to auction sales. Marketing agents play a significant role and are commonly employed by cooperatives and estates, although they have the option to obtain a grower-marketer license. However, it is the norm for most cooperatives and estates to utilise a marketing agent, often affiliated with the miller used. It is worth noting that cooperatives with their own mill usually follow this practice, whereas separate entities for marketers and millers are mandated.

Some of the individuals interviewed, including estate owners, mentioned instances where they had employed marketers who were not affiliated with the miller. In these cases, disputes arose between the millers and marketers regarding the coffee price (Koss, 2024). Millers would place the blame on the marketers, claiming insufficient marketing efforts, while the marketers countered that the coffee was of poor quality when it was delivered. Only a small portion of the coffee produced in Kenya is exported, necessitating roasting, grinding, and packaging. Most of this coffee is exported in its unroasted form. Farmers cited several marketing-related difficulties, such as erratic prices that caused them to limit inputs as a risk-avoidance measure, low payouts that decreasing interest in farming, especially among young people, and a lack of accountability and openness. Insufficient and tardy documentation, a lack of comprehension of the marketing process, and apparent collusion between millers and marketers as well as between marketers and auction dealers were all concerns with transparency. Throughout the coffee chain, cooperation among cooperatives was observed in various activities (Makinde, 2024). Seven non-certified cooperatives and ten recognised cooperatives' key informants talked about cooperative initiatives such as information exchange, training, and joint tendering for inputs. Additionally, among other outside parties involved in the coffee chain, eight informants—seven from certified cooperatives and three from non-certified cooperatives—reported engaging with NGOs, coffee consultants, farmer organisations, and processors. These partnerships included input procurement, assurance of coffee quality, training, promotion of good agricultural practises, promotion of certification facilitation, and input procurement. It should be highlighted that most partnerships tended to be short-lived (Koss, 2024). Collaboration among certified cooperatives frequently focused on obtaining and maintaining certification.

Forty-six percent of the respondents who owned coffee farms said they have worked together with other estates to produce and market coffee. Two percent, or one out of every fifty-four estates, reported collaborating with, or partnering with organisations or individuals outside of estates in the context of coffee production or marketing (Okech, 2019). The reason for the limited joint ventures among estates was attributed to concerns about potential corruption like that experienced by cooperatives, scepticism regarding the benefits of collaboration, and the perceived need for substantial capacity building for collaborative marketing. The study identified various instances where farmer empowerment was lacking across all institutional arrangements, particularly in achieving desired economic benefits. The study defined empowerment as the ability of individuals or groups to make wise decisions that result in the appropriate actions and results (Koss, 2024). The level of empowerment was assessed based on the presence, utilisation, and achievement of choices leading to the desired outcome. In the case of coffee farmers, the desired outcome is economic benefits since coffee production is undertaken as an economic activity.

When decisions were either impossible to make or offered little advantage, there was a lack of empowerment. This lack of empowerment showed up in numerous ways at the agricultural level. For instance, farmers were aware of excellent agricultural practises (GAP) but were unable to put them into practise because of the high prices of labour and inputs (Autio et al., 2021). Furthermore, there was no clear advantage to following GAP even when farmers had access to and used inputs because there was no difference in quality between farms and factories. As a result, regardless matter how closely they followed GAP, all farmers earned the same compensation rate. Farmers also had access to loans but frequently had to deal with unfavourable conditions including high interest rates and brief repayment periods (Mugwe, 2014). Another problem developed when growers had access to subsidised fertilisers, but these inputs either were not delivered promptly or were reportedly of poor quality, failing to successfully raise coffee production or enhance its quality.

At the cooperative level, there were instances where farmers had the right to attend meetings but faced intimidation that hindered their effective participation. They also had the right to vote for management but holding them accountable for recovering misappropriated funds proved challenging. Similar occurrences occurred at the milling and marketing levels (Mugwe, 2014). While the miller and marketer were legally separate entities, in practice, the separation was not effectively implemented. Farmers could check the class and quality of coffee, but there was no system in place to deal with any irregularities that were discovered. They also had access to tools for raising the calibre of the coffee, but theft of funds prevented them from realising the intended benefits. Additionally, the disadvantage of Direct Sales, which offered greater rates, was that there was lengthier payment wait times.

According to the study, the various producer agreements had varying effects on farmers' financial rewards (Koss, 2024). Farmer agency shown that it can be influenced by the producer arrangement they were participating in. The results were consistent with the theories of Transaction Cost Economics (TCE), as well. All three producer arrangements were significantly impacted by access to productive inputs, with the coffee estates experiencing the highest loss and the certified coffee cooperatives the lowest (Mugwe, 2014). This shows that access to productive inputs was more expensive in coffee estates than in cooperatives, and in non-certified coffee cooperatives than in certified ones.

The ability to bargain reduced the economic benefits for cooperatives, particularly uncertified ones, but had little effect on coffee estates. In non-certified coffee cooperatives, the drop in economic advantages was more pronounced, indicating increased transaction costs when bargaining with management, millers, and marketers (Jaffee, 2012). However, the ability to make decisions, hold others accountable, and exercise choice led to larger financial benefits in legally recognised coffee cooperatives; however, this relationship was insignificant in non-certified cooperatives or coffee estates. Both certified and non-certified cooperatives saw decreased economic benefits because of the power to negotiate, but the effect was noticeably less significant in certified cooperatives. All producer institutions experienced a decline in economic gains because of access to productive input, with certified cooperatives seeing the least impact and non-certified cooperatives experiencing the worst.

Access to health and educational benefits resulted in larger economic benefits for certified coffee cooperatives when compared to non-certified cooperatives and coffee estates. According to these findings and the TCE perspective, certified coffee cooperatives have the lowest transaction costs when compared to coffee estates and non-certified cooperatives (Varqa, 2008). In all producer arrangements, the moderating effect of farmer agency, which had a significant impact on the relationship between the institutional framework and economic advantages, was present, and was interpreted using the capability approach. According to Okech (2019), the Farmer agency also contributed to the explanation of an extra 19.9% of the difference in financial gains between coffee cooperatives and estates that are accredited and those who are not. These results show that farmer agency has a greater influence on economic advantages inside the institutional framework of certified coffee cooperatives than it does in non-certified cooperatives, where it has a relatively less influence. Overall, by evaluating the institutional framework of producer relationships, this study advances research techniques.

Multiple studies have noted a more worrying trend regarding the cultivation of coffee in the country. Most notably, Rono and Mundia (2016) indicate that the rearing of coffee in central Kenya and the Rift Valley has declined steadily over the past two decades, an element that they attribute to the selection of wrong farming techniques by coffee farmers, especially in rural areas. Even though the selection of the wrong types of crops is the chief area of focus in Rono and Mundia (2016)'s study, other multiple contextual factors are leading to the decline in the crop's cultivation. For instance, the depletion of fertile farmland that supports coffee farming has led to a significant reduction in coffee crops in the Elgeyo Marakwet region. They indicate that the type of soil and the climatic conditions in this region favour the nourishment of Arabica coffee, which is one of the two main types of coffee, rather than planting Robusta coffee. The decline in the yield of coffee plants has been the main causative factor behind the drop in this plant's cultivation. They attribute this problem to the prevalence of Robusta coffee plants rather than their Arabica counterparts in a region whose climate favours the latter type of coffee. Other studies also embrace this trend. For instance, Muriithi et al. (2018) indicate that coffee rearing has deteriorated in recent years due to multiple reasons.

However, the study also points out that the future is not entirely bleak for coffee farmers, as some insightful interventions are currently being implemented to rejuvenate this sector's performance in the coming years. Muriithi et al. (2018) indicates that introducing a coffee certification programme promises to shift the affinity that most small-scale farmers construct towards coffee farming. More precisely, the researchers hypothesise that more and more farmers will be willing to cultivate this crop if they receive accreditation from the relevant regulatory bodies. Multiple advantages stem from accreditation. Most importantly, the attainment of a coffee certificate opens new networking opportunities for small farmers. The lack of proper networks vital to sharing and learning new farming techniques and gaining access to vital agricultural supplies like seed and fertiliser has been a significant impediment to coffee farming. However, Muriithi et al. (2018) believes that the potency of the lack of supportive networks in hindering coffee farming will be suppressed further by introducing other interventions like the small farmers' accreditation process.

Various metrics have been developed to help coffee farmers enhance the productivity of their farms. One such measure that has been deployed extensively is the measure of TE. This element also forms a vital part of this research. According to Chepngetich et al. (2015), when applied in agriculture, TE denotes the execution of farming operations to yield optimal outcomes in terms of harvests while using inputs at the lowest possible amount. From another perspective, Chepngetich et al. (2015) compare TE to the lean operational model whereby firms aim to attain optimal productivity by using an aggressive cost leadership strategy. The proper installation of TE concepts in coffee farming can tremendously benefit small scale farmers.

Several academics have investigated the efficiency benefits afforded by various forms of cooperatives. Wu (2013) studied six types of farmers' cooperatives in China, categorising them based on their management style. The most effective unions were those with a supply and marketing focus, followed by cooperatives that aimed to promote product processing and marketing, with unions with uncertain goals receiving the lowest ratings. Liu et al. (2019) investigated the influence of several organisational structures on the efficiency of beef cattle farmers and discovered that participation in unions resulted in the biggest gain in efficiency. Huang and Peng (2016) investigated the influence of farmers' membership in unions on their fruit agricultural efficiency in Anhui. They discovered that membership in cooperatives was linked with a considerable boost in efficiency in manufacturing, but this impact vanished after population recruitment prejudice was removed via propensity score matching. Ma and Abdulai (2016) examined how membership in cooperatives affected income and apple production for Chinese apple producers and discovered that participation enhanced both. Ma et al. (2018) discovered that to account for observable selectivity bias, the stochastic production frontier paradigm was combined with propensity score matching cooperative members outperformed non-members in terms of efficiency (Ma et al, 2018).

Nonetheless, a close examination of the tendencies and preferences of coffee farmers in the country reveals that their TE level is lacking. Runo (2009) concurs with this definition and presents new outlooks that can be used to justify the lacklustre performances of Kenyan small-scale coffee farmers in the adoption of TE concepts. The study indicates that the lack of proper resources is one of the primary reasons for the country's coffee farmers' poor TE. The installation of farming mechanisms that instigate the ideal levels of TE is often expensive and out of the economic grasp of many small, independent coffee farmers in Kenya. In this regard, most farmers who fall in this category tend to stick to the conventional farming tactics that are less likely to attain TE. Kamau et al. (2017) concur that the lack of sufficient TE in coffee farming can be attributed to specific socio-economic factors. Both studies argue that the farmers who lie in the Kenyan socio-economic spectrum's lower prisms are less likely to adopt coffee farming mechanisms that yield high TE. Coincidentally, individuals who live in this socio-economic cohort also make up many coffee farmers. In this regard, the country's aggregate score in the adoption of technologies and other enabling factors associated with high TE is lowered systematically. The level of education and the innate resourcefulness possessed by an individual play an instrumental role in the adoption of farming mechanisms that yield optimal productivity and TE. There is a commonly accepted notion that low-income earners are usually associated with lower educational attainment levels. In the same breath, Runo (2009) asserts that small scale farmers are not conceptually equipped to uphold farming mechanisms that instigate TE. Kamau et al. (2017) indicate that the scores for Kenyan coffee farmers' performance regarding the adoption of TE-enhancing methods are lower than 54%. This is a worrying indication that the country depends on coffee as one of its key sources of income, both locally and internationally. Furthermore, according to the average TE index for large- and small-scale farms is predicted to be 97% and 93%, respectively.

The manifestation of the technical deficiency issues in the agricultural sector of Kenya is somewhat sophisticated. Ngeywo et al. (2015) hypothesised that age and the farm's size have a huge influence on an entity or individual's propensity to install farming techniques that instigate TE. They claim that a farmer's age depicts his or her affinity towards farming methods that yield TE. This notion is also supported by Kamau et al. (2017), who uncover those younger farmers are more likely to adopt specialised efficiency-boosting farming techniques as compared to their older counterparts. On the same note, Ngeywo et al. (2015) indicate that coffee farmers with larger farms are more positively attuned towards the installation of farming approaches that yield higher levels of TE than their counterparts owning small farms. The capacity of larger coffee farm owners to install such methods is centred on having access to better networks. Most of them are financially capable, and the perceived return on investment derived from these ventures seems worthwhile.

The age variation in the number of small-scale farmers taking up coffee farming could also explain the decline in the crop's cultivation in the country. Ngeywo et al. (2015) uncover that the number of people practicing coffee farming in Kenya is predominantly made up of older people. More precisely, they indicate that Kenyan coffee farmers' average age is 51 years.

The justification for the dwindling number of coffee farmers in the country is embedded in the fact that the Kenyan population is relatively young. Minai, Nyairo and Mbataru (2014) indicate that the average Kenyan population's average age ranges from 19-24 years. Figuratively, one can note that since there are fewer older people and more younger people in the country's population, the decline in coffee lack of positive preferences among young farmers is a factor in farming as the young who make up a considerable portion of the nation's population.

Understanding the factors driving the magnitude of TE showcased in the country’s coffee farming industry is also pivotal. Several kinds of research have been conducted to examine some of these factors. Nyagaka et al. (2010) reveal that some of the most potent factors behind TE in coffee farming in Kenya include the educational attainment level shown by farmers and their socio-economic status. They state that farmers of high socio-economic status are more likely to demonstrate TE proficiency. The same trend is reciprocated when examining farmers' educational attainment, with highly educated farmers more likely to portray high TE in their farming. Kenya and other counties in east Africa are well known for their prowess in the production of coffee. However, the COVID-19 pandemic has taken its toll on coffee production in the country as it has done to several other sectors. As reported by the Coffee Directorate of Kenya, the number of metric tons of coffee produced in the country fell from 50,600 in 2019 to 46,162 in 2020. The coffee export value also fell to $20.9 billion in 2020 compared to $21.7 billion in 2019. The table 3 below highlights the country’s coffee export performance from 2013 to 2020.

Table 3

Production and Value of Coffee by Grower 2012-2019

COFFEE YEAR	NO BAGS	NET WEIGHT-KG	VALUE-USD	EXCHANGE RATE	VALUE -KSH
2012/13	817,191	49,031,461.31	217,018,127.61	83.91	18,209,676,550.66
2013/14	787,285	47,237,094.11	228,645,764.63	86.39	19,752,848,355.66
2014/15	733,370	44,002,226.78	223,166,912.01	94.06	20,990,763,157.53
2015/16	739,041	44,342,470.01	205,674,854.90	101.58	20,893,006,028.47
2016/17	722,979	43,378,724.78	227,827,991.12	103.01	23,468,566,737.90
2017/18	721,494	43,289,615.31	229,514,404.53	101.55	23,307,949,319.83
2018/19	843,339	50,600,338.89	213,216,875.27	101.69	21,681,078,589.67
2019/20	769,361	46,161,638.26	209,818,143.13	104.95	22,019,573,689.54
GRAND TOTAL	6,134,059	368,043,569.45	1,754,883,073.19	97.06	170,323,462,429.26

Source: Coffee Directorate (2020)

Again, the coffee imported into the country also witnessed a 17.1% decline in September 2020 as compared to September 2019 (Coffee Directorate. 2020). The underlying reason behind this decline is ultimately the COVID-19 pandemic. However, fluctuations in the dollar exchange rate also influenced the decline. The table 4 below shows the top coffee import destinations for Kenya during 2020.

Table 4

Kenyan Coffee Export Destinations-2019

Origin	Net Weight	Value(USD)	Value (Ksh)
BELIGIUM	1,000.00	1,411.65	153,054.48
ITALY	1,078.60	7,795.84	949,760.42
MALAYSIA	20,644.00	189,721.12	19,169,150.95
NETHERLANDS	92.00	1,017.00	102,256.38
SOUTH AFRICA	60.00	56,452.80	6,057,385.44
TANZANIA	12,288.00	261,600.00	26,820,929.44
UNITED KINGDOM	104.00	720.00	87,575.72
Grand Total	35,266.60	518,718.41	53,340,112.83

Source: Coffee Directorate (2020)

Several discussions have been conducted regarding how rural producers, wider communities, and their associations can be in a better position of empowering themselves to make informed decisions, articulate their priorities of development, and being able to negotiate in an effective manner concerning their equitable partnerships with progressive private sector actors in commercial agriculture (Ghosh & Bera, 2014). The government is focusing on the idea of establishing sustainable livelihoods for smallholder farmers. It is at the core of promoting youth and women access to an agency with coffee's supply chain. For instance, Vava Coffee commenced operations in 2009. It had rich experience for more than ten years, which paved the way for it to deal with barriers to an inclusive, sustainable, and coffee sector (Government of Kenya [GoK], 2017).

A recent report done by the Kenyan government shows that stakeholders continually discuss what the changes mean for the producers and how to produce strategies, which will go forward to sustain the progress in the coffee producer agency established to date with a sharp concentration on the work on the youth and women. Besides, it is evident that now, youth entrepreneurs and women coffee farmers have not been fully supported with other actors in the value chain to secure more agency in the sector, and that leaves them with the option of quitting. One can also agree that several conditions need to be in place for the relational agency farming in Kenya to be in place. For example, it is the agriculture ministry's responsibility to provide funds to ensure that the youth and women in agriculture are in a better position of being supported with other actors in a value chain for them to secure more agency in the sector (GoK, 2017). The idea will enable them to generate more income, and they will be able to meet their daily needs in the end. The study carried out by the GoK (2019) indicates that producer agencies and value chains they connect to have been greatly affected by the COVID-19 pandemic, and the government has not responded in a manner that is required to help the coffee farmers secure the agency they need.

Measures must be put in place for the producer agency to connect with the value chains they rely on. By doing so, there is no doubt that the coffee industry in Kenya will be in a better position of generating more income for the smallholder farmers in Kenya and any person who would have an interest in taking part in the coffee business (Haggar et al., 2019). In Kenya, it has been noted that social enterprises are trying hard to support their beneficiaries, particularly the youth and women, to sustain the progress they were making before the Coronavirus pandemic. However, it can be realised that the support is not enough for all the players in the industry to sustain the progress they were making, and that is why the government must ensure that there is a perfect relational agency, which will pave the way for a handful of these farmers to continue generating the income they used to generate before the occurrence of the pandemic. Challenges are foreseen in the coming period after the pandemic (Haggar et al., 2019). Thus, the government must produce ways of dealing with the challenges, and that will be made possible if Kenya will work with the global community.

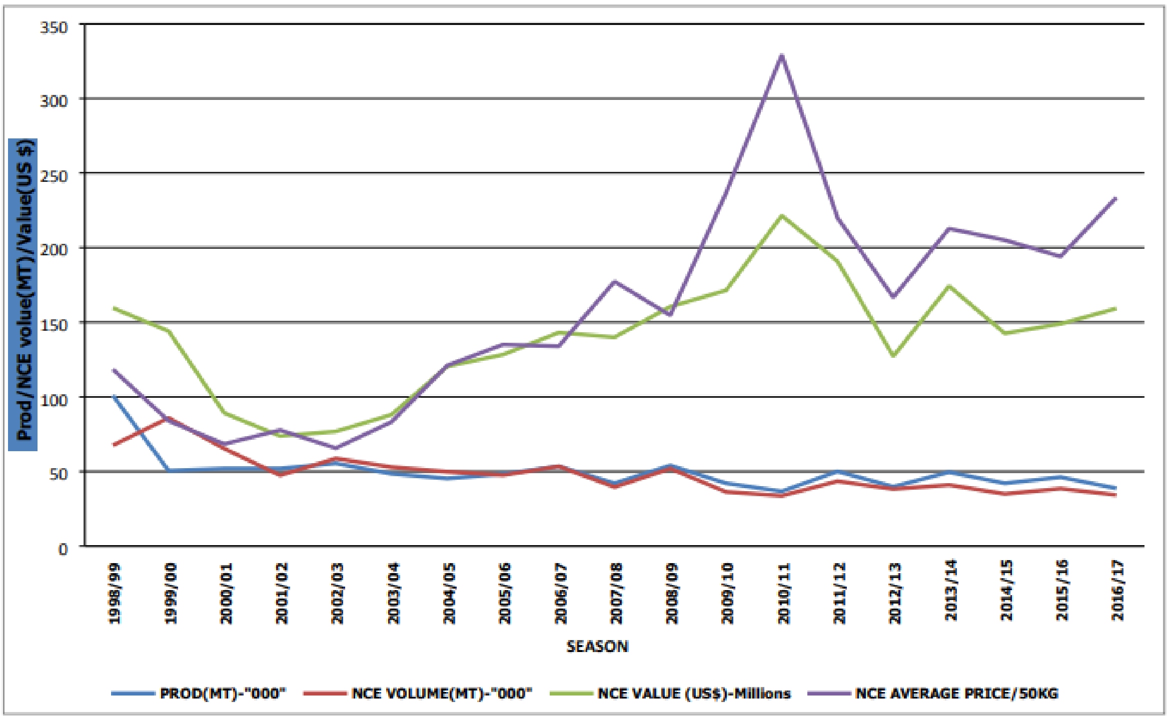
A significant portion of the research conducted on the technical skills portrayed by Kenyan farmers points towards major gaps. For instance, according to Mati (2016), in Kenya, the knowledge and expertise of Kenya's smallholder coffee farmers is extremely lacking. This undermines their efforts to increase production effectiveness and coffee quality, enhancing their income generation process. Currently, some measures have been put in place by the government regarding the adoption of new technology. There is the use of agro-chemicals, news seeds, and fertilisers. The adoption of new technology has helped because now, more than sixteen thousand small farmers have witnessed an improvement in the quality of their coffee. Their crop yield has also gone up, resulting from the adoption of new agricultural practices (Haggar et al., 2017).

Based on the research carried out by McArthur and McCord (2017), three hundred and fifty promoter farmers in Embu have been trained on the use of new technologies. Each of the promoter farmers is transferring the knowledge they acquired to other farmers to be in a better position of applying the new technologies in their farms, which will pave the way for them to generate more income. In 2017, several coffee associations, which are also referred to as cooperatives, had an opportunity to train their staff on the importance of applying new technologies, and they have witnessed tremendous financial benefits. The cooperatives are now capable of producing high-quality coffee to attract higher prices in the international markets. The Ministry of Agriculture (MoA) (2016) shows that various studies are being conducted in Kenya to evaluate the decision-making process by farmers in a decision to adopt new technologies. The studies normally entail the realisation of factors which facilitate or prevent adoption, the temporal and spatial adoption patterns, when farmers will be in a better position of adopting the new technology and the level at which the technology is applied by farmers and which farmers are adopting the new technology and why.

Coffee farmers in Kenya must adopt new technologies irrespective of their technologies because it will be for their advantage (MoA, 2016). Muriithi (2016) demonstrates that the underlying economic theory regarding factors that are believed to influence coffee farmers' decision in Kenya to adopt new technologies is based on the knowledge that Kenyan coffee farmers are rational. They have an impression on the potential advantages and costs linked to the technology via their research, either by early secondary knowledge from previous adopters, experimenting with the technology, and getting information from primary informants in society. In the economic theory, the farmer was believed to maximise an objective function like the net present value or anticipated utility regarding the advantages of adopting the new technology. The MoA (2016) shows the adoption of new technologies has also paved the way for coffee farmers in Kenya to harvest the crop in large quantities. They are in a better position of saving on cost and generating more income at the same time. The following figure 5 illustrated the amount of coffee produced, the value realised, and the volume of trade of coffee since 1998.

Figure 5

Coffee Volume Produced and Value Trend for 19 Years



Source: KNBS, Coffee Directorate (2020)

The farmers are also able to track the operations of their business online, and that makes it easier for them to do other businesses while at the same time monitoring the progress of their investments in coffee and that is a clear indication that most of the coffee farmers in Kenya have made it big in the industry (MoA 2016). The coffee associations have also had an opportunity to set up more supply networks courtesy of adopting new technologies. The supply networks have been able to avail farm inputs at prices that are affordable by the farmers. They have also been able to organise the supply of credit to farmers for the supplies and schedules of repayment as regards the receipts of coffee sales, which shows that life has become easier for the coffee farmers in Kenya (MoA, 2016).

The cultivation of coffee in Kenya has undergone multiple challenges in recent years. Demographic dynamics have had a significant impact on this industry. For instance, Murimi et al. (2019) indicate that farm sizes are shrinking because of the increase in population and the sale of the land via informal land markets with emergency needs. This was one of the primary problems affecting coffee production in Kenya. A study carried out by Ndirangu et al. (2017) demonstrates that there are higher yields on the small farms compared to the larger farms in the Kenyan coffee market. The negative impact on population pressure was greatly felt in medium and high agricultural areas of Embu County, where smallholder coffee farmers had intensified production of the crop to keep up with the demand for more land that is needed for farming. There was an inverse relationship that can be observed between the size of the firm and its productivity. This was attributed to the fact that the owners of small farms intensely utilise their farms, and they devote a small percentage of their farms for fallowing compared to those who won large farms.

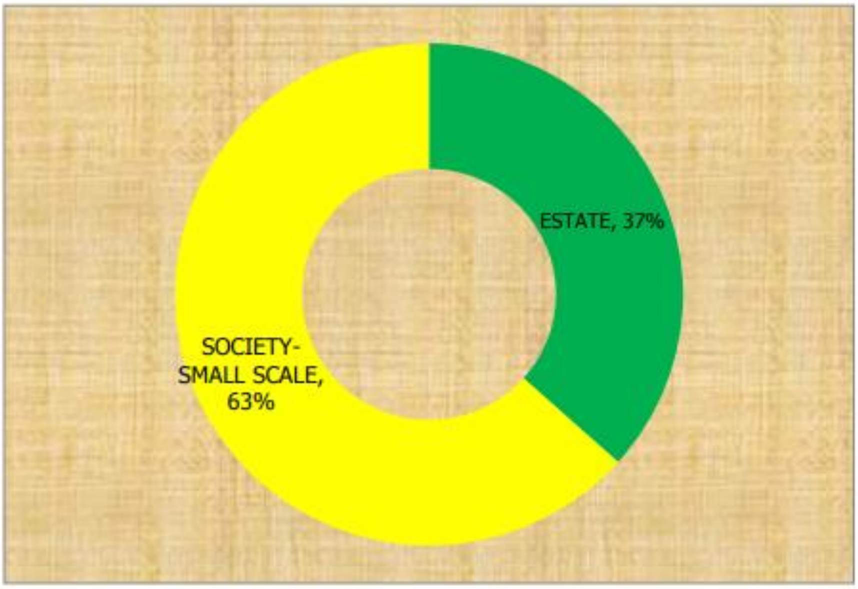
Small farms own the most significant land productivity despite the huge intensification level demonstrated by the small farms. It had also been indicated that the maximum yield of farms can be attained when the farm sizes are between 0.54 and I hectare in the sense that the constraints of resources become more binding; the productivity of land commences to go down (Oerke et al., 2015). However, the outcome indicates the maximum difference between the total yield of lands of about three percent between the large and the small farms irrespective of the small farms' vast intensification level.

The main reason for the observed difference was in the total yield of lands that entail implementing innovations, which is done partially (Oerke et al., 2015). For instance, small coffee farmers focus their innovation on food crops such as beans and maize. There was also a selective innovation uptake where small farmers utilising fertiliser were higher than using hybrid seeds and fertiliser and the miniature of gardens owned by households in the small farm option. An exact look at the relationship between the size of the farm and productivity, one can realise that there are mixed trends, especially those farmers who plant coffee.

A significant production gap emerges when aggregating small-scale coffee farmers' gross coffee harvests and their largescale counterparts. As illustrated by figure 6, recent reports by the Coffee directorate, large scale farmers produce 37% of the country's entire coffee. In comparison, small scale farmers account for the remaining 63%.

Figure 6

Farming Demography Categorisation



Source: (KNBS, Coffee Directorate. 2020)

The productivity under the land with coffee increased with the size of the farm. However, the results were not astonishing because of the gross under usage of bought coffee inputs by several households in Kenya. There was another issue regarding the relationship between the size of the farm and productivity, especially in coffee (Van der Vossen et al., 2015). While minimising variable costs does not affect the positive trend, which has been realised in the coffee market, primarily when gross land yields are utilised, the inverse relationship in terms of the gross value was reversed when the variable costs were subtracted the gross returns. Thus, the gross margin for the coffee market, like the gross yield for lands, varies positively regarding the size of the farm.

Besides, the only positive and highest value ever recorded on large farms. On average. One can realise that the gross margins for coffee and other crops are the lowest among business owners in the market, but the highest value is located to the people who have small farms. Furthermore, it can be noted that the outcome on fixed factors is more in coffee markets where farm owners have decided to allocate more variable inputs and land compared to the rest of the population, which has land for growing coffee. Thus, it was clear that for small farm owners, resource allocation was not brought about by economic indicators but by other factors like a particular crop's preference.

Technical Efficiency in Coffee Farming

Technical efficiency in production occurs when maximum output is achieved given resources, meaning production on the frontier. Allocative efficiency occurs when factors of production are optimally selected and used, thus, economic efficiency is the product of two mentioned. It explains farmer’s ability to produce optimal output with minimum cost given technology available (Bravo-Ureta and Pinheiro 1997). Agricultural productivity is usually measured theoretically by technical efficiency (TE), technical progress, productivity growth and total factor productivity (Djima & Kilic, 2024). This study focuses on productivity because it is a measure of the agricultural sector performance and therefore can act as a barometer to establish the efficiency of the sector (Shah et al., 2024). The concept of TE is consistent with the theory of the firm that postulates that businesses are formed to maximize productivity and profits (Debertin, 2012). However, this might be unachievable if smallholder farmers do not have access to inputs or the right combinations of inputs to get the right output mix given due to credit constraints.

Considerable past theoretical literature was devoted to scrutinizing the outcome of credit programs on agricultural efficiency, capital formation and productivity of smallholder farmers. These studies resulted in lack of consensus as to whether credit programs are desirable and effective in improving agricultural productivity (Manoharan & Varkey, 2022). One of the most eminent strands of literature was fronted by Shultz (Falcon, 1988), also known as the "poor-but-efficient hypothesis", which submits that smallholder farmers in conventional agricultural settings do allocate their resources fairly efficiently and react favourably to price incentives. According to Schultz's theory, if farmers are fairly efficient, then raising productivity will need new innovations in technology and inputs to push the production possibility frontier upward. This is in line with the bulk of empirical research that are in favour of Schultz's theory, which is likely what caused policymakers to place more emphasis on investments in new technologies and inputs than on initiatives to increase the productivity of farmers who are less efficient (Chandio et al., 2023; Islam, 2020; Seven & Tumen, 2020). For instance, Chandio et al. (2023) demonstrate how agricultural credit enhances access to fertilizer use and agrochemical inputs, which in turn considerably boosts wheat production and guarantees the sustainability of food. On the contrary, sheer saturation of funds availed by credit programs to procure inputs does not automatically translate to improved agricultural productivity and returns. This is because better allocation might be necessary if there are substantial opportunities to boost productivity through more effective use of farmers' resources and inputs with current technological advances (Hajiyeva et al., 2024; Hasnah et al., 2024; Radlińska, 2023). Although Schultz's theory to transform smallholder farming is incontestably realistic, good and rational, it is characterized by several infirmities.

As illustrated by Cohen et al. (2019), the economic production theory indicates that proprietors or business entities typically determine the quantity of a product to be manufactured and the magnitude of raw materials. Theoretical framework explains TE as an important aspect of agricultural production economics, which aims to help individuals or groups of farmers to achieve their objectives by efficiently allocating resources. Total efficiency, which evaluates the relative capacity to extract the most output from a given set of inputs, is a prerequisite for allocating efficiency, which is the output level where price equals marginal cost of production. Increased farmer education and technical advancement are the two approaches to increase productivity. Studies reveal that while some industries have benefited from the adoption of new technologies, overall productivity has decreased or stayed constant. Both parametric (using the Stochastic Production Frontier) and non-parametric (using Data Envelopment Analysis) methods are employed to measure TE.

A meta-analysis of the efficiency of farms done in Chile by Borsi et al. (2017) utilizing a descriptive approach discovered that the median Mean Technical recorded for all investigations is 74.2 per cent. The quantitative parameters are relatively comparable; however, some significant variances were detected when comparing regions, levels of income, and item kinds. Improving subsistence growers' output and technological efficiency may, nevertheless, aid agricultural growth in nations where subsistence agriculture prevails, such as China. According to Ruopi et al. (2020), two organizations were formed: an umbrella advertising unit of growers and an analogous non-marketing unit that failed to offer a promotional function while maintaining other activities. The primary activities of unions that might potentially raise producers' TE were discovered using the likelihood rating pairing approach. According to the data, participation in both categories is positively connected to production. The cooperatives that did not participate in promotional activities, on the other hand, had a greater TE than non-members. This shows that authorities ought to motivate unions to concentrate on things other than marketing directly to enhance TE in Chinese apple supply.

Islam et al. (2016) sought to identify variables influencing technical inefficiencies in Malaysia's fish cage farming system. Utilizing information that has been studied using the stochastic frontier technique. The findings indicate that cage culturists have extremely high levels of technical inefficiency. This provides great fish output opportunity in Peninsular Malaysia with improved effectiveness in cage culture management. Because of a paucity of fingerlings from wild sources of information, producers got grouper fingerlings from other bordering nations. Feeding expenditures for clams in caged ranches in the research locations are substantially greater than for seabass.

The drive for better health and environmental awareness in agriculture in Nepal increases organic food output- a lucrative source of income for rural areas. In their study of the effectiveness of organic and conventional coffee farms in Nepal using the Data Envelopment Analysis approach, Poudel et al. (2012) assert that the mean TE score was 0.89 for organic farming and 0.83 for conventional farming. They did this by analysing the TE scores of 240 coffee farmers, 120 from each type of farm, and arriving at their conclusions. They also found a connection between TE differences and several other characteristics, including financing availability, agricultural experience, education, and training/extension programmes. The findings suggest that farmers can improve their practices by learning from technically efficient farms and reconsidering input rationing. The implications of the study's results for production planning strategy will depend on policy considerations.

Technical efficiency refers to production that takes place outside of a producer's set of production options, whereas technical inefficiency refers to production that takes place inside of this set (Poudel et al., 2012). Observing if a rise in any output requires a fall in at least one other output or a rise in at least one input is another technique to figure out TE. A producer's performance is assessed theoretically using the idea of EE. Only in a relative sense, by contrasting a producer's output with the best practices of a representative sample of peers, can efficiency be meaningfully evaluated. TE aims to achieve the maximum output from a given set of inputs, whereas allocative efficiency focuses on using factors of production in proportions that maximize profits, considering the given input prices.

In the surveyed regions, the size of households had a positive impact on TE, as larger households were able to provide more farm labor (Poudel et al., 2012). Additionally, farmers with previous experience demonstrated better input/output management, and access to credit was beneficial for investment in both types of farming. The presence of education and training was found to have a positive effect, suggesting that educated individuals were more likely to adopt effective farming practices (Poudel et al., 2012). The emigration of male workers posed a challenge in terms of skilled labor, and a limited supply of farmyard manure was a major issue in organic coffee farming. The use of fertilisers by Zambian smallholder maize farmers had a good effect on their TE, according to a study using a non-parametric technique, and it was proposed that strengthening and forming farmer associations would help promote agricultural extension accessibility and market knowledge.

Gebrehiwot (2017) studied the impact of agricultural extension on farmers' technical efficiencies in Ethiopia, using a stochastic production frontier approach. The study found that according to the TE estimates, output levels could have been maintained while reducing overall input use by an average of 52% for the average farmer in the sample and 100% for the most technically inefficient farmer. The second question that was addressed is which variables explain efficiency differences among farm households. Based on the stochastic frontier estimates, the differences in efficiency were explained by variables such as gender, the number of crops grown and the number of dependants. Extension was found to have a significantly positive effect on efficiency, suggesting that encouraging farmers to participate in the extension programme can enhance productivity and thereby improve the livelihoods of participant households. This study showed that smallholder farmers' production could potentially be increased by 52% without increasing other inputs and using current technologies. Although not all factors affecting technical efficiency can be controlled (e.g., age and gender), several areas were identified where policy changes can make an impact. In particular, promoting vocational education (with special emphasis on agricultural skills training) and developing social capital such as Iddir and farmers' associations so as to bridge the gap between technology centres and farmers could help the efficiency level of farm production. To ameliorate the gender-induced efficiency difference, the extension service delivery system needs to be gender-streamlined. The study suggested that in addition to increasing the availability of technologies and providing quality extension services, access to these aspects should be given due consideration in the future. However, because of the potential endogeneity of extension, this result is only tentative, not conclusive.

Another research employing data envelopment analysis method, found that the gender, level of education, family size, area, tropical farm animals' system, as well as production statistics all had a beneficial impact on the overall factor output and efficiency. The productivity and efficiency of all factors were negatively impacted by other factors, including the age, the number of crops raised by the family, the average size of the plots they farm, the typical distance between them, and household involvement are only a few examples (Fantu, 2015).

A production frontier is similar to how technology is portrayed through a production function. Any variations from this pattern can be a symptom of systemic technological inefficiency. A business is considered inefficient if its output falls below the frontier. The extent to which a company deviates from the production frontier indicates its technological efficiency. Färe et al. (1985) describe a producer as technically efficient when their production occurs at the edge of their set of production possibilities and technically inefficient when output arises inside the set.

In their research Jammu & Kashmir; Mohammed & Showkatn (2014) examined the relationship between TE and farm production size. Their findings indicated that the average TE was 48 percent and that most fields displayed low levels of technological efficiency. According to the study, there is a nonlinear relationship between farm size and production efficiency, with efficacy initially declining and then rising as farm size rose. The researchers found that larger farms were technically more efficient than smaller farms and had higher net farm revenue per acre. The study discovered a number of important variables that contributed to differences in TE between various farm settings, including employment, agricultural experience, household size, land size, membership, and seed variety. According to the report, governments should concentrate on enhancing social, economic, institutional, and farm-specific aspects in order to strengthen growers' abilities and leadership.

Hayatullah (2017) studied the influence of crop diversity on agricultural technical effectiveness in Afghanistan. Using a household study conducted in 2013-2014, it was discovered that producers' acceptance of a variety of agricultural products considerably enhances TE. Accessibility to agricultural extension solutions, size of farm, livestock and machinery possession by farm families, and geographical characteristics were all major determinants influencing the effectiveness of the technology. The projected TE ratings from the selected trimmed normal distribution of samples vary from 1.5 percent to 99.3 per cent, with a sampling average of 71.9 per cent, as shown by the findings. For the possibility of endogenous variability in diversifying crop varieties, the basic Stochastic Frontier Approach (SFA) framework was studied. The Instrumental Variable technique shows that being unsuccessful to take into consideration for variability in the basic model leads to a toward the bottom bias, that is in line with diminution prejudice. Crop diversity index results revealed a very limited level of diversification among crops. According to a trans log probabilistic frontier framework's highest probability estimator, purchasing resources like land, labour, and other inputs has a positive impact on agricultural income. The results show that there are continuous yields to scale.

Geta et al. (2013) analyzed productivity and determinants of technical efficiency among maize smallholder farmers of Wolaita and Gamo Gofa zones of Southern Ethiopia using Deterministic Envelopment Analysis (DEA) and Tobit regression on surveyed data of 385 farmers. Empirical results found that, human labor, use of chemical fertilizers, use of oxen power, planting method, hybrid maize seed, farm size and integrated soil fertility were positive and significant in influencing maize productivity while distance to development centre, credit and off farm income were negative and decreased productivity. The study found that the mean technical efficiency among farmers is 40 %. Tobit regression on technical efficiency model indicates that farm size, hybrid maize seed, oxen holding, consumption expenditure and agro-ecology were highly significant in influencing technical efficiency while age, family size, distance to development centre and credits were negative and increased inefficiency. The study recommends on policies to mobilize and motivate youths in agriculture, to increase use of fertilizers, credit and extension services, and provision of training on application of soil fertility management practices.

Scholars of the empirical studies reviewed on production (technical) efficiency, most focusing on the determinants and/or sources of technical efficiency in production of maize. Age, education, extension services, gender, credit access and type of fertilizer and seed are the dominant variables used in assessing sources of technical efficiency in reviewed studies. In addition to these variables, this study takes into account the effects of rate of involvement in agriculture and living condition of the households and influence of input costs to technical efficiency of smallholder farmers. Furthermore, this study adopts a two-stage approach that involves; (1) stochastic frontier model to estimate frontier and (2) technical inefficiency model which is estimated by Ordinary Least Square (OLS) approach. An approach is different from DEA and Tobit model employed by Geta et al. (2013) in estimating technical efficiency model in the first and second stage respectively.

The approach has been used extensively in research to assess TE in a variety of industries, including agriculture (Ahmed et al., 2015; Biam, 2016; Furi & Bashargo, 2018; Huong & Anh, 2019; Kibirige,2014; Sudjarmoko & Randriani, 2019; Thông & Niekdam, 2016). Ahmed et al. (2015) investigated TE and its influencing factors using the stochastic production frontier method. Another researcher, Hailemaraim (2015), estimated TE and identified the elements contributing to inefficiency among teff producer farmers utilising the inefficiency effect model and the Cobb-Douglas stochastic frontier production analysis approach. Additionally, Musa et al. (2014) integrated an SPF model with inefficiency parameters and discovered that factors such as household size, contact with extension rate, farm size and distance from the market had a negative and significant impact on TE among landowners growing maize, but the quantity of tending and the amount of tending had a positive and significant impact.

The Cobb-Douglas stochastic frontier was used to assess the severity of EE and its causes in a study by Biam (2016). The results showed that household size, farmer age, and farm size all had a negative and significant impact on EE. In Ali and Khan's (2014) investigation on the TE of wheat output in the Peshawar District of Khyber Pakhtunkhwa, Pakistan, the Stochastic Frontier Cobb-Douglas production function was employed. According to the data, the education level of the farmers had an impact on a TE of 62%. Using the Stochastic Production Frontier technique, Kibirige (2014) concentrated on the TE of smallholder maize farmers and found that household sizes, farmer membership, and the type of seeds planted were drivers of TE. According to the results, addressing the determinants might increase production.

Temesgen and Getachew (2018) conducted a study to evaluate coffee yield effectiveness and to determine factors influencing efficiency among coffee producers in the study region. They employed a stochastic production frontier model to calculate farmers' production efficiency. Farmers in the region were found to be inefficient in growing coffee, with ratings of effectiveness of 74 percent and 89% for the half-normal and abbreviated distributions of normal, correspondingly. The average TE was 88 percent, suggesting that there remained space for improvement. labour and land had a considerable negative influence on efficiency but seed and oxen had a beneficial impact. Female household heads outperformed male family heads, while Woina dega/dega producers outperformed cola producers. In addition, the study discovered a positive and negative relationship between land square and fertilisation square and production efficiency, as well as substantial interconnections between cattle and manual labor, grain land and fertiliser. The findings advised that measures be taken to improve the efficiency of production of coffee producers in the area, which might lead to higher productivity and the commodity's competitiveness for export. Farmers should reduce inefficiencies to enhance productivity by 22 percent utilising current innovations and inputs, according to the research. Utilising.

In another study by Getachwe and Bamlak (2014), investigated the factors related to variations in maize output using a Cobb-Douglas stochastic production function model and Maximum Likelihood Estimation approach. The study utilising 120 randomly selected farmers discovered that farmland dimensions, fertiliser, and corn grain are the most important factors influencing maize yield. The research also discovered that land acreage had a favorable influence on output and a significant coefficient, implying economies of scale. Furthermore, the research revealed that maize production in the study region is inefficient, with a relative divergence from the boundary of eighty-five percent Smallholder maize growers with a mean TE of 0.66, the estimated TE ranged from 0.06 to 0.92. The study also found that significant socioeconomic factors that influence farmers' TE and maize output include the farmer's education level, household head age, land fragmentation, involvement in off-farm/non-farm activities, services for extension, and the producer's overall agricultural holding. The study estimates that by making better use of the available resources, TE in the cultivation of maize might be raised by 34% given the current state of technology.

Andrew and Philip gathered information from 122 farmers in Tanzania in 2015 and applied the extended Cobb-Douglas stochastic frontier model to study the data. The research concluded that the employment of inorganic fertilisers, agrochemicals, and labour had a significant impact on TE. It was also discovered that the farmers were not using resources effectively, as the average TE index was only 68%. The number of coffee trees and the experience of the farmer were recognised as the primary determinants of TE. To improve the overall TE of the production system, the researchers advised farmers to increase the utilisation of inputs that can boost productivity, enlarge their farms, and train younger generations in coffee production, as they tend to be more technically proficient.

Joachim et al., (2003) conducted a study on eighty-one small-scale farmers in Coˆte d’Ivoire's low-income region, using DEA methods to determine their TE. According to the results of the CCR and BCC models, the average TE values were 36 percent and 47 percent, respectively. Given the current technology, this means that there is an opportunity for improvement in output and/or cost reduction. Tobit regression techniques with two limits were also used to investigate the relationship between TE and other farm and farmer parameters. The study found that family size, membership in a farmer's club or organisation, and the farmer's background are the most promising policy variables. To boost efficiency and household incomes, the public sector could establish official farmers' clubs or organisations and provide information on labour force management.

In Côte d'Ivoire, there are inefficiencies in coffee production that suggest productivity can be improved without using more resources or new technologies. To figure out how much productivity could increase by improving efficiency, it is necessary to measure it quantitatively. It could be more cost-effective to concentrate on increasing efficiency rather than adopting new technology if inefficiency is high. This has important implications for policies aimed at increasing agricultural productivity and revenue in the short term (Belbase & Grabowski, 1985; Shapiro & Müller, 1977).

Despite efforts to increase agricultural production in Côte d'Ivoire, the TE of agriculture has not been sufficiently researched. There is not much research specifically focused on African agriculture, despite a rising body of knowledge on productivity or TE in African agriculture. Empirical studies have been conducted internationally, such as Bravo-Ureta and Pinheiro's work in 1993, Battese's study in 1992 and Coelli's research in 1995. A study on the TE of matoke-producing fields in Uganda found that these fields had decreasing returns to scale but could not determine the different sources of TE among matoke producers.

Binam et al. (2003) conducted a study of 81 peasant farmers in a low-income region of the Ivory Coast to evaluate TE measures. They applied DEA techniques to determine the TE measurements at the agricultural level. It is widely acknowledged that boosting agricultural productivity and output growth is crucial for efficient economic development, especially for small-scale producers like the coffee farmers in the Ivory Coast. Empirical research suggests that small farms are beneficial not only for their role in reducing unemployment but also for their contribution to a fairer income distribution and a robust demand structure for other economic sectors. The existence of inefficiencies implies that it is possible to increase output without additional input or new technology. When this occurs, empirical efficiency measurements are crucial for assessing the possible advantages of enhancing performance in coffee production in Ivory Coast using existing technology. One noteworthy policy implication of significant inefficiency levels is that focusing on improving efficiency might be more affordable to implement to quickly enhance agricultural income and output, rather than introducing new technologies. From a policy perspective, the analysis of the Ivory Coast peasant farmers' sample indicates the most promising factors for acting are family size, participation in farmers' organisations or groups, and the farmers' country of origin. Therefore, policymakers should give priority to the creation of official farmers' clubs or associations and enhance farmers' skills in their establishment and management (Wanzala et al., 2022).

The text presents several studies that investigate the TE of smallholder farmers in various African countries. Hassen (2012) found that increased production in crop-livestock production in North-East Ethiopian Highland led to technological improvement. Mesay et al. (2013) discovered that the age of the farmers and the accessibility of resources had a favourable impact on TE in wheat production. According to research by Musaba and Bwacha (2014), smallholder farmers in Zambia were able to enhance maize yield by 20.4% by using a certain input and technology effectively. According to Getachew and Bamlak (2014), the size of the farm had a detrimental effect on the TE of Ethiopia's maize production. Ogada (2014) discovered that a few variables, including age, gender, educational attainment, and social capital, had a negative effect on technical inefficiency. Mutoko (2015) discovered that integrated soil fertility has a favourable impact on Kenyan maize producers' TE and EE. Finally, Mekonnen (2015) found that farmers must utilise contemporary resources or technologies effectively to maximise yields due to growing population pressure and environmental degradation.

TE is shown to differ between localities and researchers in the coffee producing industry. The variation is caused by a few variables that are expected to have an impact. Data envelopment analysis was done by Poudel et al. (2015) to determine and contrast the TE of conventional and organic coffee cultivation in Nepal. They used the Tobit regression model to regress several variables. Data were gathered from 240 farmers who made up the sample. According to Poudel et al. (2015), organic coffee farmers had a higher TE of 0.89 compared to conventional farms' 0.83.

In Vietnam, Huong and Anh (2019) also used SPF to determine the TE of 92 coffee farmers. Findings showed that TE was 72.9%, indicating that the coffee producers in that area were technically inefficient. Thông and Niekdam (2016) conducted another study in Vietnam that also employed a stochastic production frontier to calculate the TE of small-scale coffee farms. The TE was discovered to be 0.64, indicating a lack of production efficiency. The study had targeted 143 households using the one-on-one survey method.

Moreover, Sudjarmoko and Randriani (2019) determined the TE of Arabica coffee farming. They used purposive sampling on seventy-two respondents and analysed using SFP. The MLE method was used to estimate the TE. The average TE was found to be 0.81 or 81%. In Cameroon, Nchare (2007) determined the TE of Arabica farmers using stochastic production frontier. By sampling a total of 140 farmers, Nchare found the average TE to be at 0.9. Ngango and Kim (2019) found the mean TE of coffee farming in Rwanda to be 82%. The study sampled a total of 300 small-scale coffee farmers and used a stochastic production frontier. It further applied the technical inefficiency model.

A project of the New Partnership for Africa's Development (NEPAD), the Comprehensive African Agriculture Development Programme (CAADP) aims to increase agricultural productivity in order to eradicate poverty and hunger throughout Africa. Getachew Magnar Kitila and Bamlak Alamirew Alemu carried out a study in Ethiopia as part of this programme in 2014. In Horo Guduru Wollega, an area in Ethiopia's Oromia Regional State, the study's objectives were to assess the prevalence of TE among small-scale maize producers and to pinpoint the variables that controlled it. Data collected from 120 sample farms chosen at random and analysed using a Cobb-Douglas stochastic model in 2011. The study revealed that farm size, usage of synthetic fertilizers, and type of maize seed used were the most important factors affecting maize yield. The analysis showed positive and significant economies of scale in terms of land area and output. However, there was significant inefficiency in maize production, with an 85% relative departure from the border brought on by inefficiency. The mean TE of smallholder maize growers was 66%, ranging from 0.06 to 0.92. The study also identified various socioeconomic factors that affected TE and maize yield, such as the education level of the farmer, age of the household head, land fragmentation, extension services, participation in off-farm/non-farm activities, and the farmer's overall landholdings. The study concluded that improved utilization of existing resources could enhance TE in maize production in the area by up to 34%.

Amadou (2007) conducted research in Cameroon to investigate the determinants affecting the TE of Arabica coffee producers using trans-log stochastic production frontier functions, where socioeconomic variables were influenced by technological inefficiency. According to the survey, 32% of farmers had TE indexes that were lower than 0.91, and the average TE index was 0.869. The analysis also showed that access to capital and the educational background of farmers were important variables that affected the TE of the farmers.

Joachim et al. (2003) investigated the parameters impacting TE among Cote d'Ivoire coffee producers. The study included 81 peasant farmers from Cote d'Ivoire's low-income area, and it employed DEA methodologies to generate farm-level TE metrics. The outcomes indicated that the mean percentages of TE for the CCR and BCC models were thirty-six percent and 47 percent, respectively, indicating that there is the possibility for considerable gains in productivity and/or cost reductions utilizing current technologies. Using two-limit Tobit regression methods, a second analysis investigates the association between TE and other farm/farmer parameters. The report recommends that government agencies give official farmer organisations and associations and farmer capability development top priority.

Mengo et al. (2015) investigated the level of TE in smallholder maize cultivation in Zimbabwe following the fast-track land reform in 2000. The study determined the variables that affect TE using a stochastic frontier production model and came to the conclusion that the usage of inorganic fertilisers, the number of seeds, labour, and the size of the planted area were all related to enhanced maize production. The researchers suggested that government and private sector initiatives should be implemented to facilitate access to productive resources and enhance agricultural extension services to enhance TE.

Similarly, Speelmanna et al. (2007) carried out a study in South Africa using Data Envelopment Analysis to quantify technical inefficiencies in farmers' usage of water. The study concluded that farmers had significant technical inefficiencies and indicated that if farmers improved their efficiency, they could be able to reallocate some irrigation water to meet other needs. The relationship between numerous farm/farmer characteristics and water sub-vector efficiency was examined using tobit regression techniques. The study found that several farm/farmer characteristics significantly affected the sub-vector efficiency for water. Andrew & Philip (2017) investigated TE among smallholder coffee producers in Tanzania's Kigoma region, who found that with a 68% efficiency index, farmers were technically inefficient but with an increase of 32, scope of growing technical efficient, the number of farmers who were technically efficient increased.

A study by Furi and Bashargo (2018) used a SPF to calculate coffee farming's production efficiency in Ethiopia. The normal efficiency was found to be at 74%, while the average TE was 88%. Further study by Tafesse et al. (2020) that concentrated on Moringa's production in Ethiopia found the TE to be 52%. The study had used the stochastic frontier model and had sampled a total of 117 Moringa farmers in southern Ethiopia. Another study carried out in Ethiopia by Parabathina et al. (2017) used cross-sectional data to determine coffee production's EE. By utilising the parametric stochastic frontier model, the TE was 71.7%, while the EE was 10.1%.

Based on Temesgen and Furi's (2019) research, the average coffee yield in Ethiopia is approximately 5.6 kuntal per hectare obtained from mature coffee trees, which have an average age of 38 years. This suggests that maintaining mature coffee trees requires a significant amount of labour. In fact, the productivity of coffee trees is heavily influenced by the labour devoted to their maintenance. On average, farmers in the study area were allocated 2.4 hectares of land, which is higher than the national average of 1.01 hectares (Temesgen & Furi, 2019). During the survey, most of the sampled households reported cultivating coffee as a sole crop. However, farmers believe that intercropping carries higher profitability potential compared to sole cropping. Nevertheless, they tend to opt for intercropping due to concerns about risks such as drought and other challenges. Coffee production thrives in areas with fertile soil, access to irrigation or moisture, and sufficient shade with moderate sunlight.

On average, farmers who own coffee trees aged between 25 to 30 years tend to be more efficient compared to households with coffee trees aged 30, which are owned by less efficient farmers. Therefore, coffee trees tend to yield higher output when they are between 15 to 20 years old (Temesgen and Furi, 2019). The typical household head has an average farming experience of about 18 years, ranging from a minimum of 8 years to a maximum of 60 years, with a standard deviation of 7.8 percent. On average, household heads have received formal education ranging from zero to 12 years, with a mean of 4.695 and a standard deviation of 3.5. The average household also has non-farm income of 1.8, with a standard deviation of 0.4 (Temesgen and Furi, 2019). Coffee farmers, on average, own land ranging from 2.3 to 6 hectares, although there are some who do not own land. This highlights that maintaining mature coffee trees requires significant labour, as the productivity of coffee trees is heavily influenced by the level of labour dedicated to their maintenance.

In Tanzania, Andrew and Philip (2015) also used the Cobb-Douglas stochastic frontier model to determine small-scale coffee farmers' TE. The study sampled a total of 122 farmers in Kigoma. TE was estimated using MLE and established TE to be at 68%. In Kenya, Kamau et al. (2016) used a two-step approach to determine the TE of coffee farming in Murang'a. The study calculated the TE measures using data envelopment analysis (DEA). The average TE was found to be at 54 percent. There is a common misunderstanding that Tanzanian agriculture is mostly centred in rural areas. Mwajombe et al. (2014) conducted a study to assess the TE of urban agriculture in Tanzanian municipalities and its policy implications. To assess the effects of technical inefficiency, they gathered data from 270 urban agricultural farmers using a stochastic frontier production function and a structured questionnaire. The maximum likelihood estimation (MLE) method was applied to jointly estimate the study's parameters and the inefficiency impacts model's parameters, and to evaluate asymptotic parameter estimations and identify efficiency drivers. The study found that the mean TE index was 0.72, indicating that urban agriculture production output could be boosted by 28% by employing current technologies. Despite their entrepreneurial skills, urban farmers had trouble allocating resources because the TE index was affected by factors like the size of the field, the total amount of variable costs, and the cost of the extension services.

Andrew and Philip (2015) contend that farmers act as rational economic actors, carefully assessing the costs and benefits when making decisions. In response to the declining coffee economy, the Tanzanian government implemented a coffee diversification programme with support from the International Coffee Agreement (ICA). This initiative aimed to encourage the cultivation of new crops on land previously used for coffee farming. As a result of the diversification program, farmers were prompted to abandon their coffee farms. Faced with alternative options, coffee growers had various choices, including: (i) adopting a passive approach and waiting for producer prices to recover, (ii) implementing strategies within the coffee subsector, such as expanding the coffee production area or enhancing the quality of coffee to target specialty markets like organic sales under the Fairtrade label, (iii) pursuing strategies within the agricultural sector, such as altering cropping patterns or transitioning to dairy farming, and (iv) exploring strategies outside the agricultural sector, such as engaging in nonfarm activities within villages or nearby towns.

In Northern Tanzania, a significant number of farmers chose the fourth strategy, which involved altering their cropping patterns or transitioning to dairy farming and non-farm activities. Conversely, in the Southern Highlands, farmers opted for expanding their farms (Andrew & Philip, 2015). In remote areas like Kigoma, where coffee production remains a vital source of cash income, farmers are likely to increase coffee production since there is available land for expansion. However, it is equally important to focus on improving productivity. Understanding the factors that promote or hinder the future development of the coffee sub-sector in the Kigoma region is crucial. These factors can vary from one location to another. For instance, a study conducted by Salazar (2006) on the use of organic fertilisers in coffee production in Guatemala, Honduras, Nicaragua, and Vietnam revealed that organic fertiliser had minimal impact on coffee yield in the first three countries, while in Vietnam, it had a positive correlation with coffee yield. Another study conducted by the African Economic Research Consortium [AERC] (2007) on factors influencing the TE of Arabica coffee producers in Cameroon found that efficiency decreased with the farmers' education level and the number of hours of instruction they received from extension services. However, for farmers still employing traditional production methods, their level of education did not significantly affect the TE of coffee production. These insights support the need for a location-specific study in the Kigoma region, specifically focusing on coffee production.

According to Andrew and Philip (2015), their findings indicate that smallholder coffee farmers in the Kigoma region, specifically in Kigoma and Buhigwe districts, exhibit technical inefficiency. This implies that increasing their TE might boost coffee production. The findings demonstrate that all inputs, except for organic fertiliser, significantly and favourably affect production per coffee tree. This implies that farmers are currently utilising inputs below the optimal level, indicating that production can be increased by enhancing input utilisation and subsequently improving TE. The experience of the farmers and the number of coffee trees play a crucial role in improving TE. The study reveals that by reducing this inefficiency to zero, coffee production can be boosted by 25 percent without the need for additional inputs. In other words, coffee farmers can achieve significantly higher profits simply by improving the efficiency of their operations. Farming experience emerges as a critical factor in enhancing input utilisation efficiency. Efforts should be directed towards supporting experienced farmers who can lead the way in business-oriented agriculture, as well as encouraging youth participation. Moreover, gaining further experience through training in good agricultural practices, particularly regarding appropriate input usage, is recommended. It is also suggested that non-governmental organisations and other actors should facilitate farmers in acquiring knowledge about optimal input utilisation, enabling them to reach their maximum production potential.

However, Ng'ong'a & Hong (2021) found that in Rwanda, the mean of the maize farm from a sample with a calculated standard deviation of 0.64 revealed that while examining the relationship between the size of the farm and the TE of the production of maize using the zero inefficiency stochastic frontiers method, the yield of maize can be increased by about 36% without increasing the amount of farm input used. The relationship between farm size and technological prowess has been proved to be positive. As a result, Rwanda needed to take actions involving land consolidation and increased aggregate productivity improvement.

Agent and structural factors are the two categories into which efficiency can be split. Agent variables include social capital, age, and education refer to individual attributes, whereas structural factors, including on- and off-farm aspects like location, size, infrastructure, and policies, are external to the individual. TE relates to how efficiently resources are utilised to maximise productivity. For instance, a study on maize farmers found that agro-ecology, oxen ownership, farm size, and use of improved maize variety were significant determinants of TE. However, the farmer's age, education, family size, and credit access were not significant. In terms of significant determinants, age, education level, household size, and credit access had a positive and meaningful impact on TE, while gender, method of irrigation, and off-farm activities had no significant effect.

Wree et al. (2018) posit that the adoption shows a significant potential for increased yields. of modern wheat breeding techniques, such as hybridisation and genetic manipulation. The researchers estimated the multi-output multi-input production technology using stochastic frontier techniques to determine the economic worth of this yield potential. The ecology, food security, and food safety are all significantly impacted by innovations in agricultural crop production. In the production of cash crops including corn, soybeans, rapeseeds, rice, and barley, hybrid and genetic modification breeding procedures have gained popularity globally, but their adoption in the production of wheat has been rather slow. As a result, the growth in wheat yield has lagged that of other crops. For example, between 1994 and 2014, the average yearly yield increase rate for rapeseed in Europe was 3.6 percent, more than double the annual growth rate for wheat (1.6 percent). To address the rising worldwide demand, breeding innovations are required for wheat because of its enormous significance for global food security (Ngoe et al. (2016). Additionally, wheat continues to be the largest grain grown by European farmers, occupying about 26% of the 100.3 million hectares of arable land in the EU-28.

In their research, Wree et al. (2018) initially employ stochastic frontier analysis and create Distance Functions (DFs) that encompass multiple inputs and outputs to represent the relationships between input and output in European crop production technology. The resulting estimated function has practical applications in assessing farm efficiency and productivity, considering the interdependence of inputs. The utilisation of multi-output functions proves advantageous because it eliminates the need to determine the specific allocation of inputs for each output, which is often unattainable with the available data, such as the European Farm

Accountancy Data (FADN) used in this study. The usage of DFs has the advantage of not requiring price data or explicit behavioural assumptions. The researchers then suggest a potential price in the form of a Marginal Shadow Value (MSV) that farmers might be ready to pay for wheat seed material that increases yields based on the estimates produced from the multi-output multi-input production method. The MSV, which assumes an ideal mix of inputs, represents the economically acceptable expenses associated with seeds that progressively increase wheat productivity or output (Tafesse et al., 2020).

The results of the study demonstrate that TE remains relatively stable over time, ranging from 0.896 to 0.925 at the aggregated EU level (Wree et al., 2018). These findings offer valuable insights for farmers, seed producers, and other stakeholders involved in policymaking. The calculated MSVs provide an indication of the economic value associated with breeding innovations. The benefits of these innovations are typically shared among the seed developer, farmer, and to a lesser extent, the consumer. However, the distribution of these shares can vary significantly depending on the region and specific trait. In our model, the MSVs for seeds reflect the economic value of crop improvements for farms. Nonetheless, the benefits of innovation are shared through seed prices or breeding premiums between the seed developer and the farmer. Additionally, increasing yields not only bring advantages in terms of food security but also have the potential to contribute to environmental conservation and resource preservation. While MSVs provide theoretical values for breeding innovations, their actual worth is influenced by practical factors such as laws and agreements. The International Union for the Protection of New Varieties of Plants (UPOV) plays a role in safeguarding breeding innovations for the benefit of society by implementing an effective regulatory system. It is important to note that not all countries in our sample have ratified the latest UPOV act. In a weak regulatory system, there is a risk of losing the MSV and long-term benefits associated with breeding innovations (Tafesse et al., 2020).

Land is one of the main determinants of TE farming in the coffee farming sector, efficiency was associated with use of a lower amount of land (Furi, (2016). Mwajombe and Mlozi's (2015) study on TE showed that among the factors affecting the TE index were resource availability and size of land. Land as a significant influencer of TE was also noted by Tafesse et al. (2020). Their study had focused on the production of Moringa in southern Ethiopia. They had targeted 117 farmers through a cross-sectional study. Besides, Tafesse et al. (2020) suggested households with limited access to land should be considered to increase the production of Moringa. An increase in land for an increase in productivity was also noted by Nyagaka et al. (2010). They focused on Irish potato production in Nyandarua in Kenya. Studies by Parabathina et al. (2017) also associated land fragmentation and the total land used in farming to improve overall coffee productivity.

The household head was another factor that was seen to influence TE. Furi (2016) found out that female households were more efficient than male households. He explained that women managed their resources better men hence the efficiency. Contrary to Furi's findings was Ngoe et al. (2016), who found that the male's TE was higher than that of the female. However, Ngoe et al. (2016) focused on cocoa farming in Cameroon while Furi focused on coffee farming. Generally, cocoa farming is male dominated as it is a tedious job that does not favour women.

Study by Besseah and Kim (2014) noted that male households owned bigger land sizes than their female counterparts. Their study on cocoa farming in Ghana revealed that the TE was higher in male-dominated households. They further associated higher productivity in male households to the access or resources needed in farming, such as inputs (Besseah & Kim, 2014). However, Hailemaraim (2015) revealed that the household head's age, the family size, was found to reduce farmers' TE.

Moreover, Parabathina et al. (2017) indicated that the household head's age played a great role in influencing both the technical and EE of coffee farming. According to Solomon (2014), age had a positive impact on TE in teff production. The study further outlined that poverty and education levels of the farmers were major predictors of technical inefficiency. Wondimu and Hassen (2014) demonstrated that area under maize farming positively influenced production in Dhidhesa district. Age affected its production positively and significantly.

The size of the household also influences TE positively according to some researchers. Kamau et al. (2016) explained that large households produce more workers to work on coffee farms. They alluded to the significant positive influence on the fact that coffee farming is labour-intensive. In Murang' a, they indicated that large households benefited small scale farmers in the area.

The availability of credit is another significant factor that affects TE in farming. In Cameroon, Nchare's study in 2007 demonstrated that access to credit was a major factor affecting the TE of smallholder coffee farmers. Similarly, Nyagaka et al. (2010) found that credit use had a meaningful impact on TE, with increasing credit availability improving the efficiency of Irish farming. Credit availability helps farmers purchase inputs such as seeds and fertilisers and make timely decisions about their farming practices. In Ethiopia's central rift valley, Musa et al. (2014) found that credit availability played a role in maize farming, and in another study, Sibiko (2012) showed that access to credit had a positive impact on TE.

In a study focusing on smallholder coffee farmers, Thông and Niekdam (2016) established that the availability of loans to farmers had a significant positive influence on coffee production. The loan's issuance was particularly beneficial to small scale farmers who had household heads from an ethnic minority (Thông and Niekdam, 2016). Ngoe et al. (2016) found out that credit accessibility significantly influenced TE. The authors noted that credit access influenced farmers' ability to purchase inputs in addition to overcoming other financial constraints that may hinder cocoa farming (Ngoe et al., 2016). Ho et al. (2014) also indicated that the farmers' loan significantly influenced TE on coffee farming.

A study by Kamau et al. (2016) also established that credit availability positively and significantly influenced TE. They clarified that the coffee farming sector was highly dependent on farm inputs such as fertiliser, pesticides, and seedlings, all of which must be purchased. Farmers, therefore, need to obtain credit from either the cooperatives or financial sectors to succeed in this venture. Thus, as credit access increases, so does the productivity of coffee output.

The level of education also impacts TE. Studies that support education as an influencer of TE include Nchare (2007). Nchare (2007) while conducting a study found out that farmers who had high levels of education reported high TE while low education levels were related to lower TE. An increase in education was seen as a means of augmenting the human capital of production. To determine the EE and TE in rice crops in the Kou Valley in Burkina Faso, Ouedraogo (2015) conducted a study. The research results showed that TE was significantly influenced by farming experience. However, it was discovered that a farmer's reading level had a considerable detrimental impact on their TE in Kou Valley.

Ali and Khan's (2014) findings indicate that a farmer's level of They agree with TE that schooling has a big detrimental effect on him. In contrast, Ahmed et al. (2015) have demonstrated that access to extension services improves TE while education improves both allocative and EE. Getachew and Bamlak (2014) have concluded that a farmer's level of education, age, and involvement in off-farm/non-farm activities positively affect TE. Tefera's (2014) study on teff production has revealed that following the latest guidelines and possessing a higher level of education can have a positive impact on teff production. Conversely, the use of poor-quality seeds and large farm sizes can lead to technical inefficiencies. Hailemaraim's (2015) study has found that education and access to credit services significantly and positively influence TE. Similarly, Abiodun and Omonona's (2015) study shows that an increase in a wetland farmer's level of education improves their TE. Lastly, Beyan (2013) reported that training and education levels among farmers in Girawa District are linked to TE, and that social status of farmers has a negative association with it.

According to Nyagaka et al. (2010), Irish farmers with more education were more productive than those with less years of schooling. Ngoe et al. (2016) discovered, however, that schooling had a significant detrimental effect on TE. According to a study by Ho et al. (2014) TE was observed to rise as education level focused on the TE of small-scale coffee farmers in three districts in Vietnam. They found out that coffee output was higher in districts with farmers with higher education levels. They explain that educated workers are good at making decisions based on the available farming information. Educated workers are also said to be good time managers, increasing productivity.

The labour force has been found to influence TE. However, the influence may be positive or negative depending on the household composition or the type of crop. Furi (2016) found labour to have a negative correlation with production efficiency. He explained that an increase in labour was associated with an increase in the number of dependents, which decreased coffee production efficiency. He further noted that as the number of labourers increased, so did the wage expenses hence low Efficiency (Furi, 2016). Contrastingly, Besseah and Kim (2014) argued that an increase in labour in cocoa plantations increased overall productivity.

However, Widjaya et al. (2017), while conducting their study, found a negative influence of the labour force on the production of arabica coffee. As per their research, small scale farmers need not add more labour to reduce their production. Sources of labour for the small-scale farmers came from family members. The unfamiliarity of labour forces to the cultivation of arabica coffee was indicated as a detriment to its increase. They further indicated that the use of unskilled labour would cause damages as they decrease production (Widjaya et al., (2017)).

Also, Ngango and Kim (2019) noted the significance of labour input in their study on coffee farming in Rwanda. Though the increase was inelastic, coffee farming production was predicted to increase by 0.182% if labour increased by one percent. Parabathina et al. (2017) revealed that as the family's size increased, so did the labour availability. The family size was associated with an increase in coffee productivity in Ethiopia. According to them coffee production serves as the significant export crop, it provides economic activity for smallholder farmers in Rwanda. However, there has been a noticeable decrease in production because of the sector's considerable changes in Rwanda. Despite its importance to the Rwandan economy, the coffee industry faces several challenges, particularly low productivity. Compared to Latin America and Asia, coffee yields in most East African countries are comparatively lower

(Ngango & Kim, 2019). Researchers worldwide have shown interest in analysing the prevalence of TE among farmers and the factors that influence it, as both farmers and policymakers must be aware of this information. Farmers benefit from improving their managerial skills, as it enables them to allocate inputs more efficiently to achieve desired levels of output. Policymakers can also use this information to develop relevant policies aimed at enhancing crop productivity.

In Rwanda, coffee yields have been relatively low, averaging between 1.5 and 2 tons per hectare from 2012 to 2016. In contrast, countries like Colombia, Venezuela, and Indonesia achieved average annual coffee yields of around 8 tons per hectare during the same period. The tragic events of 1994 had a lasting impact on coffee productivity, and the current levels have never fully recovered. The low yield is influenced by various challenges related to the environment, institutions, and agricultural administration. Crop yield is greatly reduced by insects and diseases like coffee leaf rust and coffee berry disease. Coffee yields are also threatened by farmers' failure to use correct agronomic practises, such as weeding, mulching, pruning, employing improved varietals, fertilisers, and soil erosion control (Ngango & Kim, 2019). The supply of green coffee beans from other competitive coffee-producing nations kept the average price paid to farmers roughly steady despite the decline in Rwanda's productivity and overall production of coffee.

Consequently, the current lower productivity compared to the income of Rwandan coffee fields has been directly impacted by the early 1990s. The government and development partners have concentrated on encouraging the spread and use of agricultural technologies to address the issue of low coffee productivity (Ngango & Kim, 2019). However, it is important to note that improving farmers’ TE is equally crucial for increasing agricultural productivity, as TE stands for the producers' capacity to create the greatest amount possible given the existing production parameters. Increasing TE in agriculture looks to be more advantageous in a resource-constrained nation like Rwanda where the adoption rate of technology is relatively low.

The results of the study indicated that implementing land use consolidation for coffee plantations has a significant positive impact on the level of TE in coffee production (Ngango & Kim, 2019). This consolidation process is considered a crucial policy tool in China and India for improving farmers' efficiency. One possible explanation for this finding is that the government can execute policies like fertiliser subsidies, loan accessibility, market access, and rural infrastructure development by combining scattered plots into continuous parcels. Therefore, these programmes can help farmers increase their productivity and efficiency. Additionally, it was discovered that farmers' TE was greatly increased by using a better coffee tree variety, notably the BM139 kind of Arabica coffee (Ngango & Kim, 2019). In the study area, farmers who cultivated this variety exhibited higher levels of TE compared to those who still relied on low-yielding coffee varieties. Lastly, the cropping system was identified as a variable influencing variations in technical inefficiency. It was incorporated into the inefficiency model as a dummy variable to test the hypothesis that switching to a mono-cropping system would increase the TE of coffee growers. The analysis revealed that the cropping system had a statistically significant negative impact. This suggests that farmers practicing mono-cropping for coffee production tended to achieve higher levels of TE compared to those who intercropped coffee with other crops.

According to estimates, 82 percent of the research area's coffee farmers had TE on average. This suggests that by eliminating technical inefficiency, it may be possible to boost coffee production by about 18% utilising the country's current inputs and farm technologies. All inputs in the production function exhibit inelasticity, as shown by the analysis of partial production elasticities and returns to scale. This indicates that a 1% increase in each input will yield a coffee output increase of less than 1%. Additionally, Ngango and Kim (2019) found that labour, land, pesticides, organic fertilisers, and chemical fertilisers all have an impact on coffee production. The returns to scale (RTS) coefficient were found to be 1.05, showing rising returns to scale for farmers in Rwanda's Northern Province who produce coffee. In plainer terms, this means that a proportional increase in all production parameters results in an output rise for coffee that is greater than proportional. The findings also showed that factors including improved coffee tree species, cropping strategies, land consolidation, extension services, and access to credit all greatly increased the TE of coffee producers.

These policy suggestions are put out considering the study's findings. Priority should be made to encouraging farmers to participate in training programmes and advancing education in rural regions. Furthermore, it is necessary to improve extension services and make them available to all farmers, regardless of their location. This will strengthen the farmers' managerial abilities, which will increase TE. Small-scale farmers should be assisted by the government in obtaining finance. According to the report, further funding is needed to create and market superior coffee types. The adoption of high-yielding, disease-resistant coffee cultivars like BM139 should be encouraged and guided by extension agents (Ngango & Kim, 2019). Additionally, controlling coffee plantations through land consolidation and employing a mono-cropping strategy can help minimise TE among coffee farmers in the Northern Province of Rwanda. Presently, the hilly terrain, shade tree canopy, and high machinery costs pose challenges to the adoption of mechanisation in coffee farming in Rwanda. However, despite these difficulties, introducing mechanisation can be a viable solution to effectively maintain coffee plantations and enhance labour efficiency and productivity.

Some researchers have highlighted the use of fertilisers as a determinant of TE in farming. Widjaya, et al. (2017) indicated that organic and inorganic fertiliser was not efficient. Their study focused on 36 small scale arabica coffee farmers in Jember district. Using Cobb Douglas as an SFA function, they found an average TE to be 71.4%. The minimum was 25%, and the maximum was 93%. The authors recommended the use of inorganic fertilisers for EEto increase. However, in the study on cocoa production by Ngoe et al. (2016), fertiliser increases significantly influenced the output. They noted that cocoa did well with a lot of fertiliser applications. Mesay et al. (2013) also revealed that the availability of inputs such as fertilisers and market availability increased the wheat production efficiency level.

Besides, Ali and Khan's (2014) chemical fertilisers had a significant positive influence on wheat production. The study also showed that an increase in the factors would significantly increase the production level. Among the factors influencing TE according to Musaba and Bwacha (2014) were the size of the farm and the availability of farm fertilisers. The study also indicated that the type of seed used in the farm and the education level significantly affected TE.

Also, Ngango and Kim (2019) found out that fertiliser had the highest impact on coffee production. According to the authors, an increase in fertiliser use was predicted to increase output by 0.314. Additionally, their study indicated that organic fertiliser had a higher elasticity than inorganic fertiliser. Therefore, manure and compost as organic fertiliser were recommended. Huong and Anh (2019) noted a significant positive influence on fertiliser use on TE. From their findings, an increase in fertiliser levels by 0.23% would result in a one percent increase in production. Sudjarmoko and Randriani (2019) also found that fertilisers such as Urea, ZA and SP 36 significantly influenced TE.

The number of seeds can either negatively or positively influence the TE of productivity. Furi (2016) found out that coffee production efficiency increased when the number of seeds was increased. He noted that the significant positive influence was that most farmers could efficiently combine the right number of seeds. Contrary to Furi’s findings, Ngoe et al. (2016) found a negative association between the number of seeds and the output. Their study focused on cocoa farming in Cameroon. The researchers explained that the negative association might result from inadequate shade or delays in pruning and weeding. Andrew and Philip (2015) also revealed that the number of trees significantly influenced TE. The study was done in Kigoma, Tanzania, on small scale coffee farmers.

Policy recommendation as a means of increasing TE to coffee farmers has also been raised. Furi (2016) indicated that to increase farmers' productivity and export competitiveness, policies that gear towards improving production efficiency should be created. The study noted that if good policies are followed, TE could increase by 22%. He had obtained 88% efficiency from a study of 200 households involved in small-scale coffee farming.

Relational Agency in Coffee Farming

In general research, coffee farming is under the discipline of agronomy, economics, and science of biotechnology. Agency theory explains the mutual agreement whereby the management who are agents work for the owners of the capital the principals (Safriliana et al., 2019). During an engagement, information asymmetry arises whereby agents tend to act in self-interested behaviour. Thus, the principals employ control of the agents' behaviour, giving rise to the agency cost theory. This form of agency is a competing agency model. This study adopts the collaborative agency model under the tenets of activity theory referred to as the relational agency.

The relational agency intends to capture one's scope of thoughts to align with the outside world. The relational agency's main objective is to strengthen and enhance the community's joint capability (Dépelteau, 2015). It focuses on relational interdependence between one individual with another in their working capacity. The relational agency recognises that cultural instruments' intelligence guides human actions within the community (Dwiartama & Rosin, 2014).

Meike and Bernhard (2009) studied the consequences of a severe drop in coffee prices on Costa Rican growers. Using survey data from 2002/03 and 2003/04, the study discovered that extra income-generating activities can improve coffee producers' efficiency. Experience, recordkeeping, and the number of adult home members were discovered to have a substantial influence on efficiency in the specialty coffee business. Membership in cooperatives increases agricultural efficiency for traditional coffee producers. The report advocated governmental initiatives such as providing extension services for accounting procedures, establishing income possibilities in rural regions, and supporting farmer-owned cooperatives to increase production performance and farmers' ability to cope with the coffee crisis.

They used a descriptive survey design and stratified random sampling to collect data from 95 coffee farmers in Kenya, and the results indicate that coffee farming and decision-making are largely dominated by men, particularly those over the age of 51. Although women play a significant role in coffee production, they are underrepresented in management committees and key decision-making positions. The study shows that access to credit is critical for the development of the coffee industry, and favourable marketing conditions are essential to increase access to markets, which have a significant impact on coffee revitalisation. The study suggests that involving women and young people in the coffee sector can help maximise the potential of each gender group, and the study's findings could help enhance the performance of various stakeholders in the coffee value chain.

Relational agencies in farming include all the various attributes within individual events that promote or constrain farming. It also encompasses the processes continually challenged by new relations and may de-stabilise practices (Fox & Alldred 2018). Relational agencies in agriculture allows a more robust integration of the biological, ecological, social, cultural, and political aspects. Basing the relations on values and belief means that relational agency allows a better understanding of the drivers that shape farming diversity and shape changes in farming practices (Darnhofer et al., 2016).

The study focused on exploring the correlation between coffee farming and economic benefits. It utilised the main income generated during the 2015/2016 period as a measure of economic benefits. According to the study, when coffee is auctioned off, the marketing agent subtracts their commission and distributes the remaining amount to the union. Before calculating the payment price, the cooperative deducts its operational expenses. Divided by the total given kilogrammes, the resultant sum yields the selling price, which is based on the quantity of berries supplied by the growers. Since operational costs vary among manufacturers within the same collaboration, the payment price also varies. The present research analysed the economic benefits in terms of farmers' revenue, this was computed by dividing the payment rate by the amount of provided cherries.

Kuhlin and Modig (2009) conducted a study on the coffee auctions in Kenya and Tanzania to examine the level of competition and whether coffee farmers received a fair portion of profits. The results indicated that the auctions were almost perfectly competitive, but it was uncertain if the farmers were compensated. The large number of small-scale farmers and their economic situation made it unlikely for them to receive a significant share of the revenues. However, Monroy et al. (2013) pointed out that the auction system promoted transparency and incentivised the production of high-quality coffee. Moreover, the payout price was influenced by the deducted costs, which could be analysed by studying the value chain.

Hezron (2001) conducted research examining how the agricultural sector in Kenya was impacted by liberalisation. The study found that to succeed, managers of cooperative societies must possess strong management skills regardless of their tribal or clan affiliation. Additionally, the management team should be held accountable to a board of directors or committee elected by the members. Members need to recognise that cooperatives exist primarily for economic purposes rather than social or political ones. Cooperatives have played a significant role in developing the coffee industry in Kenya by procuring inputs, managing production, adding value to products, and promoting sales. Furthermore, cooperatives have encouraged savings and provided credit to producers through Savings and Credit Cooperative Organisations (SACCOs). These efforts have led to the implementation of new cooperative development and investment policies by the government and the creation of the SACCO Regulatory Authority to boost the economy. In Mukurweini, four cooperative societies with 28 coffee factories have been established, bringing together 18,000 small-scale coffee farmers.

The importance of grades and standards in providing quality assurance, reducing transaction costs, and facilitating international trade was highlighted by Kheralla and Kirsten

(2001). However, when importing nations enforce unachievable minimum criteria, these norms can also be utilised as non-tariff trade barriers. Despite an increase in Tanzania's coffee export prices, Mhando et al. (2013) discovered that there was no proof of a rising trend in coffee production. The authors suggest that farmers may not trust the coffee market due to price fluctuations and prefer to invest in other income-generating activities instead of expanding coffee production. Therefore, the focus on coffee production alone may not accurately measure the level of empowerment. Grades and standards play a significant role in governing exchange in international markets, as explained by New Institutional Economics (NIE) and TCE theory.

Even though Rwanda's coffee-producing industry contributes significantly to the nation's economy, it faces several issues, the most prominent of which is low productivity. Coffee yields in most East African nations are lower than in Latin America and Asia, according to Aan et al. (2011). From 2012 to 2016, Rwanda produced 1.5 to 2 tonnes of coffee on average annually per hectare, compared to over 8 tonnes per hectare in Colombia, Venezuela, and Indonesia (Faostat, 2019). Since the sad events of 1994, the level of output has not entirely returned (ICO, 2017).

Furthermore, failing to follow effective agricultural coffee production could be at risk from practises including weeding, mulching, pruning, employing superior varieties, fertilisers, and soil erosion control. (Amarasinghe, 2015; Jezeer, 2018). Despite a drop in coffee productivity and total output in Rwanda, the average price paid to farmers remained consistent, ranging between 74.20 and 77 US cents per pound of green coffee beans between 1990 and 2017 (ICO, 2017). This was owing to other rival producing countries' supply of green coffee beans. As a result, the present low revenue in Rwandan coffee fields is directly tied to the decline in productivity since the early 1990s. To address the issue of poor coffee productivity, the Rwandan government and development partners have prioritised the dissemination and use of agricultural technology. However, in addition to technology adoption, enhancing farmers' TE is critical in raising agricultural output (Battese & Coelli, 1989; Poudel et al., 2015). According to Coelli et al. (1998), TE refers to a producer's capacity to maximise output utilising current production parameters.

The relational approach highlights that pattern of relations are always changing. Taking farming as a set of constituent practices bundled in different ways through time gives us three aspects that come to the fore. The first aspect was the ever-present opening to change. The second and third aspects are linked to the integrated view of the agency of humans and nonhumans. They postulate that the agency of nature is fundamental in farming and how technology expresses and stabilises modes of ordering. Different relationalities offer different opportunities and constraints. Thus, different levels of flexibility are needed to engage with change and shape change. Resilience is thus paramount when focusing on relational agency in agriculture. Therefore, the understanding of resilience should be more on the process that needs to be re-enacted continuously and performed through nurturing diverse and heterogeneous relations. A relational perspective contributes towards a more balanced approach to resilience thinking, covering how farming can buffer shocks and failure and how farming can be transformed and improved (Darnhofer et al., 2016).

Mahmuda et al. (2018) studied how fertiliser subsidies influenced farming efficiency at the micro level in Bangladesh, considering various farm configurations and a universal subsidy program. They conducted personal interviews with 300 farm households in three districts of northern Bangladesh, utilising multistage purposive sampling based on the concentration of rice production. The DEA and Tobit models were used in the study to estimate TE. It was discovered that it considerably boosted farming efficiency in marginal and small farms but not in medium and big farms. According to the researchers, boosting fertiliser subsidies would result in large productivity gains for smallholder farmers, and governmental measures should assist these farms in accelerating agricultural expansion.

From 39.8 thousand tonnes in 2012/13 to 49.5 thousand tonnes in 2013/14, coffee production increased (Economic Survey, 2015). With a 100-ha growth in both the cooperative and estate sectors, the area under coffee cultivation expanded marginally from 109.8 thousand hectares in 2013 to 110.0 thousand ha in 2014. Estate output fell for the second year in a row, despite the broader coffee sub-sector increasing production by 24.4% over the review period. The cooperative sub-sector, whose output rose from 21.9 thousand tonnes in 2013 to 32.7 thousand tonnes in 2014, was primarily responsible for this growth. While the return in the estates fell by 5.0%, the average yield in the cooperative sector increased to 48.4%.

According to Alsop and Heinsohn (2005), a person's level of empowerment is influenced by their personal agency, or their capacity to make decisions, and their opportunity structure, or the institutional setting in which those decisions are made. According to the study, agencies would mitigate the connection between the institutional setting and financial gains. The study used asset-based agencies, which included psychological, informational, organisational, material, social, financial, and human assets, as indicators of agency since they are essential for a farmer's economic activities.

Meanwhile, Parrish et al. (2005) research uses the sustainable livelihood framework to assess the impact of the interventions and identifies seven dimensions of analysis, including five forms of capital and two institutional dimensions. The authors find that both interventions are complementary, with TechnoServe's approach being useful for increasing supply-side production efficiency and a Fairtrade-styled approach suitable for demand-side market creation. In this study, asset-based indicators of the agency were determined based on a literature review to include those most relevant.

In this literature, we used the activity and agency theory to help explain the relational agency of coffee farming in Kenya.

Activity Theory

Vygotsky founded the theory. It was based on the concept that actions are preceded by thinking (Gedera & Williams, 2016). According to the theory, work is divided into subject, object, and tool. The subject represents the person undertaking the activity; the object refers to the activity being done, while the tool represents the means used to facilitate the activity. Engstrom modified the theory to include rules, community, and the division of labour (Engestrom, 2016).

According to Engstrom, the rules are to be followed by the person doing the task. The community refers to the workers engaged in the operation, while the division of labour is the measures guiding the workers or the community. As per the theory, human creativity is paramount. For instance, the tools used keep changing depending on the community's changes due to creative activity (Yasnitsky, 2018). In modern society, the tools refer to the technology employed in facilitating the activity, which has advanced to language, computers, and machines.

Hill, Botha and Capper used activity theory to explain and analyse the behaviour of sheep farmers in New Zealand. The study analysed farmers' inspirations, tasks, and individuals or firms they interacted with. They perceived the rules that guided the farmers to have both historical and cultural aspects. Among the tools thought to have a greater impact on farmers, actions were electronic gadgets. They concluded that activity theory offered a great framework for their analysis (Hill et al., 2012). Similarly, Świergiel et al. (2018) used activity theory to examine organic farming development in Sweden. The authors aimed to compare organic and conventional farmers' social and environmental problems using apple farming as a case study. They discovered that the organic farming concept was trying to break free from conventionalisation. The activity theory categorised each stakeholder's needs.

The activity under the current study is coffee farming in Kenya. Therefore, the study investigated the role undertaken by various stakeholders in coffee farming in Kenya. Key stakeholders included the subjects, objects, and tools in the process. Furthermore, the rules that govern the coffee farming sector in Kenya were also investigated. The organisations responsible for each part of the process were carefully examined.

Agency Model

Agency theory was founded in 1976 by Jensen and Meckling. It looks at the issues that arise in a firm after powers are split between the managers and owners. The firm is defined as a 'set of agreements between the production factors' (Delbufalo, 2018). Thus, all the people involved in a firm have developed a form of contractual dealings. The managers are the agents, while the owners are the principals. The theory provides a solution aimed at reducing the issues. According to agency theory, the challenges in a firm are further increased by agency costs accrued from the prevailing relationship between the agents and the principal (Rashid, 2015).

The theory's founder imagined the connection between managers and proprietors to be like agents and the principal (Delbufalo, 2018). The proprietors hire the managers to play out the controlling duties of a firm. The managers come to their firm with the personal interest of benefiting from the profits, thus causing an interest crisis (Panda & Leepsa, 2017). Since managers have control of the firm, they can take profits to the owners' detriment. The expenses brought about by the difference of interests among managers and proprietors are agency costs. Agency expenses and proprietorship structure are focal in corporate governance. The principal contributes their capital intending to procure financial advantages, while the agents are risk-averse and interested in increasing their benefits. Both parties' risks are different and conflicting, and concern about risk-sharing results in the agency problem (Hassan et al., 2018).

Agency theory explains the agency’s problem and its cost by making two propositions. The first proposition explains that if the contract's outcome is incentive-based, the agents act in favour of the principal. Second, if the principal has information about the agents, then the agents' actions will be disciplined (Delbufalo, 2018). The principals try to minimise agency costs by monitoring hired agents in an agency relationship. Since the main aim is maximising profit, deploying good cooperation and teamwork is crucial. Other players must be brought into play to ensure the firm's survival (Panda & Leepsa, 2017).

Fama upheld that the organisations can be controlled by different players' rivalry, which controls individual and group performance. Serapicos et al. (2019) study categorised the agent's role based on its decision-making process as decision control or decision management. They indicated that the decision-making process's variation was based on whether the firm was involved. Since decision control and decision management are not the same in complex firms, the agency problem is likely to occur. Other authors have shaped the agency theory by developing distinct approaches in their works, viewing the agency issue as inducement, while Mitnick considered it because of the institutional structure, yet the focal view behind their hypotheses is analogous. They recognise the principal-agent issue as the result of the payment choice and thought it was not limited to the firm. Instead, it also exists in the community. The institutional approach of Mitnick helped in building up the rationales of the core agency theory, and it was perhaps intended to comprehend the conduct of this modern reality. His theory indicated that organisations are founded around the agency and develop to resolve with the agency (Styhre, 2016).

Several researchers have criticised agency theory on different grounds (Brault and Sanderman, 2016). They propounded an alternate agency theory called behavioural agency theory. The critics contended that agency theory accentuates the conflicts between the agent and the principal, and the agency costs incurred in the process. However, they indicate that the behavioural agency theory brings about motivation, compensation, risk aversion, and time preferences (Brault & Sanderman, 2016). Thus, they argue that agency theory's new approach emphasises the agent, not the relationship between the principal and the agents, mainly accentuated by the standard agency model (Styhre, 2016; Pepper, 2019).

Jarosz (2018) criticised agency theory by indicating that they have just focused on the specialist side of the 'agent and principal issue' and thought it might occur from the principal's side. Perrow observes that agency theory is indifferent to the principals, who cheat, evade, and misuse the agents. Moreover, he added that the agents are mistakenly hauled into work in a dangerous workplace and with no degree for infringement, with opportunistic principles. Perrow argued that people are respectable and work morally for the firm's progress.

This study used the agency theory to determine the relational agency in coffee farming in Kenya. The relational agency is guided by the coffee value chain, consisting of several players such as small and large-scale farmers, cooperatives, millers, marketing agents, and exporters. The study investigated the agency problem in each relationship and examined the costs incurred by each player.

Coffee Value Chain

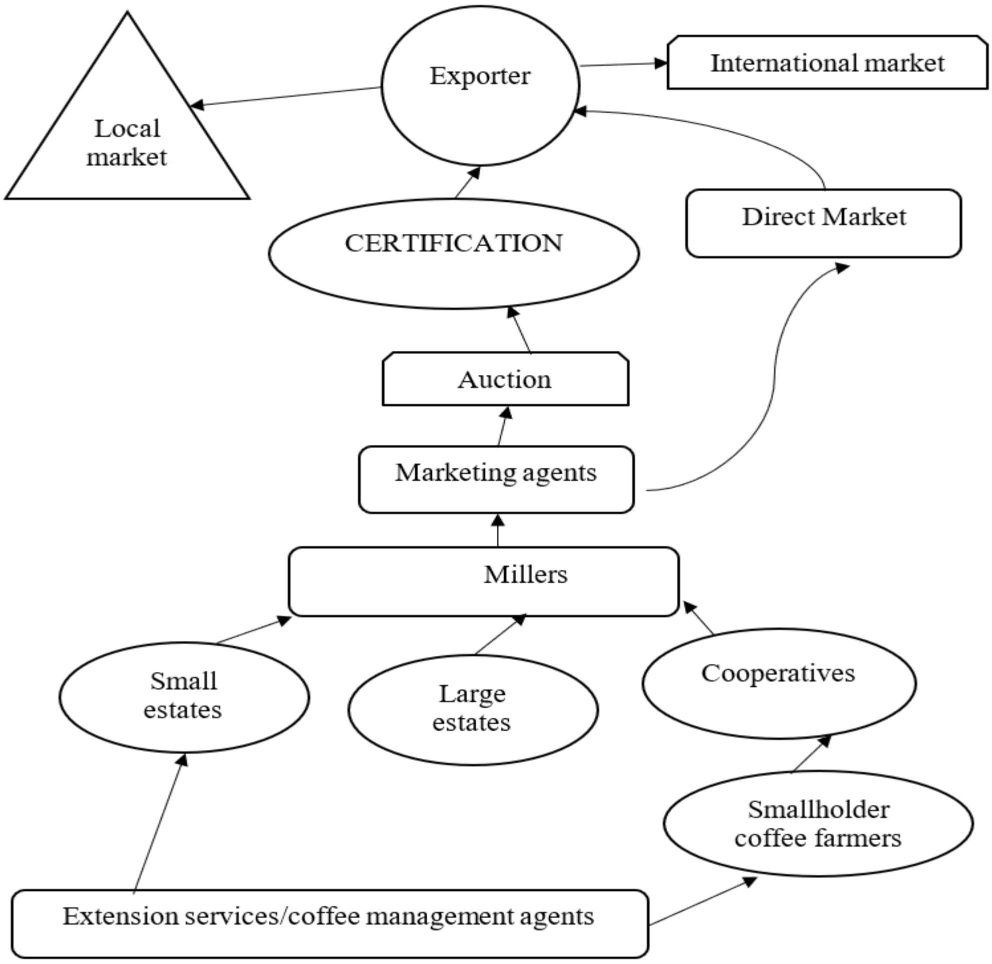
Value Chain refers to the "full scope of activities which are needed to bring goods or services going through the middle stages of production until they reach the final consumers." The value chain also refers to the players, the regional structure, and the production process's technical structure. Some authors have conceptualised a value chain as the idea portrays a scope of numerous actions performed by players in a particular industry to distribute an essential item or service to the market. The actions involved in the value chain include design, production, advertising, and movement of goods or services to the final buyers (Seville et al., 2011).

Globally, Kenya ranks number 21 in the production of coffee. In 2006 it produced more than 50 million Kgs. Coffee exports contribute about 5% of all the country's exports (Ferris et al., 2014). In the global market, the prices of coffee are determined by the availability and size of coffee stocks. Coffee is the most traded agricultural item and the most significant income earner to small-scale farmers and their households. Intermediaries in the coffee trade comprise retailers, roasters, international traders, exporters, and local traders (Chege, 2012).

Farmers are ordered as either small-scale or estates (Coffee Board of Kenya [CBK], 2013). Estates can be small or enormous domains. In a cooperative society, the small-scale producers measure their coffee in a centre area, and all classes deliver coffee to their favourite mill operator for processing. The processed coffee is given by Millers to the marketing specialist, who sells it at the Nairobi coffee trade auction held at Wakulima House. The vendors either bought the coffee at an auction or made it for local consumption. The extended value chain necessitates that the farmer is sufficiently energetic to complete the necessary undertakings at the correct time in the correct manner.

Figure 7

Showing the Coffee Value Chain Actors



Source: (Researcher, 2020)

Coffee Farmers

Kenyan coffee is grown by small-scale farmers or small and large estates. Smallholder coffee farmers have a standard land size of one and a half-acre of land, while the estates have

15 acres for coffee plantations (Stephano, 2010). The smallholder farmers mix coffee with other crops such as beans, maize, potatoes, and vegetables for their family consumption. The harvest by small-scale farmers is about 400 kg/ha. Smallholder farmers' coffee is processed by cooperatives (Ferris et al., 2014). Coffee estates have grown from 2046 in 2018 to 2132 in 2019. Estates can produce more than 1.76 tons/ha (Agriculture and Food Authority, 2019). The number of active coffee growers rose from 2502 in 2018 to 2691 in 2019.

Several variables, including demographic, plot level and institutional variables, are likely to affect the efficiency of smallholder farmers (Alene & Hassan 2003a; Mathijs & Vranken 2001). The demographic variables included in our estimation are age, gender and level of education of household head and number of dependants. Except for the number of dependants, the three variables (age, gender and education) are expected to affect efficiency positively. Age as proxy for farm experience, higher education level and gender (male) is expected to have a positive effect on farm efficiency (Haji 2006; Mathijs & Vranken 2001; Tiwari et al. 2008).

The second groups of variables are Iddir2 and number of crops grown by the farmer. While the effect of Iddir by enhancing households' access to information is expected to be positively related with efficiency, the effect of crop diversity is difficult to hypothesise a priori. Farmers can grow different crops as a hedge against risks that could occur because of natural calamities (Haji 2006) or, alternatively, growing more crops could add managerial complexity and reduce efficiency. Hence, in view of the educational level and managerial capacity of the rural households in our research areas, it is hypothesised that crop diversity is negatively related with efficiency.

Finally, by transferring new skills and information, extension service is expected to affect efficiency positively (Haji 2006; Seyoum et al. 1998). Despite the high number of studies to assess the impact of agricultural extension on productivity in Ethiopia, we could not find a study that had been conducted in the research sites to assess the impact of the new extension service system on farmers' productivity.

Songwlere (2010) conducted a study on effects of exports and export diversification on growth and the policy implications for post-crisis export strategies in India. The study used panel of 30 selected sub-Saharan African countries over the period 1995-2008, we estimate the impact of exports and export diversification on value added, labour productivity, and conditional and unconditional labour demand. The study found out that exports have a positive impact on value added, labour productivity, labour demand and the grower's capabilities to produce coffee of high quality. The study also found out that export diversification of products and markets increase value added and labour productivity, but not labour demand.

Mugweru, (2011), conducted a study on finding out the determinants of coffee production in the Kenyan economy he used a Nerlovian model to estimate supply response of coffee to these determinants and found out that there was appositive relationship between price and coffee 7 outputs, output and rainfall, output and hectare planted and coffee output and price of input. The recommendation was that the government had to intervene by addressing the credit constraints and other factors contributing to a negative change of the above-mentioned determinants so the study give the current study a better understanding of the possible factor which might be a current problem hence contributing to the decline in coffee.

Wangari (2010) conducted a study on factors that contributes to the declining trend of coffee production in Kenya: the case in Nyeri County. The assessment was done using descriptive statistics where OLS model was used to analyse the factors which could be affecting coffee production. The study used primary data collected from the interviewed sample of 30 farmers. The result of the study found out that produce price, growers' capacity, distance to market and visit by extension officers to be the major factors that had significant impact on coffee production. The study offered some recommendation on how the above-mentioned factors could be addressed to enhance a reverse in the coffee production trend.

Karanja (1998) in his study mentioned that in an effort to enhance coffee production, major changes had been introduced into the way. Coffee planters were licensed. In 1996, the minimum acreage required for a farmer to be licensed as a coffee planter was reduced from 10 to 5 acres. That change had resulted in a doubling of the number of small estates (below 20 acres) from 630 in 1994 to over1500 in 2000. Thus, the co-operatives continued to lose a sizeable number of their well-to-do members as that became licensed as planters. That had further lowered the capacity utilization of those coffee-pulping factories owned by co-operatives while creating an increasingly, important group of medium-sized coffee producers. The small estates like other estate farmers were able to process their coffee separately and therefore had more' incentives to improve on their coffee quality unlike smallholder farmers who had to pool their cherry at the co-operative factories.

Cooperatives

A cooperative is a lawful entity formed by individual members or a group of factories (Verhofstadt & Miet, 2015). Cooperatives offer various kinds of assistance to members and are key decision-makers on essential matters (Hasen & Mekonnen, 2017). Additionally, cooperatives lessen transfer fees and information disparity by reinforcing farmers' concession capacity (Trebbin, 2014). Cooperatives in Kenya are controlled by the Coffee Act Chapter 333.

The Act contains the business and command guidelines over manufacturing, advertising, and exporting coffee. The coffee act was amended in 1979 and again in 1999 through exceptional authoritative enhancement. The current Coffee Act has permitted mill operators more control in the tasks and coffee marketing, a capacity recently held in cooperative societies (Ruerd and Guillermo, 2011). Half of the coffee production is through small scales and cooperative societies. The total number of coffee cooperatives in Kenya stood at 559 in 2019, while the affiliated factories were 1065 in the same year (Agriculture and Food Authority [AFA], 2019).

Coffee cooperative societies and other farming operations like dairying make up the District Cooperative Unions. Their primary duty is to assist coffee growers with producing, processing, and selling coffee, although they do not handle it physically. The Cooperative Societies Act allows unions to collect up to 17.05% of farmers' revenues to fund their activities. However, unions have recently expanded away from hiring social personnel and into other fields like banking, resulting in less support for farmers. Because unions are no longer active in settling issues, this trend has resulted in greater conflict within communities (Mude, 2006).

Millions of coffee farmers and coffee trading enterprises lack sufficient credit. This is partly due to myriad challenges and considerable costs that formal lending institutions face serving rural, often isolated markets. It is also often perceived to be the c ase that the inability of coffee farmers and enterprises to manage risk contributes to keeping risk-averse lenders at bay. A better understanding of coffee sector risks is needed to respond with strategies, training, and tools that can help farmers and enterprises, mitigate their exposure to risk and strengthen their resilience against inevitable shocks. Such efforts might also assist in increasing the upstream flow of credit, catalysing new productivity-enhancing investments, and contributing to more profitable and more sustainable livelihoods for coffee farmers (World Bank, 2015).

Since independence, 70 % of Kenyan coffee is produced by smallholder farmers and the rest by estates (Wanzala, Marwa & Nanziri, 2021). These smallholder coffee farmers are alienated from the credit that empowers farmers to obtain the working capital for the cyclical acquisition of production inputs which improves agricultural productivity (Bernards, 2022). This financing challenge arise because financial institutions normally perceive agriculture as a very risky venture and take a position to minimize the exposure of these risks to their firms. This involves credit rationing or imposing tough requirements during smallholder farmers credit appraisal due to informational asymmetries and moral hazard (Stiglitz & Weiss, 1981). With limited options to obtain credit from formal financial institutions, a large number of smallholder farmers fund coffee production using their meagre savings credit obtained from well-wishers (family, relatives and friends), shylocks and self-help groups (Beck & Demirgüç-Kunt, 2008). These funds acquired from informal means are not normally sufficient to sustain long-term agricultural productivity. In response to aforementioned challenge, the Government introduced several initiatives in the past to improve agricultural financing. These included mandating commercial banks to allocate at least 17 % of their loan portfolio to agriculture and the establishment of the Agricultural Finance Corporation (AFC), among others (Wanzala et al., 2022).

Nevertheless, even with these reforms the coffee farmers were still facing difficulty to access credit, suggesting that these lending interventions alone have apparently failed to bridge the gap of financial inclusion so as to progressively enhance coffee productivity and decrease poverty. In 2015, the loan requirements of main agricultural commodities value chains were projected to be US$ 1300 million, but the loan deficit to the agricultural sector was US$ 900 million (FSD Kenya, 2021). Further, the proportion of agricultural credit to total private sector credit was only 4.3 % in 2016 (World Bank (2018). On the other hand, according to Central Bank of Kenya (2019) statistics, agricultural credit was made up of 3.62 % of the total credit in 2018.

Coffee Millers

Coffee millers undertake secondary processing of coffee. The second process transfers coffee from estates and cooperatives to various millers (AFA, 2019). Millers fall under three categories: business, private and small factories. Private mill operators are authorised to deal with their collection, while business mill operators give processing services to different farmers through their cooperatives. Though derivations on the farmers' returns ought not to surpass 4% of the export value as per CBK rules, processing charges fluctuate from one miller to another.

Initially, there were three significant business mill operators: Kofinaf, Thika Coffee Mills, and Kenya Planters Cooperative Union (KPCU). KPCU was the only public miller in Kenya before its collapse. Currently, there are only ten licensed millers in Kenya. They include Thika Coffee Mills, CMS Mills Ltd, Sasini PLC, Kofinanf Ltd, Hema Coffee Mills, Central Kenya Coffee, Meru Country Coffee Miller, NKG Coffee Mills, Kahawa Bora Millers, and Kenya Cooperative Coffee Millers (AFA, 2019).

The number of active millers stood at nineteen in the financial year 2018/19, with over 70% production done by the top four millers. Regional millers handle fewer tonnes of coffee with the least processing, just over a tonne. Some regional millers include Othaya FCS, Gatatha, Tharaka Nithi county coffee millers, Kipkelion, and Rumukia FCS (AFA, 2019).

Before the liberalisation of the coffee subsector, the KPCU had a monopoly on coffee milling. Despite the emergence of other milling firms, KPCU remains dominant due to its previous exclusivity. KPCU is praised for its services directly to farmers, including extension services and finance, as it has easy access to coffee manufacturers through district unions. However, there has not been enough money recovered from loans to farmers, which has hurt KPCU's cash flow and financing capabilities. Although milling costs vary amongst millers, deductions from farmers' income are limited by CBK guidelines to 4% of the export price. Due to this, there are now fewer services offered by millers (Karanja, 2002).

Membership Associations

The Kenya Coffee Producers Association (KCPA), Kenya Coffee Traders Association (KCTA), and Kenya Coffee Producers and Traders Association (KCPTA) are only a few of the membership associations for the coffee industry. To address the concerns of its members, which include all organisations involved in the coffee industry, whether in the fare exchange or its related services, the KCTA was established in 2002. The association's officials showed that the list of current members includes mill operators, advertising professionals, warehouse workers, and suppliers and carriers of coffee equipment. According to Ferris et al. (2014), KCTA had 21 full members and 16 partner members as of June 2011.

Since its founding in 2009, the KCPA has made clear that its main objectives are to advocate for tactical adjustments and support the dissemination of information to farmers (Chege, 2012). KCPTA was founded in 2005, making it relatively new. It follows the 2001 Coffee Act. It sees itself as an intentional organisation that aids members in promoting coffee by selecting the appropriate amount of coffee for each transaction. The Nairobi Coffee Exchange (NCE) also has rules for trade that are set by it. Cooperatives, bequests, brokers, and coffee mill owners make up its membership. The KCPTA's other objective is to define the agreement forms, sales conditions, code of conduct, and other instruments or rules necessary to accomplish its objectives.

CBK has various functions in the coffee industry, including controlling and regulating the industry, providing production services, monitoring processing and marketing, conducting production research, and promoting coffee in export markets. Despite changes in policy towards coffee processing and milling, CBK continues to act as the regulatory agency and controls export marketing through the appointment of coffee brokers and the regulation of their activities.

Coffee Directorate

Coffee Directorate (CD) was initially referred to as the Coffee Board of Kenya. It was set up in 1934, mandated by the coffee Act of 1933. It was given the duty to market and regulate Kenyan coffee. However, the Coffee Act of 1933 was reviewed in 1979, 1999, 2000, and 2001. With different administrative changes having been made to the area since 2002, the CD views its general order as that of policy advancement and permit. Its mission is to offer a conducive environment for the business's development by strengthening partnership, publicity competition, regulation, and value addition via branding to improve farmers' and buyers' satisfaction (AFA, 2019).

Besides managing and controlling the coffee sector, CBK also offers manufacturing services, monitoring, advertisements, research, and promotions. Despite the policy changes in coffee processing, the coffee business's governing agency and controls send out promotion at the bartering market by selecting coffee intermediaries and controlling the coffee merchants and purchasers' undertakings (AFA, 2019).

Coffee Exporters/Dealers

Kenya coffee is exported as green coffee. The exporters get coffee from auctions or other dealers. International brokers such as Volcafe and Neumann Gruppe GMBH, and Cargill buy coffee at the auction. The coffee is sold to them through NCE. The private companies in the NCE include Thika Coffee Mills, Josra Coffee Co Ltd, Diamond Coffee co. Ltd and Africoff Trading Co. Ltd, among others (Chege, 2012). As of 2019, Kenya had 72 licensed coffee exporters, an increase of nine from the previous year (AFA, 2019).

Since small-scale coffee farmers had problems promoting their coffee through the auction system, they looked for a direct market to sell coffee to overseas customers. As a result, Kenya Co-Operative Coffee Exporters (KCCE) was established to address this problem (KCCE, 2014). KCCE is a coffee exporting association set up by Kenya's cooperative sectors to link the small-scale Kenyan coffee makers and the world market through a reliable, more limited, and fair chain supply. The objective of KCCE was to investigate coffee cultivation, milling, and promotion and ways of amplifying their profits.

Typically, intermediaries or traders, often multinational companies, have handled most of their coffee, which has lengthened the value chain and reduced returns for the farmers. KCCE is an organisation created by Kenyan cooperative societies with the aim of establishing a direct and transparent supply chain between smallholder coffee producers in Kenya and international buyers (KCCE, 2014)

Marketing Agents

Almost all the coffee produced in Kenya is sold overseas (World Bank, 2016). The promotion organisations of coffee in Kenya comprise several players known as marketing agents. Their main task is to offer services such as auctions, preparing contract documents, handling, and warehousing (AFA, 2019). Additionally, they offer samples to buyers and assist producers in the auction process. CBK issues distinctive classification of licenses in marketing, such as warehouse license, roaster license, packaging license, auctioneering license (Export Processing Zones Authority [EPZA], 2005). The marketing agents with coffee auction permits are lawfully permitted to participate in the weekly auction (AFA, 2019).

Under the central auction, coffee is purchased through bidding by licensed auctioneers (Ferris et al., 2014). Before the coffee is brought to the sale, the promoter sends coffee samples to the NCE. Once bidding is over, money is paid to the marketing agents who pay the farmers or estates (Ferris et al., 2014). Payment to the farmers first moves to the respective cooperative before being wired to their respective bank accounts. Under the direct sales system, the farmer does negotiations with the buyer residing outside the country. The sales contract must be submitted to the coffee board for signing and approval. The commercial and grower marketing agents are involved in this sales system (Ferris et al., 2014).

Before liberalisation, coffee was sold through a statutory association. It was done so that coffee was pooled from the growers and sold in two separate auctions for the local and overseas markets. The producers were paid a certain amount upon delivery and the rest after successful auctioning. The payment would take up to two years to complete (Ferris et al., 2014). Coffee liberalisation came into effect in the year 1993. Growers were liberated to sell their coffee in whichever form, either locally or abroad. The freedom to register themselves as exporters or suppliers in the global market was allowed (Chege, 2012).

Initially, the government had given licenses to KPCU, Socfinaf Mills, and Thika Coffee Mills. As of 2019, the Kenyan coffee industry had ten commercial marketing agents. They include Classic Coffee Ltd, Meru Country Cooperative Exporters Ltd, Aristocrats Coffee and Tea Exporters, Tropical Farm Management Ltd, and Sustainable Management Services Ltd. Others are Thika Coffee Marketing Ltd, Oakland Coffee Marketing Ltd, Sustainability Coffee Ltd, and Coffee Management Services Ltd (AFA, 2019).

The primary role of KPCU is to organise small-scale coffee farmers in Kenya, but it has been encountering financial challenges due to several factors, including insufficient training for cooperative staff, leadership conflicts in some coffee factories, slow implementation of government reform policies, loss of government protection, political meddling, insufficient legal reforms, sluggish decision-making, prices on the global market, infrastructure issues, bad weather, competition from hawkers and private processors, and high input costs for farming are some of the factors that contribute to this.

Certification

Certification activities for coffee endurance have been in existence for more than two decades (Potts et al., 2014). The coffee industry has the most elevated endurance guidelines among major agricultural items (Bruestle & Deugd, 2010). The different certification plans encourage farmers to know the best way to execute better-cultivating methods, set up conventions for managing ecological and social issues. They help actualise evaluating and third-party affirmation on these issues and communication with buyers about the coffee on the three backbones of manageability toward the end of trade chains (Hoebink et al., 2014).

Certification involves giving honest information to the buyers. It permits the fair-trade association to separate its item. The item separation permits the fair-trade association to market their coffee overseas (Potts et al., 2014). In international trade, certification is incorporated into two models. One of the models predicts an increase in trade between the two countries. Secondly, they reduce the intermediaries' raw materials, increasing income for all the participants (Podhorsky, 2013).

Several certification programmes guide coffee farming in Kenya. One of the programmes is the common code coffee certification or the 4C. The certification aims to create a standardised output. Thus, it focuses on improving coffee quality, reducing farming costs, and uniting the coffee producers. It mainly focuses on large scale producers such as those producing over 20 tonnes of coffee. Another certification for Kenyan coffee is UTZ certified. The programme focuses on improving coffee growers' livelihoods together with their families by improving their living conditions (Voora et al., 2019).

Coffee marketing is also regulated by Fairtrade certified coffee. Kenya is among the 70 countries that are served by the FLO-Cert. The certification allows producers to set a minimum price for their coffee. Additionally, Fairtrade certification offers provision for producers to show whether their coffee is organic or conventional. Rainforest is another global certification requirement that coffee from Kenya must meet. The certification is concerned about the welfare of smallholder farmers. It aims at protecting the rights of the vulnerable in the community, wild lands, and wild animals (Voora et al., 2019).

Kenyan coffee is required to be approved through CAFÉ practices. The certification shows that the coffee meets the social, economic, and environmental standards stipulated by Starbucks. Kenyan firms that give this certification are highlands, Sangana, and SMS (ECOM, 2016). It is mandatory for coffee produced in Kenya to bear the Kenya Bureau of Standards (KEBS) icon. The certification shows that the coffee meets the required standards set by

Kenya's government (ECOM, 2016). KCPA is focused on non-political objectives and aims to provide equitable representation for all lawful entities involved in the coffee industry in Kenya.

Extension Services

The extension services were customarily seen as methods for disseminating innovation from research stations to farmers (Luusaa et al., 2018). Agricultural extension services refer to the various organisations that help farmers in solving problems, acquiring information, skills, and technologies to enhance their livelihoods. These services should lead to noticeable changes in attitude, technology adoption, and an improvement in quality of life, including housing, education, and health. They noted that agricultural extension services play an important role in disseminating innovation to improve crop production.

According to Dinar, Karagiannis and Tzouvelekas (2007), the literature dealing with the impact of extension on the performance of farms has followed two different directions. On the one hand, several studies (e.g., Huffman 1977; Jamison & Moock 1984; Owens, Hoddinott & Kinsey 2003) have been based on the estimation of a production function in which extension service is considered as a separate input, assuming producers are producing on the same production frontier. In this approach, the impact of extension service on farm performance is evaluated through its marginal product and, in a sense, its direct effect on output is captured. On the other hand, by relaxing the full efficiency assumption, extension service has been used as a factor explaining the differences in the technical efficiency levels among groups of farmers rather than as an input in the production function (e.g. Bravo-Ureta & Everson 1994; Seyoum, Battese & Fleming 1998; Young & Deng 1999). Thus, extension service has been included along with other socio-economic and demographic variables as a factor influencing technical efficiency in farming. As such, the impact of extension service on farm production is indirect and may be evaluated through the potential output gain arising from the elimination of technical inefficiency in farming.

Previous research on the impact of agricultural extension service on efficiency in Ethiopia has produced mixed results. An insignificant effect of extension service on efficiency has been found by Alene and Hassan (2003a), Alene and Zeller were carried out in the highland areas of Tigray. Also, Alene and Hassan (2003a) found an insignificant impact of PADETES in two sites in the eastern part of the country. However, when the extension service was captured via a continuous variable (the number of years the farmer participated in extension programmes), its effects on technical efficiency became positive and significant. Yohannes and Garth (1993) reported higher technical efficiencies for extension participants, but lower allocative efficiencies compared with the non-participant group. Haji (2006) estimated determinants of technical efficiencies for smallholders' vegetable-dominated farming system in eastern Ethiopia. The impact of an agricultural extension service on technical efficiency was found to be negative.

It is apparent from observing the coffee-producing areas in Kenya that extension services are available. The services come in the form of training and field days for coffee farmers in the country. Additionally, farmers get information from agricultural shows, magazines, television, radio, newspapers, among others. Information dissemination is done through traditional and participatory learning approaches to small-scale coffee farmers in Kenya. Efforts have therefore been made in Kenya to have more participatory approaches. The participatory approach has mainly been very effective (Luusaa et al., 2018). One of the participatory approaches undertaken by extension services is the Farmer Field School (FFS).

Management agents do extension services. In Kenya, there are only four licensed management agents. They are Thika Coffee Mills, Tropical Farm Management, Coffee Management Services Ltd, and Sustainable Management Services Ltd (AFA, 2019).

Internet of Things

Internet of Things (IoT) management is proposed in Zheng et al. (2016) that screens the components, for example, soil, wind, air, and water over a vast zone. IoT-based farming checking arrangements have been recognised depending on the sub-spaces to which they have a place. IoT worldview improves human cooperation in the actual world through ease of electronic gadgets and correspondence conventions. IoT also screens diverse ecological conditions to make thick and instantaneous maps, air, harming radiation, water contamination, noise, and temperature (Torres-Ruiz et al., 2016).

In order to map soil and yield for precision agriculture, Sonaa et al. (2016)'s study used multispectral imagery from an unmanned aerial vehicle (UAV). To collect soil information and yield heights with useful ground targets, they photographed a test field, a 100 x 200 m patch inside a maize field, using multispectral and multi-transient Ortho mosaics. De Oca et al. (2018) created a low-cost multispectral imaging system for crop monitoring that makes use of a microcontroller, and two cameras mounted on a robot. Infrared radiation is captured by one camera, while ordinary RGB radiation is captured by the other. The system collects data and photos, which are then analysed by software to determine the NDVI and the health of the crops.

Research by Shaobo et al. (2010) proposed a cheap Bluetooth-based design for monitoring different farming factors. Sakthipriya (2014) designed a real-time rice crop checking system to increase efficiency. It gathered precipitation and temperature data. It was meant to alleviate crop loss and improve output. Lee et al. (2017) planned a monitoring design dependent on IoT technology to break down the crops climate and extemporise the dynamic in dissecting the harvest measurements. Nema et al. (2018) examined three-dimensional crop planning and precision calculation employing GIS and wireless sensor. They did unique crop planning utilising satellite Landsat. They completed a Satellite data sorting precision, and the results indicated 87.6% accuracy. Devi and Kumari (2017) with Zigbee conventions' assistance, natural conditions are firmly checked. For saving water halfway, zone root drying measure is executed. CAN, WSN, Zigbee, and so on innovations are used for more harvest yield.

The work of Farooq et al. (2020) established that cloud computing gives an astute and secure stage for examining crops. The cloud design offers modest information stockpiling administrations to the producers, such as pictures, text, recordings, and other farming information, encouraging the farming undertakings by lessening storage expenses (Farooq et al., 2020). Although the cloud system helps the rancher through its high-level strategies, there are still a few constraints because producers face technology misfortunes identified with web network and low influence. Edge computing lessens the computational burden by improving information transmission speed and ensures farming information since preparing in edge processing happens more than cloud computing (Farooq et al., 2020).

IoT and machine learning both feed into each other and create an ecosystem of automation, IoT device collect data on millions of criteria, which is then collected in the cloud, used to train and improve AI algorithms (Garg et al., 2019). ML algorithms in conjunction with sensors can lead to accurate detection of deceases with low cost and with no environmental issues and side effects (Balducci et al., 2018). Recently different methodologies have been used for pest, weed and daises identification and monitoring, which employ image processing and complex algorithms for detection and classification. The existing approaches have covered different areas in improving crop production but they are limited in emerging both IoT and deep learning technics specially in coffee production.

In Rahman et al. (2020) study on identification and recognition of rice diseases and pests using convolutional neural networks, a total of 1426 images of rice diseases and pests from paddy fields were collected in real life scenarios and classified into more than eight classes. Three different training methods have been implemented on two state-of-the-art large CNN architectures and three state-of-the-art small CNN architectures (targeted towards mobile applications) on the rice dataset A new concept of two-stage training derived from the concept of fine-tuning has been introduced which enables the proposed Simple CNN architecture of this work to perform well in real life scenario. In (Fuentes et al., 2017) a robust deep-learning-based detector for real-time tomato diseases and pests' recognition was proposed. Using images captured by different cameras in place by camera devices with various resolutions. The dataset was trained in three main families of detectors: Faster Region-based Convolutional Neural Network (Faster R-CNN), Region-based Fully Convolutional Network (RFCN), and Single Shot Multibox Detector (SSD), which for the purpose of this work are called "deep learning meta-architectures". Each of these combined meta-architectures with "deep feature extractors" such as VGG net and Residual Network (ResNet) for local and global class annotation and data augmentation to increase the accuracy and reduce the number of false positives during training.

In Agnihotri (2019) paper on machine learning based pest identification in paddy plants, Quadcopter(drone) is used to fly above the field for identifying the pests and their density, the quadcopter is with Raspberry pi along with a camera attached at the bottom, that microprocessor will be used for the identifying the pest and storing all information on the cloud. Using the camera big pest like mouse, snake, mongoose, spider, was successfully identified. In identifying small pests like Stem-borer, green leafhopper, Hispa, Mealy Bug. All the living being have some amount of heat in their body which can be identified using a thermal camera and attaching a camera on the Quadcopter resulted in identifying all the available pest in all over the field by just flying the Quadcopter over the field. And support victor machine was used in clustering. In Bhoi et al. (2021) on the IoT assisted Unmanned Aerial Vehicle based artificial intelligence model for rice pest detection., an IoT assisted Unmanned Aerial Vehicle (UAV) based rice pest detection model using Imagga cloud is proposed to identify the pests in the rice during its production in the field. The IoT assisted UAV focuses on artificial intelligence (AI) mechanism and Python programming paradigm for sending the rice pest images to the Imagga cloud and providing the pest information. The Imagga cloud detects the pest by finding the confidence values with the tags. The tag represents the object in that image. The tag with maximum confidence value and beyond threshold is selected as the target tag to identify the pest. If pest is detected then the information is sent to the owner for further actions.

Thorat et al. (2017) studied the IoT based smart solution for leaf disease detection. deployed different sensors in the farm, like soil moisture sensor, temperature humidity sensor and camera for detecting diseases on a leaf. Data was collected from sensors and send it to Raspberry PI through wired or wireless devices. In server-side data is verified and matched with ideal values of data like temperature value, humidity value, and soil moisture value. If difference occurred with respect to predefined threshold value, then notification send to the farmer on his mobile or website. In Kifle (2022), raspberry PI was used to detect and prevent plant disease from spreading. The k means clustering algorithm was used for image analysis.

It has numerous focal points for use in vast harvest ranches and in this way distinguishes indications of sickness naturally at whatever point they show up on plant leaves. In pharmaceutical research, the recognition of leaf ailment is essential and a critical theme for research, because it has the advantages of monitoring crops in the field in the form and thus automatically detects symptoms of disease by image processing using an algorithm clustering k - means.

The effect of CLR in coffee plants is devastating and it can cause a huge economy loss which affects many lives. IoT and ML based precision agriculture is a simple and effective way to monitor coffee leave crops in a real-time, where sensed data is sent to the cloud via Wi-Fi for storage, analysis, and visualization on web-based application and in google cloud platform. The system collects images using a pi camera sensor connected to a raspberry pi, and the raspberry pi sends the data to google cloud and firebase through Wi-Fi. A python script code is written to connect raspberry pi with google cloud and firebase through APi. A model is trained in deep learning algorithm, ResNext and deployed in google cloud platform. The trained model achieved 91% training accuracy and 87% test accuracy (Kifle, 2022).

Sensors

High-level imaging and sensors abilities have given the farmers numerous better approaches to improving harvest and reducing crops' damage (Spoorthi et al., 2017). Carnegie Melon University improved a plant nursery by use of remote sensors technology (Junaid, 2009). Sun et al. (2010) did a study and showed the attainability of using an RTK GPS to depict relocated segment vegetation territory. They used a positive-circumstance crop harvest transplanter containing an RTK GPS beneficiary, plant, propensity, odometry sensors, and an onboard continuous data logger to relocate plotting the field during planting.

Crop Monitoring

Obtaining information on crops helps farmers understand the farm's process and patterns (Zhao et al., 2010). Obtaining such a definite record allows absolute decision making to improve the yield, increase profits and reduce risks. For example, solar radiation information gives data about the plants' sun exposure. The information may help the farmer know whether the plants are appropriately exposed to the sun (Farooq et al., 2020). Getting timely and precise climate prediction information such as climatic changes and precipitation patterns may help improve output. Receiving prior information can also help in the preparation, hence lessen the labour expenses. Farmers can further take remedial and preventive measures ahead of time, dependent on the information given. The pest development information can be gathered and shared with farmers, thus guiding farmers to control pests when they invade (Rubala & Anitha, 2017).

Study conducted by Hunt et al. (2005) checked the nitrogen and biomass status of crops using Digital Photography. He used a model aircraft to attach the remote sensor. The aero plane model captured pictures using an automated camera and shaded canvases. They watched enormous differences in automated numbers for a relative reflectance, which was a consequence of differentiation in the presentation settings picked by the high-level camera. Hunt et al. (2005) also used the Normalized Green–Red Difference Index (NGRDI). They separately linked it to the normalised differentiation of the green and red images. Hunt et al. showed that for dry biomass, soybeans, corn, and horse feed, less than 120 $g{\cdot}m^{-2}$ images corresponded to NGRDI. As per the outcomes, the NGRDI did not increase further for soybean and corn above 120 $g{\cdot}m^{-2}$.

Soil Monitoring

The soil moisture content gives data on the soil's wetness, which can help control soil conditions and decrease plant danger. Sensors help the analysts and agriculturists settle on better choices. With the progression of current technology, climate checking tactics offer additional offices in administration and dynamic. A specially designed avalanche hazard checking design has been built up that permits snappy executions in antagonistic conditions without client intercession (Giorgetti et al., 2016). The more fascinating thing about the design is that it manages hub problems and redesigns the low-quality correspondence that joins the organisation without anyone else.

One of the technologies used to monitor soil is using soil moisture sensors. Sensors help to precisely know the level of wetness on the ground or near the vegetation of interest. The sensors are put near the roots of the crops (Giorgetti et al., 2016). Such sensors additionally help in essentially rationing water. With the help of sensors, water is put in only when it is needed, thus avoiding wastage. When the planned time shows up, the sensor shows the moisture level for a specific location. This allows watering only in that region and not the others. The sensors need the launch time and each area's period (Yong et al., 2018). The study by Vellidis et al. (2008) employed watermark wireless smart sensor for assessing soil temperature and humidity. The design had numerous detectors introduced in a cotton farm. The sensors sent gathered information remotely to a midway found recipient. They introduced a few sensor hubs to describe soil wetness conditions in the area. The outcome demonstrated that the savvy sensor cluster effectively checked soil water pressure as estimated by the Watermark® sensors. The irrigation planning procedure brought about many higher soil water strains at 0.4 and 0.6m deepness.

Several sensors were employed by Lailhacar and Duke (2010) on plots with essential Bermuda grass. The sensors were from manufacturers such as Water Watcher, Rain Bird, Acclima, and Irrometer. They were covered at 7–10 cm deepness. A scaled ECH2O test was fitted in all plots to screen volumetric soil water content ceaselessly at a similar deepness. The ECH2O readings were compared with volumetric soil water content detected by the soil humidity sensors. Significant relationships were established for the three Acclima RS500 (AC) designs, and two of the three designs of Irrometer Watermark 200SS/WEM (IM) and RainBird MS-100 (RB).

Research work by Wang et al. (2010) introduced a remote sensor network which were various levelled to quantify soil-related components like mugginess, temperature and so forth. In their proposed plot, sensor hubs are put underground for gathering all the fundamental soil estimations. Such hubs will have radios to move those estimation values to the hubs present over the ground level. Such hubs are named hand-off hubs that will move the information to a base hub's workstation. The design likewise uses a correspondence convention to give a low obligation cycle and gives a long-lifetime application. In China, Xiao et al. (2013) produced a wireless, coordinated, recurrence area soil wetness sensor for paddy field applications. The soil sensor could quantify soil wetness substance and water deepness simultaneously.

Irrigation

Research by Haefke et al. (2011) developed a smart sensory platform for checking diverse natural conditions, for example, stickiness, sunshine, temperature, and weight. The design gave a quick information rate, minimal effort equipment, and an exact sensor chipping away at network organisation so every hub can speak with one another adequately. Pavithra and Srinath (2014) in his study developed a GSM-based irrigation design utilising an android application for estimating diverse ecological conditions, such as temperature, humidity, and control of the water level. The fundamental motivation behind this design was to build up a minimal effort remote design. The design's negative feature was to realise the working order to activate the field engine and agriculture boundaries.

To create a design with decreased asset utilisation and increased output, Kumar (2014) investigated the various irrigation systems. Devices like a richness metre and a PH metre are placed up on the field to determine the soil's readiness by determining the concentration of its vital nutrients, such as potassium, phosphorus, and nitrogen. Remote technology is used to remotely plant programmed plant irrigators for trickle irrigation on the field. This method ensures that the soil is mature and that water resources are used efficiently.

Besides, Bartlett et al. (2015) made an online evapotranspiration-based irrigation booking apparatus called Water Irrigation Scheduling for Efficient Application (WISE). It utilised the soil water balance strategy and information inquiries. A cell phone application was built up that permits a client to rapidly see their soil wetness shortfall, climate estimations, and the capacity to enter applied irrigation sums into WISE. It assisted and activated required client communication with the product interface.

Research by Gondchawar and Kawitkar (2018) recommend a keenly controlled smart irrigation strategy with dynamic scholarly capacity in the gathered field information. It additionally collects temperature and warmth upkeep for stockroom through ZigBee modules, actuators, raspberry pi. Nandurkar, et al. (2019) proposed a design that will build the plantation’s productivity by giving the right water quantity. Their core aim was to plan a cost-productive remote sensor strategy to handle the wetness and temperature factors in the systems administration climate.

Robots

Robotics has played a considerable part in farming and its management. Robots' key reason was supplanting human labour and producing successful profits on little and big productions as noted by (Manivannan & Priyadharshini, 2016). Robots perform different farm activities, for example, weeding, guarding the ranches, irrigation, conveying viable reports, and guaranteeing against unfavourable natural conditions. A computerised model can also decide the places to put seeds, thus offering high exactness placement. The status of the improvement of the plant can be recorded via mechanised machines. Different biosensors are also set up to screen the plant development in addition to identifying crop diseases.

Irrigation

The work of Shekhar et al. (2017) created a Machine-to-Machine technology to facilitate the cloud through the entire organisation between all the farming field hubs. They built up a robotised automated model to recognise the wetness substance and temperature of the Arduino and Raspberry pi3. The information is detected at customary stretches and is shipped off the microcontroller of Arduino, which converts analogue data to digital. Raspberry pi3 received the signal, and it imparts the sign to Arduino to begin the water hotspot for irrigation. The asset supplies the water as per the prerequisite, and it refreshes and stores the sensor values. Smart irrigation technology is created to expand the output without introducing immense labour. It is done by identifying the degree of water, soil temperature, nutrient level, and weather prediction. The microcontroller performs the activation by turning ON/OFF the irrigator siphon.

The study by Speelman et al. (2007) examined small-scale irrigation projects in South Africa's North-West Province and identified factors that influence the efficient usage of water. The study employed DEA methodologies to analyse farm-level TE and sub-vector efficiencies for water consumption. The results revealed that small-scale irrigation projects have a significant role in rural development. However, water charges and increased strain on water supplies have raised concerns about effective water utilisation. The study found significant technical inefficiencies in water consumption, with a considerable influence on water sub-vector efficiency. The study's findings suggest that improving TE in water consumption is essential to maximise the benefits of small-scale irrigation projects in rural development.

To ensure effective water use, Varatharajalu and Ramprabu (2018) presented an automated irrigation system that makes use of a variety of sensors to track the temperature, pressure, and moisture content of the soil. Through a wireless network such as Zigbee or a hotspot, the data gathered by these sensors is transmitted to a multiplexer. In a similar vein, Savitha and UmaMaheshwari (2018) developed a remote sensor system using Arduino technology that could increase crop output by as much as 40%. To cut down on manpower and the amount of time needed for irrigation, Jha et al. (2019) also created an automated irrigation system utilising Arduino. To measure greenhouse characteristics like temperature, Dinesh and Saravanan (2011) suggested a system that used the Global System for Mobile Communications (GSM) and Field Programmable Gate Array (FPGA). The system provides timely monitoring solutions for soil conditions and crop yield. Additionally, researchers have developed various sensors such as soil wetness and rainfall sensors that are connected to remote broadband networks and powered by solar panels. These sensors send Short Message Service (SMS) messages to farmers about the soil's moisture content and allow farmers to turn the water supply on or off using SMS commands.

Weeding

Weeds are detrimental to the growth of plants, and therefore, their removal from fields is essential. Zimdahl (2010) found that plants' competition for water starts when their roots overlap to absorb water and nutrients, and weeds are the strongest competitors for water. Before developing an automated weed control system, Chang and Lin (2018) suggested separating the crop seedlings from the weeds. Various techniques have been developed for weed detection, including vision-based weed recognition technology, morphological characteristics measurement, and advanced imaging using a self-organising neural network. Aitkenhead et al. (2003) developed a method for discriminating between carrot seedlings and ryegrass using leaf shape measurement, while Nakai and Yamada (2014) used farming robots to suppress weeds and control the robot's position in uneven fields. Åstrand and Baerveldt (2002) presented a mechanical weed control system with black level vision and color-based vision, which was used to differentiate between weeds and crops.

Drones

Drones or UAVs are automated aircraft that are controlled from a distance. They are developed with an assumption to compensate for the pilot's absence (Spoorthi et al., 2017). UAVs work in conjunction with Global Positioning System (GPS) and are mounted with sensors and microcontrollers (Mogli and Deepak, 2018). They are usually employed for practical motives do take infrequent flights. The drones have sensors attached to them with trailblazing cameras being the customer's eyes on the ground (Farooq et al., 2020). Farmers use

Drones to monitor crops, for irrigation purposes, disaster management and spraying (Ahirwar et al., 2019). Drones help farmers augment their harvest by identifying issues early and dealing with the yields by utilising explicit cameras to recognise vermin and water deficiencies (Reinecke & Prinsloo, 2017).

Spraying

Drones had been used as substance sprayers by producers in different years. They are considered successful and critical in the circumstances of a dark atmosphere. They have tackled detachment to a field of tall crops (Simelli & Tsagaris, 2015). The sprayer disintegrates the splashed fluid, potentially a suspension, an emulsion into little drops and dispatches it with the outside force for coursing it properly (Nørremark et al., 2008). It is also accountable for pesticide measures to keep an essential separation from the extraordinary application. Extreme utilisation of pesticides may show wasteful or unsafe to the earth to the yield. The buildup meanings of pesticides are scattered with the help of dusters. Sprayers are organised depending on how they are powered, i.e., centrifugal, kinetic, hydraulic, and gaseous (Jannoura et al., 2015).

In addition, Zhu et al. (2010) built up a Pulse Width Modulation (PWM) Precision Spraying Controller for UAV. They showed how a PWM regulator for UAV precision sprayer uses a TL494 fixed-repeat beat width modulator. It was programmed to obtain information from the board. Since a UAV automated or controlled remotely, the system could do high precision spraying when fed with the right data. To achieve a controlled hover for agricultural purposes, Kale et al. (2015) employed drones to spray chemicals on the crop. Drones and Wireless Sensor Network (WSN), which managed applying the herbicide and pesticide mixtures, were used. The information retrieved from these remote sensors enabled constrained drones to spray poisons into the designated areas.

Huang and Reddy (2015) developed a low volume sprayer for a drone with a maximum load of 22.7 kg and a standard rotor distance of 3m. Developing UAV applications in agriculture with higher yields, a higher objective rate, and a larger Volume Median Diameter (VMD) bead size is possible thanks to the system's encouraging performance.

Zhang et al. (2015) assessed the M-18B and Thrush 510G planes' powerful area breadth and bead flow of aerial spraying systems. The study discovered that the breadth of the spraying area for agricultural planes is influenced by flight height. A UAV-based customised spraying system was created by Xue et al. (2016) using a super low power MSP430 single-chip microcontroller with a free functional module for spraying at chosen fields. The consistency of the spraying was better than the standard benchmark for ultralow volume spraying.

Trackers

Tracking and tracing the farming item tie permits the buyer to know the item's history. It thus improves the customer's trust in the item security and health-related issues. While tracking can detect, gather, and store information identified with the inventory network from upstream to downstream, tracing permits the item to be recognised from downstream to upstream. Tracking and tracing permit a few pieces of information to be gathered along with the inventory network. The buyer and different shareholders are assured on the starting point, position, and life history of an item (Huang & Liu, 2014).

A few components that can be followed are the prevailing climate, production conditions, bug factors, management factors, stockpiling conditions, transportation, and advertisement issues. These elements can likewise present an immediate or potential risk to customers' health. The critical components which influence the developing climate are the soil, air, and water. The produce conditions are impacted using herbicides, manures, pesticides. Farming items can commonly be influenced by bothers along the complete cycle, influencing the item's amount and nature. Tracking the items can improve the production and supply chain network (Olakunle et al., 2018).

A tracking and tracing design ought to include data input, stockpiling, move, cycle, and yield. The info data incorporates the item's complete life pattern, the topographical starting point, the current position, objective, and the partners engaged with the complete production network (Olakunle et al., 2018). The designs ought to likewise incorporate memory to store the data over a period for innovative work purposes. The data move alludes to the way toward bringing together and normalising the complete data.

The tracking and tracing design should likewise handle the information gathered and yield it to everybody required, along with the production network. It featured Radio-Frequency Identification (RFID) utilisation in tracking from the production stage, preparing, transportation, stockpiling, dispersion, and management. It gives the capacity to gather, store, and break down information over a long distance at a fast speed (Olakunle et al., 2018).

Technology Use Between Young Coffee and Post-youth Coffee Farmers

Technology adoption and serious coffee producers are the best answer to counter environmental changes (Sarirahayu & Aprianingsih, 2018). Availability of farming innovation is a significant task in expanding adoption rates. Acquisition of farming technology by farmers helps in increasing their adoption. Administration assistance from planting to post-gather preparing, new land clearing, and restoring old and non-yielding coffee trees kick starts improvement. To adequately change cultivating practices, a more escalated approach is supported. By embracing current technology, coffee producers can build their efficiency.

Technology adoption can be perceived as three stages: awareness, try-out, and adoption. Each stage presents difficulties for producers. Awareness is restricted by variables, for example, farmers' versatility and information access and availability of extension services. The try-out stage is restricted by availability and authority over the land, water, work, inputs, and different resources needed to utilise the technology (Johnson et al., 2016). Capital or credit needed to invest in a particular technology impacts the try-out stage (Ragasa et al., 2014). Cultural acceptability, design and suitability of either gender also play a significant role in the try-out of technology (Hunecke et al., 2017). The adoption phase is affected by all the above factors. According to Lambrecht et al. (2014), farmers’ experience in a particular technology determines whether it gets to the adoption phase.

Transition to specialty coffee production demands a programmed approach. Specialty coffee is lucrative and offers a ready market through direct sales (Bro & Clay., 2017). Technology adoption in areas of seeds (cultivars), fertilisers, use of agro-equipment’s, pruning, harvesting, post-harvesting, and marketing impact positively on the coffee farmer earnings and TE (Bro & Clay., 2017; Lin et al., 2017; Thompson et al., 2019). According to Lin et al., (2017), e-agriculture database under blockchain technology leads to origin traceability of specialty coffee. Payment traceability has eased up and new channels of marketing have opened. A study on Indonesian coffee farmers concluded that embracing disease control techniques such as spacing, pruning, and fair-trade certification led to improved incomes because of technological transformation (Sarirahayu & Aprianingsih 2018). Besides, precision agriculture using the flexible rate fertiliser resulted in costs trade-off and more yield (Thompson et al., 2019).

Association Between Agency Networks, Technology Use, Farm Size and Productivity Among Coffee Farmers

Technology can enhance productivity, accelerate economic growth, enable knowledge and information sharing and increase access to basic services. Disruptive technologies in agriculture, such as use of Internet, can help reduce inequality by making information available to all farmers. They are, therefore, able to have information about market prices for their farm output and farm inputs. Technologies in agriculture consist of digital and technical innovations that enable farmers and agribusiness entrepreneurs to leap from current methods to increase their productivity, efficiency, and competitiveness, thereby facilitating access to markets, improving nutritional outcomes, and enhancing resilience to climate change, while contributing to sustained economic growth. Agri-tech solutions range from mobile phone apps to solar applications, portable agriculture devices, and bio-fortified foods (Kim et al., 2020). Other examples include IoT, which simplifies the work of farmers in the agriculture sector. Sensors are used to gather data on the soil content, rainfall, humidity, temperature, and other factors that enable automation of farming techniques. Satellite imagery helps in the early detection of seasonal problems in the farms such as presence of pests and diseases and nutrient deficiencies. The presence of this information enables farmers address their crops to ensure high yields. Big data and Artificial Intelligence (AI) are being used to reach the needy people during emergencies such as COVID-19 pandemic. Geographical positioning system (GPS) technology helps farmers to accurately locate specific area in the field where they can monitor crop conditions and collect soil samples for laboratory analysis.

The agriculture sector faces such challenges as inadequate ICT literacy skills, which hinder uptake of disruptive technologies, inadequate ICT infrastructure, unreliable supply of electricity, and poor network coverage (World Bank, 2020). Cutting across regions, disparities in Internet access characterized by low network coverage across the country, prevalent poverty levels, reduced household income in the face of the pandemic have led to disparities in utilization of disruptive technologies. Various sectors such as ICT and finance have produced competitive and innovative strategies in search of favourable competitive positions in the agriculture sector and industries to adapt to the changes.

Several researchers have shown that technology adoption improves the efficiency of farms. Alene and Zeller (2005) concluded that crop production in farming improved by 21% when the appropriate technology was adopted. The study indicated that the TE of 79% was realised through the adoption of the right technology. Similarly, Anang et al. (2020) advised that the TE of maize production in Ghana was improved by the adoption of the right varieties of the crop.

In Ethiopia, Misganaw et al. (2015) investigated the influence of coffee technologies. The study noticed an increase in agricultural management technologies in the area. The study's findings showed that the farmers' overall livelihood had improved in terms of increased savings and better education for their children. In studying the TE in maize production, Geffersa et al. (2019) argued that it was important for farmers to consider the maize varieties before imposing technology. Thus, efficiency in farming was not necessarily based on the technology adopted but rather on which type of crop.

Table 5

Technology Adoption in Coffee Farming

Technology	Types of technology design	Areas	Status checked
Internet of things	UAV multispectral	Crop monitoring	Vegetation
	Bluetooth-based design		Temperature, Field information, Rainfall
	WSN-based polyhouse		Temperature, Humidity Carbon dioxide, Harvest
	Satellite Landsat		Crop planning
	Cloud computing		Crop monitoring
Sensors	Digital Photography	Crop monitoring	Nitrogen and Biomass status
	Normalized Green–Red Difference Index		Biomass status
	Watermark® sensors	Soil monitoring	Temperature, Humidity
	ECH2O test		Water content
	Zigbee based smart sensing	Irrigation	Sunshine, Temperature
	GSM-based irrigation design		Humidity, Temperature, Water regulation
	PH meter		Nitrogen level, Phosphorous, Potassium
	Water Irrigation Scheduling for Efficient Application	Soil monitoring	Humidity
Robots	Machine-to-Machine technology	Irrigation	Warmth, Humidity, Temperature
	FPGA based real time monitoring system		Humidity
	Wireless Irrigati on System via Phone Call and SMS		Humidity
	Laser Range Fielder (LRF)	Weeding	Weeds
	Computer vision-based weeding		Weeds
	Weed Suppression Robot		Weeds
Drones	Unmanned aerial vehicles	Spraying	Pests, weeds
	Pulse Width Modulation (PWM) Precision Spraying Controller		Pests, weeds
Trackers	RFID	Information gathering	Weather, Transportation Harvesting

Mebruta et al (2017) conducted a study in Ethiopia with 337 smallholder coffee growers using multistage stratified random sampling. They used Triradiate probit econometric modelling with GHK Simulated Maximum Likelihood Estimation to investigate the factors that determine smallholder growers' Transactional Arrangements for Coffee (TAC). The study found that several factors such as human asset specificity, trust, years of experience in coffee production, coffee to total land ratio, uniformity of ripeness of coffee cherry within a basket, and TE scores are significant and negatively correlated with the primary market type of TAC.

However, educational status and searching information before sale are positive and significantly correlated with the primary market type of TAC. The study also found that human asset specificity, connectedness of transactions, uncertainty of coffee prices, and trust are factors that are significant and positively correlated with smallholder coffee growers' choice of bilateral contract type of TAC. The study further revealed that uncertainty of coffee prices, trust, connectedness of transactions, number of trainings in coffee quality, and TE scores are significant and positively correlated with smallholder coffee growers' choice of cooperative type of TAC. The study provides empirical evidence to the transaction cost theory and highlights smallholder coffee growers' level of TE as a determinant attribute that is worth considering in analysing coffee TACs in less developed countries such as Ethiopia.

Kamau et al. (2017) investigated the drivers of TE in Murang'a County, Kenya's main coffee-growing area. They calculated TE metrics using a non-parametric DEA model. The investigation discovered that the mean TE in coffee growing was fifty-four percent, and it highlighted farm size, coffee variety, availability to financing, farmers' age, and household size as key factors of TE. According to the research, adopting enhanced coffee types, particularly by young farmers, and boosting access to credit facilities will assist farmers in purchasing market resources for coffee enterprises, eventually enhancing TE and coffee output.

Influence of Size of the Farm on Productivity

The successful cultivation of coffee requires farmers to maintain an intricate balance of potent factors that affect the quality of and quantity of their harvest. Several scholars agree that most of the factors affecting coffee productivity are unpredictable and uncontrollable. However, there are a few manageable factors that can be adjusted including the size of the farm. Ngeywo et al. (2015) uncover a positive correlation between farm size and coffee production as farmers with larger farms are more likely to experience a richer yield and harvest as compared to their small-scale counterparts. The manifestation of the farm size phenomenon in the coffee productivity is not straight forward. They conceded that the size of the farm does not necessarily influence the magnitude of production. For instance, Mango et al. (2015) indicated that TE was a more potent factor in depicting productivity as compared to farm size. Even though the study focuses on maize production, it yields relevant insights into the relationship between productivity and farm size.

Ngonga and Hong, (2021) conducted a study in Rwanda to examine the correlation between farm size and TE in maize production. As the level of TE in sub-Saharan Africa farms can differ significantly, with some being fully efficient and others being inefficient, the traditional stochastic frontier method is not adequate. The authors utilised a zero-inefficiency stochastic frontier method to investigate the TE of maize farms in Rwanda. According to the study, the average TE of maize farms was 0.64, suggesting a 36% increase in maize yield without increasing the number of agricultural inputs utilised. According to the statistics, there is a positive correlation between farm size and technological efficiency in the production of maize, highlighting the necessity of enacting land reforms like land consolidation to promote overall productivity growth. Other major and beneficial factors influencing TE included education level, cooperative participation, extension services, credit, income, land tenure, and livestock ownership.

Most notably, incontrollable factors like the weather, crop diseases, and market forces surrounding the availability of the inputs of cultivating coffee can and often affect the productivity of farms regardless of their sizes. Hailemaraim (2015) dig deeper to demonstrate specific theme in other potent factors that necessitate a farm size to be an influential force behind coffee production. The researchers argue that farm sizes have a strong relationship with the professionalness of the farming mechanisms used with smaller farms being technically deficient while larger farms possess a higher degree of prowess in implementing astute coffee rearing techniques. Ultimately, the economies of scale and the enhanced technical capacity of larger coffee farms increase the crop's production. Dorcey (1999) also supported this view by noting that small scale farmers fail to produce higher amounts of this crop because they lack the technical capability to attain optimal operational efficiency in their farms, an element that is essential to coffee production. According to the CD (2019), the number of coffee growers in the country at the end of the 2018/19 season was 2,691. The number of coffee growers in the country continues to increase, an element that is evidenced by the extra 154 licenses to coffee producers in the country.

The same trend is also echoed in Carsan et al. (2013)'s study, whereby more scientific evidence regarding the influence of farm size on coffee productivity is demonstrated. Carsan et al. (2013) examined the effect that a farm size has on the production of coffee from a different perspective. Earlier on, Dorcey (1999) had argued that small scale farmers are less likely to produce a higher amount of coffee when pitted against their large-scale counterparts from an equal parcel of land largely because the lack the technical knowhow to get the most out of their small pieces. On the other hand, Carsan et al. (2013) contend that large coffee farms were able to get the most out of the available plants because they utilise the soil and its nutrients more mindfully. They further clarify that small farmers have a higher level of farm usage intensity, whereby a small parcel of land becomes inhabited with different types of crops in an effort by small-scale farmers to increase the economic yield of the small arable space that is available to them.

On the contrary, the intensity of land usage demonstrated in larger farms is more lenient to the sustainability of coffee crops. It indicates that larger coffee farms not only have the technical prowess to enhance the productivity of their crops, but they also accommodate useful farming techniques that immensely contribute towards the optimisation of their yield. The scholarly evaluation on how the size of a coffee farm affects the productivity of the plants it hosts has taken a different turn over the past few years (ICO, 2019). As the issue of global warming and environmental pollution gains traction in the coffee industry, some researchers are arguing that a large coffee farm may fail to get a more yield from its plants as compared to small farms.

Maina et al. (2016) indicate that large farms are associated with more incidents of environmental pollution as compared to smaller farms. They present a case that large coffee farms often have a commercial miller on site or within their vicinity. These commercial millers have been documented to emit toxic greenhouse gases that are not conducive for both human and coffee crops' consumption. However, Zeng et al. (2018) believed that farm size does not necessarily indicate increased operational efficiency because even though there is a positive correlation between farm size and productivity, there are other factors that influence the yield other than the size of the farm.

As a result, Maina et al. (2016) argue that larger coffee farms are more likely to attain less yield as compared to smaller farms because they are often more intoxicated with the affluents, and toxic gases released by millers located within them or nearby. Maina et al. (2016) indicate that one kilogram of fresh Arabica coffee cherries diminishes with the emission of 0.05 kg of CO_2 emissions for high producers. On the same note, 0.54 kgs of CO_2 emissions led to a 1 kg reduction in the coffee cherries produced by medium producers. The study concluded that the processing of coffee cherries within their site of production negatively affects the environment because it leads to the release of toxic waste, which eventually damages the fertility of the farm. This notion may form a basis to form a counterargument against the insinuation that large farms are associated with higher levels of coffee production as compared to smaller farms.

Subsistence Versus Commercial Cash Cropping

Subsistence farming involves farmers practicing agricultural activities with the aim of sustaining themselves and their families. Land area for subsistence farming is small in most cases less than 2 hectares (Hancock et al., 2003) with traditional methods cultivation (unorganised). Produces are mainly for consumption (subsistence) and there is little or no surplus. Most subsistence farmers have other occupations that generate income for their family usually in the informal sector as postulated by (Rapsomanikis, 2015). Family members are the main source of labourers on these farms. Subsistence farming is often characterised by minimal capital outlay, lack of modernised or mechanised farming practice and lack of access to market for sell their surplus produces as noted by (Khalil, 2017).

On the other hand, Commercial farming involves the growing of crops or rearing animals with the aim of selling and earning a profit. In Kenya, commercial farming accounts for 67% of employment, and is equivalent of 24% of the Gross Domestic Product (GDP) and attributes to 65% of foreign export (Kanyua et al, 2015). Unlike subsistence farming, the commercial farming sector is much organised with government playing a greater role in empowering farmers to boost productivity for food security and export market. One of the major roles that government plays is in research where they have various government mandated organisations that provide farmers with information and emerging issues relating to agriculture. One such organisation is The Kenya Agricultural Research Institute (KARI) which is tasked with conducting research in food crops, horticulture, and animal rearing, land, and water management. KARI advances agricultural research, innovation, and information to enhance productivity and food security (Miruka et al, 2012).

Food security is one of the Sustainable Development Goals (SDGs), but with unreliable and unpredictable rainfall, farmers must seek other efficient means to boost production and maximise their income from agriculture. Commercial farmers in Kenya have resorted to green-house farming and agricultural farming. The government of Kenya through the National Irrigation Board (NIB) has promoted irrigation activities to help farmers in arid and semi-arid to venture into commercial agriculture. Some of the crops that rely on irrigation include vegetables, coffee, rice, maize, and horticultural produces. As of 2010, 114,600 hectares of land were under irrigation which is only 20% of the potential land that needs irrigation (GoK, 2015). The sprinkle irrigation activities are also undertaken by private companies that practice horticultural activities mainly in flower and fruit farms.

Green house farming is practiced by small-holder farmers who seek to maximise productivity from small tracts of land. Greenhouse farming relies on drip irrigation and helps farmers lower their input cost that includes fertiliser, and pesticides (Czyzyk, 2014). Some of the crops grown in greenhouses include tomatoes, capsicum, watermelon, and fruits. Other farming methods that are used by farmers to increase their yields are Genetically Modified (GM) crops. These are crops that are genetically altered to withstand diseases that may affect cash crops like maize and wheat. Although GM promises great yield and disease resistance, it has not been fully accepted by farmers and agricultural lobbyists because of claims that they have long term side effects to consumers.

In Kenya, some cash crops are prominent in the international market, earning the country billions of shillings in foreign income. Tea is the country's top export accounting for 4% of the country's GDP and 26% of Kenya's export (World Trade Organisation [WTO], 2019). Major tea growing regions are Kericho, Nandi, Limuru and Nyeri. Tea grows mostly in highland regions with cool and wet climates. Coffee accounts to 3.9% of Kenya's exports revenue. The major type of coffee grown is Arabica which is grown in highland regions and Central Kenya.

The Production Produce of Coffee Farmers in Central Kenya

Arable Land in Kenya

Smallholder production systems are heterogeneous in terms of production systems and vulnerable to climate variability, land degradation soil erosion and a decline in soil fertility. This heterogeneity leads to district agro-ecological zones, with unique production techniques, challenges, and opportunities for investment. For example, pastoralism is widely practiced in the Kenyan arid and semi-arid lands, whereas most households practice mixed farming (Hunt et al., 2019). Agricultural production in Kenya is dependent on rainfall, with little irrigated production taking place. The agricultural sector is vulnerable to changing climatic conditions including erratic rainfall patterns, increased temperature, drought, and flood. Over 80% of Kenya's agricultural land is arid and semi-arid, making it vulnerable to variability in climatic conditions. Thus, it is difficult to achieve satisfactory productivity when rainfall patterns become more difficult to predict and very few farmers irrigate their farms. Thus, investment in agricultural production systems requires specific and targeted policies and interventions. Agricultural productivity depends on the adoption of technological factors like irrigation, fertilizers, pesticide use, improved seed, and agricultural mechanization. These factors are vital for enhanced production.

Over the last five years, the yield gap for most crops has been widening, for example, there is an estimated 50% yield gap in maize production and 70% yield gap in legume production. To reduce this yield gap, farmers need to adopt technology in the form of modern farm practices, and input use accounts for 38%, manufactured feeds 22%, crop chemicals 18%, and livestock vaccines and drugs 9%. These are a pointer towards the continuous efforts that the government had made through the fertilizer subsidy programme. However, the gains on this investment are yet to be realized due to various challenges, including weather variability that has resulted in frequent drought and floods episodes, and high pest and disease incidences. Notwithstanding, there are other factors that affect the number of inputs used for production, including production system and technical capabilities.

The farming area (sq. km) in Kenya was estimated to be 276,300 sq. Km in 2016, as per the World Bank assortment of improvement markers, accumulated from formally perceived sources. Kenya - Agricultural land (sq. km) - genuine qualities, recorded information, estimates, and projections were sourced from the World Bank in November of 2020. Rural land alludes to the portion of the land zone that is arable, under perpetual yields, and under lasting fields. Arable land incorporates land characterised by the Food and Agriculture Organisation (FAO) as land under impermanent harvests (twofold edited regions are tallied once), brief knolls for cutting or for the field, land under market or kitchen gardens, and land incidentally neglected. Land deserted because of moving development is prohibited. Land under lasting yields is developed with crops that possess the land for significant stretches and need not be replanted after each season, for example, cocoa, espresso, and elastic. This class incorporates land under blossoming bushes, organic product trees, nut trees, and plants, yet prohibits land under trees developed for wood or lumber. The lasting field is utilised for at least five years for scavenging, including common and developed yields. Bulagi et al. (2019) associate chemical infusion and TE with increased productivity.

Arable land (hectares) in Kenya was accounted for at 5,800,000 ha in 2016, as per the World Bank assortment of improvement pointers, incorporated from authoritatively perceived sources. Kenyan Arable land (hectares) real qualities, recorded information, gauges, and projections were sourced from the World Bank in November of 2020. The farming area is hindered by climate change generally because of the rise in temperatures, unpredictable and unreliable rainfall, and extraordinary climate functions. A few harvests are relied upon to encounter better-developing conditions because of climate change, though others may face adverse weather conditions. For instance, maize yields are probably going to increment in blended downpour took care of calm and tropical good countries by 2050, though the parched and semi-bone-dry grounds are extended to observe a huge decrease in crop yields and domesticated animals' numbers as water assets become progressively scanty.

Climate Conditions Relevant to Coffee Farming

Environmental change is genuine in Kenya, with negative effects on rural areas. Temperature changes have influenced crop potential, a model being low temperatures causing ice in the tea bequests. The domesticated animal's area has atmosphere touchy and dry season has added to animals' horribleness and mortality. The rising temperature would uncover many individuals to dry spell and hunger. Climatic changeability and change have consistently introduced a danger to food security in Kenya through their impact on precipitation, soil dampness, and creation. Unreliable rainfall influences agricultural productivity and food security since most Kenyans live in farmland and depend on agribusiness for its jobs.

Kenya's climatic condition varies from place to place with high temperatures low lying areas and cool temperatures in the highlands. The normal yearly rainfall goes from under 250 mm in dry and semi-semi regions to more prominent than 2,000 mm in highly likely arid areas. The GoK (2016) stated that 580,367 square kilometres which are approximated complete territory, just 12 percent of Kenyan land is seen to be a high potential for cultivating and for animal rearing. Climate change is recognised worldwide as a genuine developmental challenge confronting the agricultural sector and production in general. It is apparent that by 2050 agricultural production should increase by at least 60% to fulfil the high food needs of an ever-expanding population.

Kenya is proud of its volcanic soils, height, rainfall, and pleasant climate, which enable the nation to produce top-notch coffee that is regarded as some of the best on the world. More than 700,000 smallholder growers have been able to find work thanks to the sector, which has also made significant contributions to foreign exchange profits. 32 of the country's total 47 counties, or an estimated 115,570 acres, are home to the production of Kenyan coffee. With over 700,000 smallholder growers and over 3,000 large estates, the nation has a twofold production structure. In the past, coffee was farmed in many regions of Kenya, but in the 1990s, farmers began to face new difficulties, and in particular, coffee died out in some of the more remote regions in the southeast, far north, and west. What's left are eight crucial regions: the Mount Kenya region including Nyeri, Murang'a, Kirinyaga, Embu, and Meru, Kiambu and Machakos to the south, and Nakuru to the west.

Due to its optimal growing climatic conditions, including evenly distributed rainfall, high altitude (1,500–2,000 metres above sea level), mild temperatures, and dark red volcanic soils, Kenya prides itself on producing coffee of the highest quality. The best coffee in Kenya is grown by smallholder farmers who are a part of co-employable social orders and on coffee estates, which are solely managed coffee farms. In total, 115,570ha of land are used for coffee production over 32 counties, with estates accounting for 26,222ha and co-operatives for 88,278ha. Despite a significant increase in coffee production from 109,000 ha in the harvest year of 2012/2013 to 115,570 ha in the crop year of 2018/2019, net coffee revenues have been falling (ICO, 2019). Small-scale coffee farmers face entry obstacles to international business sectors due to factors such export licencing, growing disparity to value addition, poor export volumes, and quality requirements (AFA, 2016). As a result, there are less economic incentives and low profit margins for these farmers.

High production expenses, including those for farm supplies, labour, power, and the control of coffee pests like Coffee Berry Disease and Coffee Leaf Rust, are mostly to blame for the drop in Kenyan coffee production. As a long-term strategy to controlling these diseases, the Kenya Agricultural and Livestock Research Organisation-Coffee Research Institute (KALRO-CRI) has created disease-resistant coffee types. Despite the drop in exports, coffee is still a significant cash crop in Kenya's central highlands and some areas of its western coast, where smallholder farmers cultivate over 70% of the crop in Embu County (GoK, 2013).

Coffee is highly ranked at number 4 in trade profit in Kenya coming just behind after the tourism industry, tea, and horticulture. Despite its high quantities in export, it does not provide enough profits for smallholder coffee farmers to support their livelihood (ICO, 2018). Despite Arabica coffee's high ratings, smallholder coffee farmers are not profiting enough, and production has decreased by 50% over the past 25years. Many initiatives have been enacted to encourage the sustainable production of coffee, such as the expansion of sustainability certification by Non-governmental Organisations (NGOs), but coffee farming is not commonly viewed as a stable way of earning income and younger generations are beginning to abandon family farms to pursue other jobs.

Land Reforms and Coffee Production

The Kenyan political landscape has experienced untypical stability over the past decade. However, key issues remain regarding the conduciveness of the country’s political environment in supporting sustainable economic activities. Land reforms form an integral part of these political issues. Consequently, a significant level of scholarly scrutiny has been channelled towards the issue of land reforms. Thuku and Gachanja (2013) explored how policy reforms have shaped the country’s coffee productivity. The researchers conceded that policy reforms have a huge impact on the production of coffee in the country. The effects that political reforms have on the coffee industry are double-edged as explained by Thuku and Gachanja

(2013). On a positive note, reforms created a conducive operating environment for largescale millers and professional farms. More their indicate that the government eliminated several systemic constraints in the licensing process used to certify commercial millers during the 1990s.

This move led to an increase in the number of commercial coffee millers in the country, a move that enhanced the productivity of the nation's coffee industry. Akumu (2017) on this study that indicated the number of stakeholders with vested interests in the land reformations network are numerous. Land reforms in sub-Saharan Africa are deeply intertwined with political forces, and thus, they are highly unpredictable and often unmanipulable for small farmers (Narh et al., 2016). However, Bassett (2017) on his study indicated that the 2010 constitution brough some much-needed stability in the Kenyan land management and regulation framework. Huggins and Frosina (2017) attested to these developments by highlighting the progressions achieved in the coffee sector whereby various administrative functions are executed through advanced ICT systems.

Youth and Land

According to Ndirangu, Mbogoh and Mbatia (2017), Kenya's coffee is considered one of the finest coffees across the globe. Its popularity is also critical for the economy of the nation, with the coffee sector being the fifth foreign exchange earner after tourism from Kenyans in the diasporas. For several years, coffee has played a significant role in the lives of Kenyans, with the industry supporting the livelihoods of almost sixty percent of the rural population in Kenya. However, currently, the loss of interest from the youth in farming due to lack of land has led to a reduction I the production of coffee to the current 42,000 tonnes per year from 134,00 tonnes in the previous years. It is evident that the youth in Kenya have been restricted to access arable land for framing. The primary reason is that land is seen as a man's asset and the eldest man in the land who is the father does not like to give control or decisions of agriculture to the youth (Oerke et al., 2015). The youth needed access to land so that they could be in a better position to invest in farming, especially in coffee farming, which will boost the economy of the nation. Coffee plants take almost 4 years to bear fruit, so the youth need to commence planting early on in their careers, which will pave the way for them to witness economic returns later in life.

The cultural factors at play in Kenya and other sub-Saharan African countries necessitate that young farmer own coffee farm after significant fragmentation (Balogun & Akinyemi, 2017). According to the report compiled by Oerke et al. (2015), if the youth had similar access to resources such as land like elders in the society, worldwide malnutrition would fall by twelve percent and the output of agriculture would go up by five percent and the GDP of the world would also go up by $29 trillion. Thus, it is imperative for one to note that the youth should not be overlooked in the efforts of trying to bring back the glory of the Kenyan coffee, which has been lost.

The study conducted by Van der Vossen et al. (2015) showed that the production of coffee faces several challenges across the globe, In Kenya, things are not different, as most farmers in the nation are getting to an age where managing a farm in an independent way is becoming a challenging issue and that is an indication that an urgent generational gap has gone up. To loosen the gap, the youth must take up the production of coffee and for that to take place, there is the need for the availability of arable land, which will pave the way for them to enter industry in a smooth way. There is the need for land succession, which is critical for efforts of production to continue across generations. Oerke et al. (2015) show that several producers are not ready to pass on their land to their kids and grandchildren and that leaves them with no land on which they can continue to grow the coffee crop. Additionally, experienced families when it comes to production are not encouraging the youth to take part in coffee farming. Besides, these families are not giving the youth land they can use to take part in farming, which makes them live in the city pursuing white-collar jobs because they think these jobs are paying better, are clean, and that they are more secure compared to taking part in farming (Van der Vossen et al., 2015).

Cultural Inclination on Land

In addition, Murimi et al. (2019) on their study demonstrated that Coffee farming in Kenya has been affected by the issue of cultural inclination to land. In several Kenyan cultures, the eldest men in the family, especially fathers are the ones who are supposed to own land. In such a situation, the youth are not motivated to take part in the farming of coffee due to the lack of land ownership. Due to the inability to own land, they are forced to leave the rural areas and move to towns in search of employment opportunities, which is an indication that the continuation of coffee farming by the next generation is at risk. Oerke et al. (2015) showed that the youth and women produce less coffee compared to men in Kenya and that is not because they less manage their farms, or they are not working hard.

The main reason is that men have access to resources such as land compared to women and that is because of the Kenyan culture. If the youth had the same resources as elder men in the society such as land, they would produce thirty percent more coffee and the country would earn more income from the sale of coffee. Thus, there is the need to change some of the cultural norms regarding land ownership, which will pave the way for the youth to own land and eventually food security would be greatly improved, and the nation would grow richer, not only from an economic perspective but also in terms of education and nutrition. Besides, the cultural inclination to land has brought about youth migration to urban areas and even though the migration is slow, it poses a threat to the production of coffee in terms of quality and quantity in the coming years (Van der Vossen et al., 2015).

In accordance with research carried out by Murimi et al. (2019), an important factor that the agricultural sector of Kenya must learn was that when it tries to modernise the production of coffee and chains of supply in a professional manner, trade and production of coffee can bring about good returns and offer motivation for the youth to stay in rural areas. The biggest problem was the lack of access to land, which has been brought about by cultural beliefs in the nation. If the issue is addressed then it is clear beyond a reasonable doubt that the youth will be the perfect catalyst for change, given their tremendous willingness and propensity to adopt new concepts, ideas, and technology (Van der Vossen et al., 2015).

These issues are all crucial in changing the way coffee production is being perceived and practiced. It is therefore imperative to device new ways of convincing the youth to join the value chain of coffee. In a critical analysis of the several cultures in Kenya, it is evident that most parents do not have a future for the youth when it comes to the production of coffee. These parents do not give them a role in it, even if the youth are present on the farm. Currently, there a no or few youths who own coffee trees or are part of the farming contract schemes. The primary reason here is because traditions and heritage rules prevent families from handing over legal responsibility of the land to the youth, which is likely to interfere with the capability of working on their own land or overseeing their own workers (Oerke et al., 2015). Thus, for coffee production to gain back its glory, these traditions must end.

Land Size and Hypothesis of the Study

This section of the literature review makes contributions to this research's topic since it illuminates how a farm size influences productivity. It also evaluates key themes in this focus area that may amplify or mediate the effects that the size of a coffee farm has on its productivity. The core purpose of this research is to explore how relational agency, technology, and TE manifest in the production of coffee in Kenya. This section contributes to each of these subsections by demonstrating how a farm's size influences these factors. This section also explores how political and legal factors influence access to arable land. It highlights the geographical and climatic factors that overshadow farm size in driving productivity. A more in-depth understanding of the factors influencing productivity of coffee farms is facilitated through this section of the literature review. It also demonstrates how the coffee industry has evolved over the past 5 decades in Kenya. This subtopic builds up on the study research question number 3 and the hypothesis of the study associated with the research question.

Table 6

Land Size and Study Hypothesis

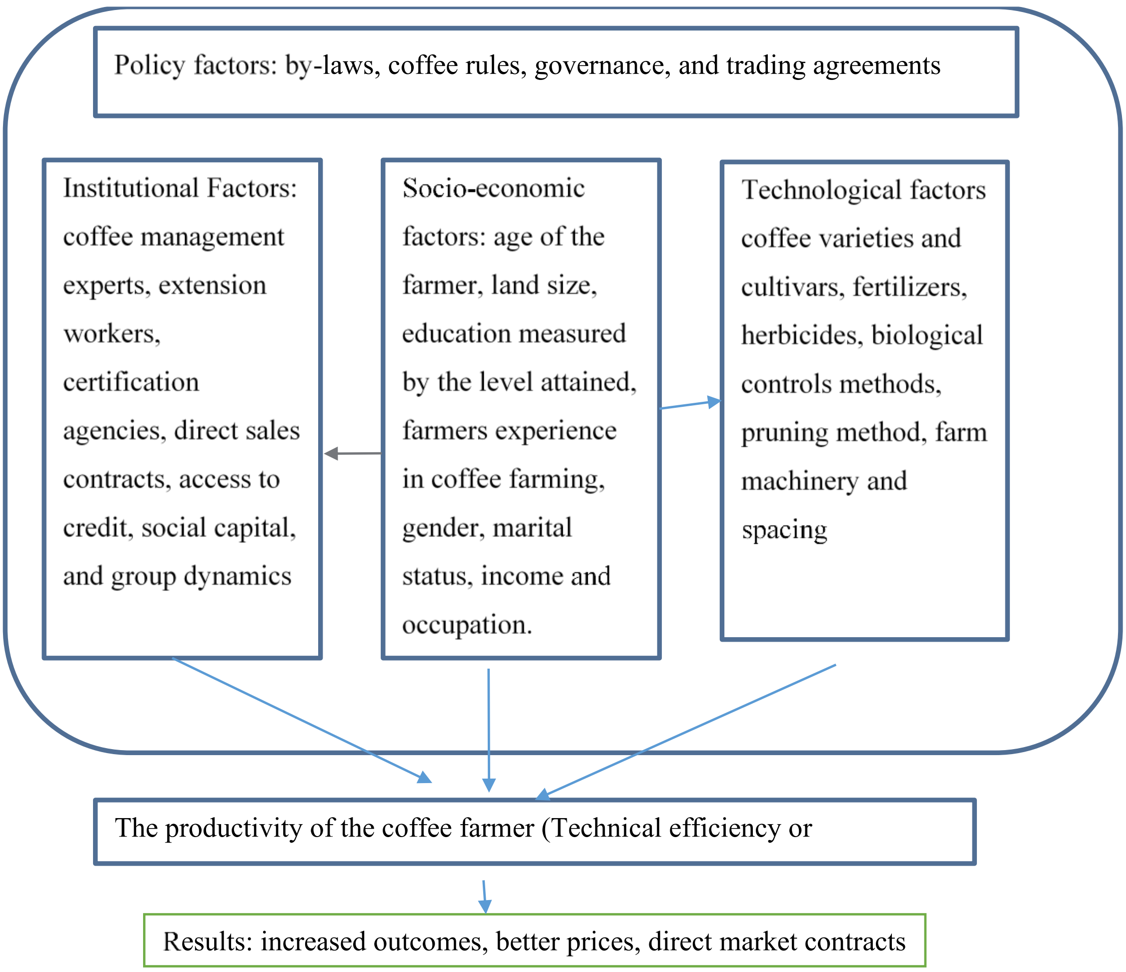
Subtopic theme: influence of farm size	Empirical findings
Technical efficiency and farm size	Low significance; Mango et al. (2015)
Agency usage and productivity	Large estates were found more professional unlike small farms: Ngeywo et al. (2015)
Land resource usage	High intensity in resource management by small coffee farmers unlike the large estates who only grow one crop type; Carsan et al. (2013)

Conceptual Framework

The conceptual framework for the study is a relational table of the various exogenous variables for the research showing diagrammatical relationships of the variables under study (Miles & Huberman, 1994). The conceptual framework is presented by Figure 8.

Figure 8

Conceptual Framework for a Variable in Coffee Farming



The conceptual approach was deduced from the activity theory. It is anchored on three attributes the subject, object, and tool (Cole et al., 2018). This study postulates subjects as the value chain actors in coffee farming; farmers, agro-inputs suppliers, marketing agents, managing agents, coffee buyers, brokers, and the policy actors.

Socio-economic factors include inter alia age of the farmer, land size, education measured by the level attained, farmers experience in coffee farming, gender, marital status, income, and occupation. Institutional factors- Agency network variables include coffee management experts, extension workers, certification agencies, direct sales contracts, access to credit, social capital, membership to cooperative and group dynamics. Technological factors comprise of coffee varieties and cultivars, fertilisers, herbicides, biological controls methods, pruning method and spacing. The action is the object, which is represented by the coffee cultivars adopted, land size, agro-inputs used, membership to certification bodies and social groupings. Whilst the tool is the device that facilitates the activity, in the conceptual framework is explained by the level of technology adopted, agency networks in place, crop husbandry practices in use, family labour employed and productions social-economic power of the object under study.

Moreover, production theory of economics expounds the conceptual framework relationships on how inputs, labour, land, and capital under constant returns to scale relate to producing a certain level of output (Cohen et al., 2019). The social-economic factors; age, level of education, and family size were variables found to be positive influencers of TE (Nyagaka et al., 2010). The large size of the land was also statistically significant in the technology adoption Ngeywo et al. (2015). Other variables identified by way empirical studies were inorganic manure, pesticides, and seedlings (Kamau et al. 2016), size of the family positively contributed to labour input (Parabathina et al. 2017), government regulation in liberalisation (Karanja, 2002).

Policy intervention factors are represented by the statutes, by-laws, coffee rules, governance, and trading agreements for coffee farming as well as the political and economic factors within Kenyan. These factors indirectly affect the productivity of coffee. Where the government offers subsidy on the fertiliser it expected farmers to adopt fertiliser which will influence the quality of the coffee beans harvested.

CHAPTER 3: RESEARCH METHODOLOGY

Introduction

Anchoring on the role the coffee sub-sector plays in poverty alleviation; the study seeks to investigate the nexus of constructed relationships and technology adoption on TE amongst the coffee farming populace. Research objectives shall be to explore the nature and extent of agency relationship that exists in coffee farming, establish the level of adoption of technology, and ascertain the relationship amongst the continuous variables (land, labour, agency networks, technology, and land size) on the TE.

According to the cross-section design technique, the study is quantitative. While all of Kenya's small-scale coffee producers made up the study's population. Both stratified sampling and straightforward random sample techniques were used in this investigation. The researcher will divide the population by county because it is known how many small-scale farmers there are in each county. After determining the overall sample size for each county, simple random sampling was employed to select the respondents for the study. The log-likelihood function was used to do the stochastic frontier analysis on the data. This model is a superior estimator of TE since it includes an error term. Data analysis was done using the statistical package SF cross Stata. To sum up the data, descriptive statistics were utilised data, and inferential statistics tested the null hypothesis of the study.

As previously stated, this chapter outlines the study's approach and methodology for studying the link between relational agency, technology, and TE in Murang’a coffee farming using a stochastic production frontier technique. This study contributed to government and management by an advisory report on best practices to be incorporated in reforms and agency relationships incorporation in coffee farming. Also, there was an enrichment of the production theory by showing the social aspect of synergy in production. Besides, this study filled the gap for the lack of agency relationships study in coffee farming in Kenya.

Research Approach and Design

Research Approach

There are three main research approaches that a study may consider using. They are quantitative, qualitative, and mixed-method approaches (Creswell & Creswell, 2018). The quantitative approach involves the collection of data in numerical means, which can later statistically be analysed. The qualitative approach considers the social aspects of life. It attempts to reveal the deeper meaning of a phenomenon, experience, or human behaviour such as emotion, belief, values, and attitude (Babbie, 2010). The sole purpose of the qualitative approach of research is to uncover human experience and not generalizability, as is the case with the quantitative approach (Creswell & Creswell, 2018).

The mixed method is the combination of both quantitative and qualitative approaches. The two techniques may be used simultaneously or one after the other. Thus, a researcher may have the freedom to incorporate aspects of the above two approaches (Creswell & Creswell, 2018). For instance, a study may opt to collect qualitative data using in-depth interviews followed by focused group discussions. It may then gather quantitative data using structured questionnaires or checklist observations. When analysing the data, qualitative data may be transformed into quantitative and vice versa, although quantitative data is rarely transferable.

In 1998, Seyoum et al. evaluated the TE and productivity of Ethiopian corn farmers by contrasting those who took part in a technological demonstration programme with those who did not. According to the findings, farmers who participated in the programme had a greater mean efficiency of 94% than farmers who did not, who had a mean efficiency of 79%. Most farmers in South Africa operate under constant returns to scale, according to research by Townsend et al. (1998) that looked at the relationship between farm size, return to scale, and production among the country's wine growers. Weir (1999) investigated how education affected farmers' ability to produce grain harvests in rural Ethiopia and found that it had a considerable positive impact on farmer productivity, with a 15% improvement in TE seen as the family's educational attainment rose from 0 to 4 years. In rural Cameroon, Nyemeck (1999) investigated the relationship between various farms and farmer factors.

This study evaluates the relational agency, technology, and TE in Kenyan coffee farming using a stochastic production frontier approach. The nature of the study allows the researcher to use a quantitative approach. One reason for choosing the quantitative approach is because it enhances the comparison of phenomenon or situations since data is presented in numerical form. A person viewing the findings does not need interpretation as the results are precise, for instance, when frequencies or percentages are used (Creswell, 2013). Numerical data on the relational agency, technology, and TE will be obtained. Objective results are produced in a quantitative approach as data are codified and developed using relevant statistical software. The researcher also prefers the quantitative method because of the minimal time consumed conducting it (Muijs, 2010).

The quantitative approach also creates room for generalizability (Singh, 2007). Under this approach, the study uses a representative sample that has similar characteristics to the study population. The outcome obtained is used to explain the general phenomenon touching even the subjects that were not part of the study but bear similar features. Cases of bias are minimal in the quantitative approach as the researcher can have reduced interactions with subjects investigated. Compared to other approaches, the quantitative approach is also thought to be accurate. The approach can also be replicated in other studies in different periods (Babbie, 2010).

The study could not select qualitative or mixed methods approaches due to some shortcomings. A qualitative approach is used when content data is sought. Both qualitative and mixed approaches have a few statistical elements, which are prevalent in this study. In the study, the researcher intends to obtain numerical data such as farm size in hectares, farm experience in years, number of labourers, etc. The cost of irrigation, seed, pesticide, fertiliser, and labour will also be in Kenya shillings, which is also a numerical aspect. The qualitative approach can be time-consuming, mainly when the researcher has targeted a higher number of respondents (Creswell & Creswell, 2018).

Research Design

Creswell (2009) defines research design as the plan or proposal for conducting research. It involves making decisions about the topic to be studied, the population to be included, the research methods to be used, and the purpose of the study (Babbie, 2010). Several research designs exist in the field of research. They are dependent on the approach, whether qualitative, quantitative approach or both. The research designs considered are associated with a quantitative approach. Research design enables the researcher to reasonably address the research problem (Creswell & Creswell, 2018). For the quantitative approach, the design can either be experimental, causal, cross-sectional, or descriptive. Cross-section design has no time dimension and relies on prevailing differences in the study subjects. Data is conducted at a specific time, for instance, in a week, month, or year. The researcher does not interfere with prevailing circumstances but instead collects data as it exists (Hall, 2008). Data collected for a cross-section design is not bound by geographical boundaries and may involve many subjects. The design allows the researcher to use a sample size from the entire population (Bourque, 2004).

The study utilised a cross-section design in collecting data. Primary data from farmers under marketing agents will be collected at a specific period. The unavailability of information on a periodical basis limited the use of the longitudinal design in this study. Farmers are likely to remember or have kept records of the recently incurred expenses and other elements that the present study seeks. The use of the cross-section method is also common in studies closely related to this.

By targeting maize farmers in Zambia et al. (2015) also used cross-section sampling. Their total sample was 160 households using a 2008 survey by the Central Statistical Office (CSO) of Zambia. Mango et al. (2015) also used a cross-section design to study smallholder maize farmers' TE. The study was carried out in Zimbabwe and observed the yield differences for a given technology level and inputs. Another study that made use of cross-section design was Ayele et al. (2019). The study targeted wheat farmers in southern Ethiopia and used a sample of 125 farmers. The data was collected in the production season of 2015/2016. The few research that have been done on the variables that affect TE among smallholder farmers in Kenya have shown consistent findings. Kibaara (2005) noted that factors that boost TE include the adoption of improved seed types, mechanised agriculture, farmer education, farmer gender (male), off-farm income, access to finance, and high agricultural credit. Similar findings were made by Owuor and Ouma (2009) and Nyagaka et al. (2010), with the addition of other variables as social capital and market accessibility. The methodological approaches used in the investigations varied, with one-step approaches used in Kibaara (2005), Owuor and Ouma (2009), and two-step approaches in Nyagaka et al. (2010).

In China, Ruoipon et al. (2020) conducted a face-to-face survey with trained enumerators to investigate apple production in four provinces that collectively produced 67% of China's total apple production in 2018. The researchers selected two regions in each province, one representing the highest-yield apple-producing areas and one representing medium-yield areas. They randomly selected six villages at the county level and ten farmers from each village for a total of 480 participants. The survey asked questions about farmers' cooperative membership and the services provided by cooperatives, with eleven distinct services identified. The study was granted ethical approval by one of the cooperative institutes in 2019.

The major reason behind the use of cross-section design is that it is relatively cheaper to use since the study does not require follow-ups (Bourque, 2004). Data is gathered once on all the variables. In this study, the researcher will collect data on both dependent and independent variables at the same time. In cross-section design, the number of variables can be many but that will not hinder the analysis. Under this study, several variables will be considered. They include input costs such as labour, fertiliser, seed, irrigation, fertiliser. Other factors considered were demographic factors such as education level, marital status, and education.

The current research used questionnaires to gather data from small-scale coffee farmers in Kenya. The reason for choosing questionnaires is because they are a relatively inexpensive, fast, and effective way of gathering large quantities of data from many people (Creswell & Creswell, 2019; Saridakis & Cowling, 2020).

Population and Sample of Research Study

Population

The population is an aggregate or average of all things, subjects, or representatives conforming to a set of requirements. Population refers to the subjects, objects or people that meet the characteristics investigated in the study. The present study is aimed at investigating the relational agency, technology, and technician efficiency of Kenyan coffee farming. The population for this study will be comprised of all small-scale coffee farmers in Kenya. Coffee is grown by about 478,936 small scale farmers (KNBS, 2020). Mt Kenya region accounts for about 60% of the coffee grown in Kenya. The study will therefore concentrate on the five main countries in the Mt Kenya region namely Kiambu, Murang'a, Kirinyaga, Nyeri and Meru.

Table 7

Population of the Household Practicing Coffee Farming

County	Target population
Kiambu	181,400
Murang'a	41,000
Kirinyaga	29,200
Nyeri	29,000
Meru	24,000
Total	304,600

Source: Kenya Population and Housing Census (2019)

Sampling

Sampling is the process of choosing a representative population subset named sample. The sampling process decides the generalizability of test results. Sampling is an important method for study projects since the interest group typically consists of so many people participating in any research experiment (Singh & Masuku, 2014). Two sampling methods are used to determine a study's sample: probability and non-probability sampling.

Probability Sampling

Every member of the population has an equal chance of being surveyed, according to probability. The three main types of probability sampling are stratified sampling, cluster random sampling, and simple random sampling. Simple random sampling is a careless way to choose a sample (Singh & Masuku, 2014). Each member of the population has an equal chance of being picked to participate in the sample. The simplest sampling method is random sampling since it selects samples fairly. Simple random sampling is the most well-known probability sample since every member of the community has an equal chance of being chosen. In comparison to any other sample selection system, the result achieved using this approach still exhibits good external validity or generalizability (Thompson, 2012).

Systematic sampling is a chance sampling technique that randomly chooses the nth respondent in the survey to engage in the analysis (Creswell, 2014). The approach demands full population knowledge. In this sampling process, one unit is picked from the sampling frame, and then measurements are made based on the interval distance. As systematic sampling is a straightforward method, any "nth" participant from an entire list is selected. A mixture of elements has different probabilities in systematic random sampling. One of the benefits of systematic sampling is its flexibility since it allows the researcher to incorporate a method into the random selection process. Additionally, rigorous sampling ensures that each subject in the community has a fair probability of being equally sampled (Kothari, 2012).

Stratified random sampling improves over sequential sampling. In this system, the population components are grouped into strata based on similar characteristics, and a predetermined number of units draws from each of these smaller homogeneous classes. Stratified random sampling may either be proportionate or disproportionate random sampling (Thompson, 2012). When the sample size is proportionate to unit size, it is called proportionate stratified sampling. When not proportionate to unit scale, it is considered disproportionate stratified sampling which relies on individual judgment and ease. Cluster sampling is one of the random sampling techniques in which the population is first separated into clusters and then randomly drawn from the clusters. Clusters should have heterogeneity and homogeneity within clusters (Kothari, 2012). The more homogeneity within clusters, the less error margin or vice versa. Mostly, the technique is feasible with complex populations scattered around various regions.

Non-probability Sampling

Non-probability sampling is used where the researcher has little previous knowledge of the exact population of the sample (Singh & Masuku, 2014). Elements of the population do not have equal chances of being included in the survey. This sampling procedure is considered less costly, less complicated, and easier to implement than its counterpart. Non-probability sampling requires judgment, and participants are chosen for easier access. One of its main drawbacks is that results from this approach neglect generalizability (Daniel, 2012).

Non-probability approaches include convenience sampling, purposeful sampling, quota sampling, snowball sampling (Creswell, 2014). Convenience sampling is a sampling technique that chooses subjects if they like. The researcher chooses the nearest people as respondents. Whoever matches the researcher counts as the sample element. The probability of prejudice in convenience sampling is higher. The conclusions drawn could not be generalizable to the whole community (Thompson, 2012). A general rule is to always use the biggest sample size available. The bigger the sample size, the more representative it would be. Purposive sampling is a form of sampling where the researcher selects the participants according to their own decision by considering the study’s intent (Creswell, 2014). It uses an expert's discretion in choosing cases or chooses cases for a particular reason. This method of sampling is used in an exploratory study. The researcher hardly knows if the selected cases match the community. Since many sampling issues are solved with a clear strategy, most sampling approaches can be called purposeful.

To learn more about the daily activities, care, and information interchange among coffee producer farmers in Sasiga and Limu Woredas in Ethiopia, Temesgen and Furi (2019) conducted a study. They gathered time series data from 200 randomly chosen farmer households, of which 120 were from Sasiga and 80 were from Limu, on purchases, sales, prices, assets, liabilities, credits, repayments, dividends, profits/losses, and defaults. Ten kebeles from 17 coffee-growing kebeles in Sasiga and 5 kebeles from 10 coffee-producing kebeles in Limu were chosen by the researchers using purposive sampling. To ensure fair representation, farmers were chosen at random from each kebele using a random selection technique. Input procurement, irrigation system revenue, financial and economic analysis, employment, labour, and wealth creation were also examined in the study.

Quota sampling is a method of sampling where the researcher pre-plans the number of participants in categories then picks the sample through a set quota (Daniel, 2012). This sampling process may also be categorised into unregulated quota sampling and regulated quota sampling. In unregulated quota sampling, the researcher chooses the sample as they please. Such limits are placed to reduce researcher preference in regulated quota sampling. The researcher in the quota sampling approach chooses available subjects that meet the criterion instantly (Singh & Masuku, 2014). Snowball sampling is necessary where representatives of a specific group are difficult to find (Thompson, 2012). It starts with gathering data from one or more contacts that are typically familiar to the researcher. Afterwards, the data collector requests contact details regarding additional future respondents from the respondent (Daniel, 2012). The prospective respondents are approached, questioned, and subsequently requested to include additional contact information. This method is repeated before the researcher's objective is attained.

This study employed both stratified sampling and simple random sampling methods. Since the number of small-scale farmers in all the counties is known, the researcher will group the population as per county. Once the total sample size of each county is known, simple random sampling will be used in identifying the respondent to take part in the study.

Sample Size

The sample size is a criterion for deciding the number of population items to use in the sample (Creswell, 2013). A sample is a portion of a population chosen for the study. It is a fraction of the total population chosen for the analysis project. Several formulae are used in determining the sample size. When the target population is over 10,000, the sample size obtained should be able to act as a representative without bias. A key feature of sample size models is the measurement of variation in the study's primary variables. It is proposed that researchers use 0.50 as an approximation of the population proportion when calculating the variance of categorical or dichotomous variables.

Two common formulas used in calculating sample sizes for the large population are Krejcie & Morgan (1970) & Cochran (1977) formulae. The value of alpha is assumed to be 0.05 in these formulas, and the degree of precision is assumed to be 0.05. According to Krejcie & Morgan (1970), the demographic variance is calculated by squaring the adopted population proportion. For instance, if the population proportion is set to 0.50, the population variance is reduced to 0.25. According to Cochran (1977), determining the sample size requires determining the limits of the errors in the elements found to be the most important in the study. According to Cochran formulae, a different estimate of the necessary sample size is made for each of the survey's critical items. Thus, the researcher would be able to choose from a variety of sample sizes, including smaller sample sizes for scaled and continuous variables and greater sample sizes for dichotomous categorical variables.

In most behavioural sciences, a significant level of 5% has been identified as a socially appropriate level of trust. According to Krejcie and Morgan (1970), the sample size rises at a decreasing pace as the population grows, gradually remaining stable at slightly more than 380 cases as the population grows. To eliminate errors in inference back to the community, researchers can try to use a large enough sample size when performing survey studies. When calculating the variation of a dichotomous attribute like gender, researchers can use a population proportion of.50 as an approximation of the population proportion. This study utilised Cochran formulae in calculating the sample size.

Equation 1

Cochran formulae

$$n = \frac{Z^2 p(1-p)}{e^2}$$

Where:

n= the minimum size of the return sample needed

z = value for chosen alpha of 0.025, which equals 1.96

p= highest population proportion (0.5 for this study))

q=1 (maximum population proportion possible) = 1 - 0.5 = 0.5

e= the error margin at 95% confidence

As a result, the survey would consist of 384 respondents.

The formula works for continuous variables and categorical variables. The formula helps calculate sample sizes for basic random and systematic random samples. Given the study's use of a formal random sampling technique, Cochran's (1977) formula was deemed suitable for calculating the sample size. The formula makes use of two critical variables. First, the researcher's willingness to consider the danger in the sample is usually referred to as the margin of error. The study sample size will be as shown in table 8.

Table 8

Calculated Sample Size for Coffee Farmers

County	Sample size
Kiambu	229
Murang’a	52
Kirinyaga	37
Nyeri	36
Meru	30
Total	384

Source: Study compilation (Kenya Population and Housing Census, 2019)

Instrumentation of Research Tools

Data may be collected using primary or secondary data collection. Primary tools are used to gather first-hand information, while secondary tools retrieve stored data. Primary data collection instruments include surveys, questionnaires, interview guides, tests, focused group discussions, or observations (Cooper & Schindler 2008). Secondary data collection tools include magazines, newspapers, published journals, government publications, among others. The current research will use questionnaires to gather data from small-scale coffee farmers in Kenya (Creswell & Creswell, 2019).

The reason for choosing questionnaires is because they are a relatively inexpensive, fast, and effective way of gathering large quantities of data from many people (Saridakis & Cowling, 2020). Furthermore, since the researcher is not required to be present when the questionnaires are done, data can be obtained reasonably easily. Questionnaires also help the sides save time. Finally, questionnaires can reach a wider audience. The same questions are asked to all respondents in the same order (Kothari, 2004). This ensures that a questionnaire can be quickly repeated to ensure its consistency. As a result, a second researcher may use the questionnaire to double-check the findings. Since questionnaires provide anonymity, respondents may be honest, leading to more accurate and valid study results. As a result, the chances of a scientist making bias are often reduced.

Questionnaires often employ both open and closed questions, allowing for the collection of quantitative and qualitative data (Creswell & Creswell, 2019). The questionnaire was divided into four sections: section one was about socioeconomic factors, section two was about institutional factors, section three was about technological factors, and section four constitutes production yield. The questions were Multiple-Choice Questions (MCQs), allowing respondents to choose an answer from a list of choices. They are simple to use in various ways, aid in producing easy-to-understand results and offer mutually exclusive options. Respondents have an easier time filling out the survey because the response choices are set. Other questions were generic and required a yes or no response. The rest were left open merely for the respondents to provide a number or digit such as the size of household, age in years, or size of land in acres.

Closed-ended questionnaires were chosen for this analysis because they are cost-effective. They save both time and money. They promote a broad geological spectrum and allow respondents to complete the survey at their rate. As less time is consumed answering close-ended questions, it was much more likely that respondents would complete this type of questionnaire than open questions (Saridakis & Cowling, 2020). A significant sample size can be achieved representing the population and from which, a researcher can extrapolate. The data generated can be quickly translated into numerical data, allowing for the statistical interpretation of the responses.

However, close-ended questionnaires have their disadvantages. The respondents are unable to move beyond the constraints imposed by the decisions. Questionnaires are often used, and poor response rates are often a concern due to "resistance" to them. Another possible stumbling block is that meticulously structured questionnaires can make internal and external examinations incredibly difficult. The respondents' level of schooling often restricts questionnaires. Questionnaires seldom convince respondents to be interested in the research. Nonetheless, the approach used by the researcher determines the response to the instruments. The researcher used his persuasion techniques to ensure as many respondents as possible took part in the study.

Pilot Study

A pilot study is a small-scale test to ensure that participants understand the issues addressed by the research instruments (Andres, 2012). The main study is preceded by a pilot project, which is a condensed form of a larger sample used to prepare the research or to field test the survey to validate the idea. To determine the validity and reliability of the instruments, pre-testing is necessary (Creswell & Creswell, 2019). With a different but related group from a different place, the researcher pilot-tests the tools and makes any necessary adjustments.

A pilot project encourages the researcher to test the study with a small group of people to make changes before the main trial hence saving time and resources (Creswell, 2013). Pilot research is relevant because it allows the researcher to see whether respondents understand the language used in the survey. It ensures that no emotive questions are asked since they can make people defensive and invalidate their responses. It also ensures that no leading questions are used, as these may sway the respondent's answer. It ensures that the instruments used are completed in a reasonable amount of time (Cooper & Schindler 2008).

The researcher conducted a pilot analysis to assess the questionnaires' reliability and validity. It will check whether the question design is rational and if the questions are straightforward to understand. The pilot study helped determine the time respondent’s takes to complete the survey. The researcher might also use the pre-test to see whether the variables gathered could be efficiently processed and evaluated. The questionnaire was adjusted accordingly to suit the respondents in terms of comprehension and time taken.

The pre-testing was done on a 5% subset of the total number of respondents. Since the study targets a total of 384 respondents, a total of 20 small-scale farmers were used in the pilot study. Since the study area is the Mount Kenya region, the respondents for the pilot test were selected from a different location. Nakuru area was to produce the participants for the pilot test. Its selection was because one, it is near the area of study, and two, it produces quite a significant amount of coffee. The pilot study sampled also helped in testing the instruments' reliability and validity.

Validity

Validity refers to the degree to which the data analysis findings accurately represent the phenomena under investigation (Cooper & Schindler 2008). It refers to how well a test instrument tests what it claims to calculate. Validity is a criterion for accuracy and significance. It refers to the precision and relevance of inferences drawn from research findings (Payne & Payne, 2004). Data collection methods must provide information that is both appropriate and correct to the study questions. There are three types of validity: face validity, content validity, and criterion validity (Cooper & Schindler 2008). Face validity refers to how often a calculation system tends to calculate the construct of interest "on the surface." Face validity is a flimsy indicator that a measurement system is calculating what it claims to be measuring. It is founded on people's perceptions about human behaviour (Creswell, 2013).

Content validity is the degree to which an instrument "covers" the idea of interest. A test of people's attitudes toward a construct needs to show all factors to have strong content validity. Content validity, like face validity, is rarely measured quantitatively. Instead, it is evaluated by carefully comparing the calculation process to its logical meaning (Cooper & Schindler 2008). Criterion validity is the degree to which people's scores on a measure are associated with other factors that one would assume them to be correlated with. Criterion validity can be either concurrent or predictive. Concurrent validity is where the criterion is evaluated simultaneously as the construct, while predictive validity is used when the criterion is calculated later.

The researcher sought advice from his supervisor. A visit to the county's agricultural extension officers was instrumental in the accuracy of research instruments. Before data collection, the pre-testing replies given by respondents were examined and used to improve the questionnaires. After the pre-test, any question that was found to be understood differently by multiple respondents were rewritten to have the same interpretation for all respondents. The modifications included changing sentences and query types.

Reliability

Reliability is a metric of how reliable a search instrument's findings or data are after multiple trials (Andres, 2012). When a tool can correctly and continuously calculate a variable and produce the same effects under the same conditions over time, it is considered reliable. Reliability is measured in three ways: test-retest, internal, and inter-rater reliability. Test-retest measures consistency over time. The measure is given to a group of people once, and then it is given to the same group of people again later to establish test-retest reliability. The test-retest correlation is then examined between the two sets of results. The data are graphed in a scatterplot and Pearson's r is calculated. A test-retest correlation of +.80 or higher is generally known to show good reliability (Creswell, 2013). Test-retest is usually recommended for studies whose variables investigated are stable, such as IQ when measuring intelligence.

The consistency of respondents' responses on a multiple-item assessment is known as internal reliability. Scores should be correlated since each question on these tests must demonstrate the same broad structure. Internal accuracy can only be determined by data collection and analysis. Examining a split-half correlation is one means of calculating internal reliability. It entails dividing the objects into two groups, such as the first and second halves, or even odd-numbered items. For each set of products, a score is calculated. The relationship between the two sets of scores is then investigated (Saridakis & Cowling, 2020).

Internal reliability can also be computed using Cronbach Cronbach’s α (alpha) method. The recommended value for α is usually equal to or greater than +0.80 for both methods. Inter-rater reliability is the degree to which multiple observers' decisions are compatible. The scores of numerous observers need to be strongly correlated. When the assessments are quantitative, Cronbach's alpha is used to measure interrater reliability; when they are categorical, Cohen's κ (kappa) is used.

The study employed a split-half correlation to determine the reliability of the questionnaires issued to small-scale coffee farmers. Since the pilot study considers 20 respondents, the responses were divided into two after obtaining data. Each group had a total of ten responses. Then Cronbach alpha for the two groups were then calculated. The value for alpha for each set must be over 0.8 for the instruments to be considered reliable. Further, the two groups must show a great correlation.

Procedure

The researcher obtained an introductory letter from the University before data collection. Thereafter, he had to apply for a permit from the National Commission for Science, Technology, and Innovation (NACOSTI). This is an official permit recommended by the Kenyan government for researchers wishing to collect data within its boundaries. The researcher also had to liaise with relevant country bodies such as agricultural officers in the coffee sector and extension officers to connect him with the small-scale farmers in their region.

A list of farmers to include in the study was made beforehand. Since most small-scale farmers associate with coffee factories, societies, or millers, the researcher had to obtain prior information. Afterwards, he had to sample the appropriate number of respondents that matches his sample size in each county. The respondents were contacted and informed of their intention to obtain data from them. Dates were set depending on farmers' availability.

Alternatively, the researcher had to approach certain cooperatives that host small-scale coffee farmers in each county. Through the factories, the researcher obtained information on when and where farmers usually gather. Approaching farmers in a group was considered the best means of access as it was easier to reach quite a number or the required sample size at the same time. This saved the researcher time and money.

If the farmers are accessed individually, the researcher then trains five research assistants, one from each county. The assistants were to help in the distribution and collection of questionnaires from farmers. The researcher was to ensure that his assistants had vast experience in coffee management and are familiar with the area. To accomplish this, it was paramount to consider the existing extension officers who work with various cooperative societies in the country. Since they had worked with some farmers, it was easier for them to track down and approach small-scale coffee farmers.

Operation Definition of Variables

The study variables were divided into independent and dependent variables. The independent variables were categorised into three main variables: social-economic factors, institutional factors, and technological factors. The data collection tool follows the classical testing theory which does a summation of construct responses, unlike the item response theory which views respondent's responses variably to their level of understanding (Reeves & Fayers, 2005). This data collection follows a response style scale. The response style scales are maladaptive in nature and reliable in defining a construct under study (Knowles et al., 2005). The responses were coded to allow the data input into the statistical software compatible.

Social-economic Factors

The socio-economic variable has several indicators. Gender is the sex of the household head owning a coffee farm. The response was either be male or female and thus measured in Binary form. Tools of analysis were frequency and percentage. Age is the real age of the household head. The response was then measured in scale using years. Tools of analysis for age were mean, standard deviation, minimum, and maximum.

The household head's educational level is their greatest degree of education. The response will take the form of a notional ranking from 1 to 5, where 1 denotes no education, 2 represents primary education, 3 secondary education, 4 college education, and 5 university education. Frequency and % will be displayed in the presentation. The total number of residents who live with the household head is known as the household size (HHS). Numbers were used to scale the response. The minimum, maximum, mean, and standard deviation will be used as age analysis tools.

Farm Size (FS) is the total acreage under coffee farming. The response was measured in scale using acres and frequency, percentage, and cumulative percentage as the analysis tools. Data will be presented in tables and bar graphs. Human capital is the total household head experience in coffee farming. Data on human capital were in years in scale format. Mean, standard deviation, minimum, and maximum were the analysis tools and presented using tables. Occupation is the kind of job the household head engages in other than coffee farming. The response will either be formal or informal and thus measured in binary form. The presentation will be in tables showing frequency and percentage.

Labour is the kind of labour used in coffee farming. The response was binary, with option one as family and two as hired, while the presentation showed frequency and percentage. Labour cost (LC) is the total annual labour used in coffee farms. The amount spent in a year were in Kenya shillings. Tools of analysis were mean, standard deviation, minimum and maximum. Data of variables of socio-economic factors were collected using questionnaires. The analysis will be through descriptive statistics and presented in tables as shown in Table 9.

Table 9

Operational Definition of Social-economic Factors

Variable	Description	Measurement	Data scale	Type of analysis	Tool of analysis
Gender (GENDER)	Independent variable	1=male 2=female	Binary	Descriptive statistics	Percentage, frequency
Age (AGE)		Years	Scale		Mean, standard deviation, minimum, maximum
Education level (EDL)		1=no education 2=primary 3=secondary 4=college 5=university	Binary		Percentage, frequency
Household size (HHS)		Number	Scale		Mean, standard deviation, minimum, maximum
Farm size (FS)		Acres	Scale		Frequency, percentage, the

			cumulative percentage
Human capital (HC)	Years	Scale	Mean, standard deviation, minimum, maximum
Occupation (OP)	1=formal 2=informal	Binary	Percentage, frequency
Labour (L)	1=family 2=hired	Binary	Percentage, frequency
Labour cost (LC)	KES	Scale	Mean, standard deviation, minimum, maximum

Source: Author compilation

Institutional Factors

The variables under institutional factors are coffee management experts, extension workers, certification agencies, sales contracts, access to credit, and social capital. Under coffee management, the expert's indicator was membership. Membership refers to household head involvement with any coffee management association such as KCTA, KCPA, or KCPTA. The response will be in binary format with options one as yes and two as no. The presentation was in tables showing frequency and percentage.

Extension workers variable was indicated by visits, the number of visits, NGOs, government, farmers. Visits refer to whether the coffee farmer is paid a visit by an extension officer. The response was in binary form with a yes or no. The number of visits refers to the total of visits by extension officers. The responses were in scale form as several visits will be indicated and analysed using mean, standard deviation, minimum and maximum. NGOs, government, and farmers refer to visits by NGO extension officers, government extension officers, and fellow farmers, respectively. These indicators will be binary and collected using a question by a yes or no response analysed using percentage and frequency.

Certification agencies were to have certification and certification cost indicators. Certification refers to whether the coffee farmer is certified. Responses were in binary format with options one as yes, and two as no, while the presentation was shown in tables showing frequency and percentage. Certification cost is the total annual cost for certifying the coffee farmer. Certification cost data will be in scale form. The amount spent in a year were in Kenya shillings, and presentations was in tables. Tools of analysis were mean, standard deviation, minimum and maximum.

Sales contract variables were indicated by exporters, marketing agents, millers, and cooperatives. Exporters refer to coffee farmers who sell directly to exporters. Marketing agents refer to coffee farmers who sell through marketing agents. Millers refer to coffee farmers who sell through millers. Cooperatives refer to coffee farmers selling through cooperatives. Data on sale contract variables will be in binary format with option one as yes, and two as no for each, while presentation were in tables showing frequency and percentage.

Access to credit was measured using credit access and credit amount. Credit access measures whether the coffee farmer receives credit or not. The measurement scale was binary with a yes or no response, with analysing tools being percentage and frequency presented in tabular form. Credit amount refers to the total loan amount obtained in a year from commercial banks, SACCOs, chamas, or friends to assist in coffee farming. The response was in scale form and amount in Kenya shillings. The presentation was done using tables with analysing tools being mean, standard deviation, maximum and minimum.

The social capital variable also has two indicators: social and training. Social were the coffee farmer association with a social group such as cooperative society, farmers union, research project, training project, certification project, or NGO project. Training was whether the coffee farmer receives training from either of the social groups he/she associates with. Data on sale contract variables were in binary format with option one as yes, and two as no for each, while presentation will be in tables showing frequency and percentage. Data of variables of institutional factors were collected using questionnaires (Appendix I). The analysis was conducted through descriptive statistics and presented in tables. The summary is shown in Table 10.

Table 10

Operational Definition of Institutional Factors

Variable	Description	Measurement	Data scale	Type of analysis	Tool of analysis
Member	Independent variable	1= Yes, 2= No	Binary	Descriptive statistics	Percentage, frequency
Visit		1= Yes, 2= No	Binary		Percentage, frequency
Number of visits		Number	Scale		Mean, standard deviation, minimum, maximum
NGO		1= Yes, 2= No	Binary		Percentage, frequency
Government		1= Yes, 2= No	Binary		Percentage, frequency
Farmers		1= Yes, 2= No	Binary		Percentage, frequency
Certification		1= Yes, 2= No	Binary		Percentage, frequency
Certification cost		KES	Scale		Mean, standard deviation, minimum, maximum
Exporters		1= Yes, 2= No	Binary		Percentage, total
Marketing agents		1= Yes, 2= No	Binary		Percentage, frequency
Millers		1= Yes, 2= No	Binary		Percentage, frequency
Cooperatives		1= Yes, 2= No	Binary		Percentage, frequency

Credit access	1= Yes, 2= No	Binary	Percentage, frequency
Credit amount	KES	Scale	Mean, standard deviation, minimum, maximum
Social	1= Yes, 2= No	Binary	Percentage, Frequency
Training	1= Yes, 2= No	Binary	Percentage, frequency

Source: Author compilation (2021)

Technological Factors

The variables under institutional factors are coffee varieties, fertiliser, pesticides, pruning method, cultivation, irrigation, weeding, spraying. Coffee varieties variable has indicators such as variety, coffee age, crop farming, animal farming, and income. Variety is the type of coffee grown by the coffee farmer measured by 1 for Arabica and 2 for Robusta. The coffee age is the existence of coffee plants since they were planted measured in years. Crop farming is a plantation of other crops such as banana, maize, beans, pineapple, and tea in the farm measured by a yes or no. Crop income is the annual amount generated from other crops besides coffee measured by Kenya shillings. Animal farming is the keeping of domestic animals for commercial purposes measured by a yes or no. Animal income is the total annual amount generated from the sale of animals, or their coffee products measured by the amount in Kenya shillings.

The data scale was binary for indicators such as variety, crop farming, and animal farming. The presentation was in tables showing frequency and percentage. Data was in scale format for indicators such as coffee age, crop income, and animal income. The presentation was done using tables with analysing tools being mean, standard deviation, maximum and minimum. Fertiliser was indicated by Fertiliser Quantity (FQ) and Fertiliser Cost (FC).

Fertiliser quantity is the total annual amount of fertiliser used in coffee farming. It was measured in kilograms (kg). Fertiliser cost is the total annual cost incurred purchasing fertiliser for the coffee farm measured in Kenya shillings. FQ and FC data were in scale format. The presentation was done using tables with analysing tools being mean, standard deviation, maximum and minimum.

The pesticide was indicated by Pesticide Quantity (PQ) and Pesticide Cost (PC). Pesticide quantity is the total annual amount of pesticide (herbicide, fungicide, and insecticide) used in a year in coffee farms. It was measured in kilograms (kg). Pesticide cost is the total annual cost incurred purchasing pesticides (herbicide, fungicide, and insecticide) used in coffee farms measured in Kenya shillings. PQ and PC data will be in scale format. The presentation was done using tables with analysing tools being mean, standard deviation, maximum and minimum.

Pruning was indicated by pruning technology (PRT) and pruning cost (PRC). Cultivation was indicated by cultivation technology (CT) and cultivation cost (CC). Irrigation will be indicated by irrigation technology (IT) and irrigation cost (IC). Weeding will be indicated by weeding technology (WT) and weeding cost (WC). Spraying was indicated by spraying technology (ST) and spraying cost (SC). Pruning technology refers to the use of technology in pruning indicated. Cultivation technology refers to the use of technology in cultivation (in place of hoes, plough, tractors, pangas). Irrigation technology refers to the use of technology in irrigation. Weeding technology refers to the use of technology in weeding. Spraying technology refers to the use of technology in spraying indicated by a yes or no. PRT, CT, IT, WT, and ST will be in the binary form indicated by a yes or no. Technology results will have percentages and frequency as analysing tools.

Pruning cost is the total amount incurred in pruning. Cultivation cost is the total amount incurred in cultivation. Irrigation cost is the total amount incurred in irrigation. Weeding cost is the total amount incurred in weeding. Spraying cost is the total amount incurred in spraying using technology. PRC, CC, IC, WC, and SC data will be in scale format measured in Kenya shillings. Cost results were reflected using mean, standard deviation, maximum and minimum. Data of variables of technological factors will be collected using questionnaires (Appendix I). The analysis was done through descriptive statistics and presented in tables. The summary is shown in Table 11.

Table 11

Operational Definition of Technological Factors

Variable	Description	Measurement	Data scale	Type of analysis	Tool of analysis
Variety	Independent variable	1=arabica 2=robusta	Binary	Descriptive statistics	Percentage, frequency
Coffee age		Years	Scale		Mean, standard deviation, minimum, maximum
Crop farming		1= Yes, 2= No	Binary		Percentage, frequency
Crop income		KES	Scale		Mean, standard deviation, minimum, maximum
Animal farming		1= Yes, 2= No	Binary		Percentage, frequency
Animal income		KES	Scale		Mean, standard deviation, minimum, maximum
Fertiliser quantity		Kgs	Scale		Frequency, percentage, the cumulative percentage
Fertiliser cost		KES	Scale		Mean, standard deviation, minimum, maximum
Pesticide quantity		Kgs	Scale		Frequency, percentage, the cumulative percentage
Pesticide cost		KES	Scale		Mean, standard deviation, minimum, maximum

Pruning technology	1= Yes, 2= No	Binary	Percentage, frequency
Pruning cost	KES	Scale	Mean, standard deviation, minimum, maximum
Cultivation technology	1= Yes, 2= No	Binary	Percentage, frequency
Cultivation cost	KES	Scale	Mean, standard deviation, minimum, maximum
Irrigation technology	1= Yes, 2= No	Binary	Percentage, frequency
Irrigation cost	KES	Scale	Mean, standard deviation, minimum, maximum
Weeding technology	1= Yes, 2= No	Binary	Percentage, frequency
Weeding cost	KES	Scale	Mean, standard deviation, minimum, maximum
Spraying technology	1= Yes, 2= No	Binary	Percentage, frequency
Spraying cost	KES	Scale	Mean, standard deviation, minimum, maximum

Source: Author Compilation

Production Yield

The dependent variable has two indicators: coffee yields and income. Coffee yields are the quantity of coffee harvested per farm measured in kilograms. Income is the annual gross income from coffee farming measured in Kenya shillings. Both indicators of production yield will be in scale form and analysed descriptively and inferentially. Presentation of data was in tabular format, showing mean, standard deviation, and significance. Data was collected using questionnaires (Appendix I). The summary is shown in Table 12.

Table 12

Operational Definition of Variables

Variable	Description	Measurement	Data scale	Type of analysis	Tool of analysis
Coffee yields (Y)	Dependent variable	Kilograms (Kgs)	Scale	Descriptive, inferential	Mean, standard deviation, significance
Income (Y1)		KES	Scale		Mean, standard deviation, significance

Source: Authors compilation

Study Procedures and Ethical Assurances

Study Procedure

The study received approval from the UNICAF University Research Ethics Committee before embarking on data collection. In addition, the researcher sought the research permit (Appendix 2) from the National Commission for Science, Technology, and Innovation (NACOSTI) for data collection in Kenya. In each county, the researcher will liaise with agricultural offices to obtain permission. These documents will be used when approaching the coffee factories, societies, or farmers to confirm the authenticity of the task.

Data was collected using questionnaires as the main primary instrument. Secondary data will back up the information gathered by the questionnaires. To gather the primary data, the researcher prepared a list of structured questions that align with the study's objectives (Appendix I). The questionnaire was divided into four sections. The first section focused on socioeconomic factors by collecting age, gender, education level, household size, and land size. This section also addressed the duration in farming, occupation, earnings, and labour.

The second section of the questionnaire covered the institutional factors. They included the presence or absence of coffee management experts, extension workers, certification agencies, sales contracts, and credit access. Technology factors were in the third section focusing on areas such as coffee varieties, fertilisers, pesticides, pruning, cultivation, irrigation, weeding, and spraying. The fourth section covered the production yield by looking at the total coffee harvested, and the money earned from its sale.

The data collection process was expected to be undertaken within three months, from June to August 2021. The coffee season starts in October and ends by May of the following year. Thus, within this research period, it was a suitable time to meet the coffee stakeholders. It is during this period; fewer activities are carried out in coffee farms. The ease of meeting and having face-to-face conversations with farmers was enhanced by the research dates timing.

The data were collected in five counties in the Mt Kenya region, Kiambu, Kirinyaga, Meru, Murang'a, and Nyeri as they are the main coffee-producing regions in Kenya. The main producer is Kiambu, and thus, it has the largest sample size of 229 respondents. It is followed by Murang'a with 52, Kirinyaga 37, Nyeri 36 and Meru 30.

The researcher sought the assistance of enumerators. The researcher engaged a minimum of five assistants. Four enumerators covered Murang’a, Kirinyaga, Nyeri and Meru County each. The researcher, in collaboration with one assistant, collected data from Kiambu county. The research assistants were recruited based on familiarity with the area and experience in data collection. The recruited enumerators had a vast understanding of the language and cultural practices in their respective regions. For instance, those recruited in Kiambu, Murang'a, Nyeri, and Kirinyaga were fluent speakers in the Kikuyu language. The enumerator covering Meru County was able to speak and understand the Meru language and Swahili language.

The assistants were able to translate for farmers who were unable to read and write. It had been anticipated that the small-scale farmers in the region may not be good at reading and writing; hence the enumerators did the translation for them. The researcher had a two-day training to understand the study and to be able to guide the respondents accordingly. During training, the enumerators were taught how to keep the participants confidential and anonymous. They were trained to approach the respondents, whether at home or in their Sacco meetings.

A few surveys were obtained for pilot testing. The questionnaires were assessed for reliability and validity. The researcher revised the instruments accordingly once the pilot testing was done. After that, the tools were reproduced equivalent to the study's sample size. The researcher aided by the enumerators approached the respective managers in the coffee cooperatives and coffee factories within the counties.

The research assistants were issued questionnaires equivalent to the sample size for the area allocated. They were informed of the availability of small-scale farmers as relayed by their cooperatives. The assistants contacted the farmers during their official meetings at their respective coffee cooperatives or millers. In addition, the research assistants visited the small-scale coffee farmers at their homes. The assistants explained to the respondents what was expected of them and how to fill in the questionnaires. There was a good collaboration as all questionnaires were administered face to face.

The few questionnaires left behind were collected later. After obtaining all the instruments, the researcher checked if they were duly filled. Questionnaires with major omissions were disregarded. The filled tools were given serial numbers to ease the coding process. All the data was then input in SPSS using appropriate codes for categorical data. Coded data in SPSS will later be uploaded to the STATA for study analysis.

Ethical Assurances

In undertaking this research, the researcher observed several ethical issues: protection from harm, informed consent, right to privacy, and honesty with professional colleagues.

Obtaining Permission

The researcher obtained permission before embarking on the data collection process. Approval granted by the national government was enough for the region under study. The nature of the study determines the approval levels more so where the study involves the use of respondents' medical data as well as depending on the organisation or the target population (Atkinson, 2011). In this study, the main target population is the small-scale coffee farmers in the Mt Kenya region. First and foremost, the researcher obtained approval from UNICAF University. In addition, a confirmatory letter was issued to ascertain the researcher was a student from the institution.

Another important document that was obtained was the NACOSTI permit. It is a document issued by the government of Kenya through the ministry of education to regulate and authorise the research process in the country.

Protection from Harm

Certain risks were associated with the data collection process. They included psychological, social, and health risks (Walliman, 2006). Psychological risk is emotional harm to the participant as they narrate past occurrences. Some participants may be uncomfortable with this exercise if it reminds them of things that happened to them. They were also unwilling to disclose crucial data for fear of breach of confidentiality. To counter this risk, the researcher prepared structured questions that do not require the participants to recount previous experiences. The questions asked are general ones that do not in any way breach their confidence.

It was also anticipated that the study might face social risks. Social harms include relationship alterations due to embarrassment or damage to one's respect (Payne & Payne, 2004). The research questions ensured that no social risks are triggered among small-scale coffee farmers or within their homesteads. There was no embarrassing question, and no response was considered wrong. However, the participants were encouraged to retrieve past documents if they cannot remember the exact answer.

As the data collectors interacted with the respondents, health risks were anticipated. Health risks are conditions or diseases that arise or exist that may adversely affect the participant's health. Due to the COVID-19 pandemic, the researcher followed several measures to contain the spread. The researcher ensured that all the enumerators were aware of the health hazards associated with the pandemic. COVID-19 personal protective equipment was provided. The researcher advised them on keeping a social distance of about one to one and a half meters when collecting data from the participants. Enumerators were encouraged to spend minimal time with the respondents to feel that their health welfare was considered. The researcher also considered leaving the respondents with the questionnaires and collecting them later.

Informed Consent

All human-participation research necessitates disclosure of permission and confidentiality information (Parsons & Dickinson, 2016). The respondents should not be put under undue pressure no matter how well-intentioned the study is. Pressurising the participants is unethical and may invalidate the findings. The researchers obtained informed consent, the researcher educated all research participants on study purpose, their participation in the study, what happens to the data gathered from them, and what they consented to do. Informed consent normally specifies how the data will be stored and disposed of and how the requisite secrecy will be maintained. It also states how the participant can withdraw their consent at any point, if you would stop using their data/interview, etc.

The aim, methodology, interview procedures, and the research topics and nature of the interview questions were all explained to the interviewees before the start of the interview. The researcher explained to the respondents all aspects and procedures of the research to make an informed decision to participate in the study voluntarily/willingly. The participants were provided with this information verbally in the presence of the local adviser.

Privacy and Confidentiality

Unless utilising a research method where a particular identity is crucial to outcomes and participants consent to their affiliation with the research, participant anonymity is typically a fundamental condition in business research (Mertens & Ginsberg, 2009). Anonymity for participants is not always as simple as excluding their names from the final report. It will be crucial to decide if you need to create a code for each participant or whether the research does not need it, in which case no one will have a code or a name. If the researcher records the respondent's title, function, department, and location, the respondent's identity can be easily determined.

All information provided by respondents that relates to their personal lives will be kept private by the researcher. To ensure anonymity, the researcher advised the respondents that the information they supply will be used solely for the study and that no third parties will have access. The respondent's names will not be divulged to any third parties, according to the researcher. The responders were assured that no personally identifiable information would be disclosed in any form of contact, written or oral.

In data collecting, data recording, reporting outcomes, and publication of conclusions, the researcher must aim for academic honesty. Data must not be fabricated, falsified, or misrepresented by the researcher. The researcher must honour pledges and agreements, operate honestly, and strive for consistency in his or her thinking and actions.

Objectivity

The motive of the study was to be honest. Data was collected by filling in questionnaires in writing. Thus, relevant data was input on the spaces provided. Answers were coded in the form of ticking within appropriate boxes for the answers given. The researcher, therefore, printed the questionnaires that were distributed in hard copies. To ensure objectivity, the researcher or the assistants returned the filled questionnaires.

Data Collection and Analysis

Using a standardised questionnaire, the study gathered information from small-scale coffee growers in the main coffee-producing regions of the Mt. Kenya region. Additional information was gathered from various sources, including reports from the Nairobi Coffee Exchange and the Kenya National Bureau of Statistics. To cut down on the cost and time of data collecting, the technique used a sample size of 384 respondents. To guarantee a fair representation of productivity levels, smallholdings and big farms in all regions were included. Excel and Stata were used to analyse the data.

Principal Component Analysis (PCA)

The use of PCA was employed to reduce the dimensionality of variables related to relational agency, technology adoption, and technical efficiency in Kenyan coffee growing. This method reduced multicollinearity and ensured reliable inputs for the stochastic production frontier model. PCA also helped identify important latent components like technology intensity and collaborative efficiency, which were incorporated into the study to understand their impact on productivity. By simplifying the input set while maintaining important information, PCA aligned the dataset with the model's analytical needs, reducing the dimensionality of variables and avoiding multicollinearity problems (Abbas et al., 2023).

Descriptive Statistics

The examination of a data sample is covered in the book to investigate the socioeconomic profile of respondents in a study. For categorical and continuous variables, descriptive statistics were used to calculate the means and standard deviation, and hypothesis testing was performed to determine whether the variables were significant. If the p-value was higher than 0.05, the null hypothesis was valid. To uncover the connections between variables and ascertain the impact of predictor factors on criteria values, regression analysis was also carried out. Regression analysis was used to quantify the importance of the variables and detect outliers.

Objective 1: Explore the existence of relational agency in coffee farming in central Kenya.

The study hypothesis was that the presence of these explanatory variables; extension agents, certification agencies and coffee management agents positively impact the yield of the farmers. The priori expectation is that the computed t-values if greater than the t-critical value, thus the null hypothesis will be rejected and the alternate hypothesis accepted.

Objective 4: Identify the production yield of coffee farmers in Central Kenya.

In this study coffee output was the explained variable. The regression equation that explains the association of the variables to the output was tested for its significance. An F-test which tests the regression equation will be assessed. If the calculated F-value is greater than the F-critical we conclude that the explanatory variables predict the yields significantly (Salehi et al., 2018).

Technology Acceptance Model

Objective 2: Compare the levels of technology adoption by young and post-youth coffee farmers in central Kenya.

The questionnaire was administered with questions on the various technological innovations in coffee farming. Data concerning the amount in kilograms of fertilisers used, fungicides applied, pruning costs per man-day, coffee variety and its costs shall be floated to the sampled farmers. A regression test analysis was done on the variables to establish the relationship between technology use and its impact on coffee production. A coefficient of correlation ($r > 0.5$) will explain the strength of the variable relationships. An adjusted coefficient of determination ($r^2>0.5$) shall analyse how the variability is explained by the predictor variables. The inferential statistics of $P>0.05$ on this objective will lead to acceptance of the null hypothesis (Anang et al., 2020).

Production Function

Objective 3: Explore the relationship between coffee farmers in Central Kenya regarding the use of technology, the size of the farm, productivity, and agency.

The Stochastic Frontier (SF) model was used to evaluate the data in a study on small-scale coffee farming in Kenya. The SF model estimates TE and drivers of efficiency. The model consists of two error components, one for TE and one for output variable measurement error, weather, and other unobserved inputs. The SF model is preferred in agriculture due to the unpredictable nature of agricultural productivity and measurement inaccuracies. The Cobb-Douglas version of the SF model was used in this study with a log-log functional form because it is more flexible and does not limit substitution elasticities. This was modelled as shown in the following equation:

Equation 2
Cobb-Douglas version of the SF

$$LnP = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \mathcal{E}_t (V_t - U_t)$$

Where P denotes coffee yield (kg/ha)

B_n are the parameters to be calculated

X_1 is the size of coffee farms in hectares

X_2 is the labour used in coffee farms (human-days)

X_3 is the number of fertilisers utilised (kg/year)

X_4 is the number of pesticides used (kg/year)

$\mathcal{E}_t$ is the error term

V_t is the two-sided random error element beyond the farmer's control

U_t is a one-sided inefficiency element.

Technical efficiency

The TE was arrived at by using the stated equation;

Equation 3
TE Equation

$TE_t = Exp(-U_t)$

U_t is a one-sided inefficiency element.

Thus, $0 \leq TEt \leq 1$.

The following equation determined the technical inefficiency;

$$\ln(U_t) = \alpha_0 + \alpha_1 M_1 + \alpha_2 M_2 + \alpha_{3M3} + \alpha_4 M_4 + \alpha_5 M_5 + \alpha_6 M_6 + \alpha_7 M_7 + \alpha_8 M_8 + \alpha_9 M_9 + \alpha_{10} M_{10} + \alpha_{11} M_{11}$$

Where,

U_t is the technical inefficiency

M1 is the gender of the household head

M2 is the age of the household head

M3 is the education of the household head

M4 is the household size

M5 is the occupation of household head

M6 is the coffee management experts

M7 is the extension visits

M8 is the certification

M9 is the marketing agents

M10 is the credit availability

M11 is the social capital availability

α_n are the unknown parameters to be determined.

The test of significance was done for each variable of the study. The rule is that if the computed t-value is greater than the t-critical, the variable is significant. The null hypothesis was rejected, and the alternate hypothesis accepted.

Description of Explanation Variables

Table 13

Explanatory Variables Definition and Measurements

Variable	Types and definition	Measurements
Occupation	Dummy, pure or non-pure farmer	1 if pure farmer, 0 otherwise
Age	Age of the household head	In years
Extension officer visiting farmer	Dummy, yes or no	1 if yes, 0 otherwise
Coffee farmer group membership	Dummy, yes or no	1 if yes, 0 otherwise
Household size	Total family size	Number of households
Years of education	Level of formal education	in years
Land size	Total land owned	In acres
Marital status	Dummy, married or otherwise	1 if married, 0 otherwise
Gender	Expressed sex affiliation	1 if Male, 0 Female
Certification	Dummy, yes or no	1 if yes, 0 otherwise
Credit availability	Amount advanced	In Kenya shillings
Marketing agents	Dummy, yes or no	1 if yes, 0 otherwise

Summary

This study evaluates the relational agency, technology, and TE in Kenyan coffee farming using a stochastic production frontier approach. The research study approach was quantitative in nature. The quantitative approach creates room for the generalizability of the results (Singh, 2007). The research design considered for this study aligns with the quantitative approach adopted. Research design enables the researcher to reasonably address the research problem (Creswell & Creswell, 2018). Under this study a cross-section design was used in collecting data. Cross-section design has no time dimension and relies on prevailing differences in the study subjects. Data is conducted at a specific time, for instance, in a week, month, or year. The researcher does not interfere with prevailing circumstances but instead collects data as it exists (Hall, 2008). The major reason behind the use of cross-section design is that it is relatively cheaper to use since the study does not require follow-ups (Bourque, 2004).

The population for this study comprised all small-scale coffee farmers in Kenya. Coffee is grown by about 478,936 small scale farmers (KNBS, 2020). This study employed both stratified sampling and simple random sampling methods. Since the number of small-scale farmers in all the counties is known, the researcher grouped the population per county. Once the total sample size of each county was known, simple random sampling was used to identify the respondent. The sample size is a criterion for deciding the number of population items to use in the sample (Creswell, 2013). This study utilised Cochran formulae in calculating the sample size. As a result, the survey would consist of 384 respondents.

The data were collected using a structured questionnaire. The reason for choosing questionnaires was because they are a relatively inexpensive, fast, and effective way of gathering large quantities of data from many people (Saridakis & Cowling, 2020). The study received approval from the UNICAF University Research Ethics Committee before embarking on data collection. In undertaking this research, the researcher observed several ethical issues: protection from harm, informed consent, right to privacy, and honesty with professional colleagues.

CHAPTER 4: DISCUSSION OF RESEARCH FINDINGS

Introduction

This study's aim was to identify TE among coffee farmers following the adoption of constructed relationships and technology. Coffee exports lead to dollar inflows to the economy to alleviate poverty (KNBS, 2019). The aim of the study was to explore the relationship between the various interrelated subjects which are involved in the coffee value chain. The study was guided by the activity theory, which postulates how individuals cooperate in undertaking a task with the help of technology (Kaptelinin & Nardi, 2019). The Activity of every subject in a constructed relations is paramount for the solution to be achieved. The production theory of economics underpinned the stochastic model which was used to test the TE of the coffee farmers. Factor combination in an efficient manner leads to TE. For input-oriented TE, the producer ensures the least inputs are used in the production. An output-oriented TE ensures the highest output is realised from the available inputs. However, to factor in the external shocks, the error term is introduced (Raa & Greene, 2019).

The chapter presents the results of the data processed during analysis. Results were processed in line with the study objectives from which the study problem was investigated, and interpretations of results were carried out. The objectives were as follows; Firstly, to explore the existence of relational agency in coffee farming in central Kenya; secondly, to compare the levels of technology adoption by young and post-youth coffee farmers in central Kenya; thirdly, to explore the relationship between coffee farmers in Central Kenya regarding the use of technology, the size of the farm, productivity, and agency; fourthly, to identify the production yield of coffee farmers in Central Kenya and lastly was to formulate recommendations to coffee farmers in Central Kenya to increase efficiency in coffee production.

This chapter reports the findings as per the objectives and takes note of the data reliability and the response rate. The rate of response was 88.54%. Kaiser Meyer Olkin (KMO) test for construct validity was done and returned a value of 0.642. Social demographic data was analysed into frequency tables and appropriate pictorial used to summarise the findings. The trans log stochastic production function was used to determine the constructed relationships between relational agency, technology, and TE. The model was statistically significant implying that technology use (mechanised, improved variety) significantly affects productivity among coffee farmers in Central Kenya (Prob > chi2 = 0.0003). The chapter also gives a summary of findings at the end of the chapter.

Response Rate

Data were collected from different sectors of the region. A total of 384 questionnaires were issued of which 340 were filled and returned, which represents a response rate of 88.54%. A response rate of 75% and above is acceptable as per Holtom et al. 2022 guidelines. The findings were displayed in table 14.

Table 14

Response Rate

Response	Frequency	Percent (%)
Returned	340	88.54%
Unreturned	44	11.46%
Total	384	100.00

Social Economic Information

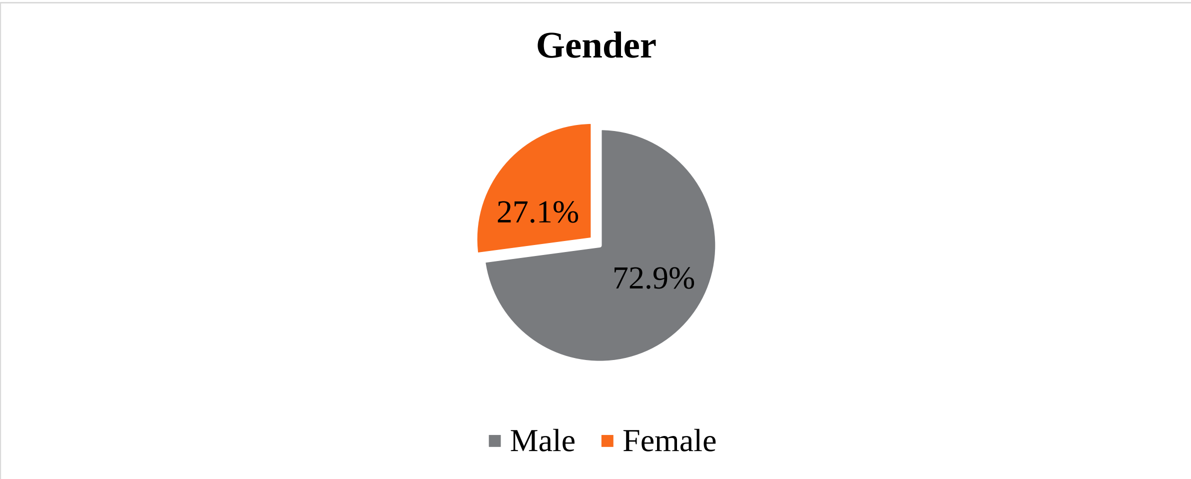
The social economic information was processed by analysing the demographic data of the respondents. The key demographic data was analysed and presented using tables and figures as shown in the subsections below.

Gender of the Respondents

The gender of the respondents was analysed, and the results were processed. More than half (72.9%) of the respondents were males while 27.1% of them were their female counterparts. Figure 9 presents the summary of the statistics pertaining to the gender of the respondents.

Figure 9

Gender of the Respondents



Source: Survey Data (2021)

This is in line with Ngeywo et al. (2015) who indicated that 70.6% of the coffee farmers were males while 29.4% translated to females. Their study also revealed that gender has no effect on coffee production. This indicates a gender imbalance element in accessing the existing coffee farming resources and information.

The Relationship between Gender of the Respondents and Coffee Productivity

Table 15 indicated that there was no significant interaction between the gender of the respondents and productivity among coffee farmers in Central Kenya (χ^2=8.159a, p= 0.148)

Table 15

The Relationship between Gender of the Respondents and Coffee Productivity

		Gender * productivity among coffee farmers						Total	(χ^2), P (χ^2)
Gender	Measures	Less than 5000	5,001 - 20,000	20,001 – 80,000	80,001 - 200,000	200,001 - 500,000	Over 500,000		
Female	Frequency	2	7	12	76	40	11	48	8.159a, 0.148
	Percentage	6.7%	3.6%	0.9%	69.7%	83.3%	100.0%	72.9%	
Male	Frequency	1	4	6	33	8		2	
	Percentage	3.3%	6.4%	9.1%	30.3%	16.7%	0%	7.1%	

Age of the Respondents

The respondents were requested to indicate their age bracket. The results indicated that (0.3%) of the respondents are of less than 30 years, (4.4%) of them are between 30 and 40 years, (25%) of them are between 41 and 50 years, (35.6%) of them are between 51 and 60 years, 25.6% of them are 61 and 70 years while (9.1%) of them are above 70 years. However, according to Sumarti and Falatehan (2016), while middle productive-aged workers (35-54 years old) increase slowly, young productive-aged workers (15-34 years old) decrease. Therefore, workers aged between 20 and 35 years old, are mostly self-agribusiness and had considered agriculture as their livelihood, and they have entrepreneurship spirit. The factors considered in analysing agricultural production in Rwanda. Unlike in other countries, farmers in Rwanda do not use agricultural machinery such as tractors. Instead, the main factors considered are land labour, fertiliser, and seeds. Land is measured in hectares planted with maize during a particular crop season. Labour input includes hired and family labour, and it is measured in person-days per hectare. labour is defined in terms of adult males, adult females, and children between 5-14 years old. Fertiliser input is measured by the total amount of di-ammonium phosphate and urea applied in kilograms per hectare during the crop season, while seed input is measured as the number of maize seeds used in kilograms per hectare during the crop season. The findings were tabulated in Table 16.

Table 16

Age Bracket

Age	Frequency	Percentage (%)
less than 30 years	1	0.3
30 - 40 years	15	4.4
41 - 50 years	85	25
51 -60 years	121	35.6
61 - 70 years	87	25.6
Above 70 years	31	9.1
Total	340	100

The Relationship between Age of the Respondents and Coffee Productivity

There was a positive and insignificant relationship between those farmers who are 30 and 40 years and productivity compared to those who are less than 30 years ($\beta = 0.210$, $p = 0.781$). There is, however, a negative and insignificant relationship between those farmers who are between 41 and 50 years and productivity compared to those who are less than 30 years ($\beta = -0.073$, $p = 0.921$). There was also a negative and insignificant relationship between those farmers who are between 41 and 50 years and productivity compared to those who are less than

30 years (β = -0.018, p = 0.980). There was a positive and insignificant relationship between those farmers who are between 41 and 50 years and productivity compared to those who are less than 30 years (β = 0.515, p = 0.483). There was also a positive and insignificant relationship between those farmers who are above 70 years and productivity compared to those who are less than 30 years (β = 0.872, p = 0.242).

According to Ngeywo et al. (2015), the age variation in the number of small-scale farmers taking up coffee farming could also explain the decline in crop cultivation in the country. They uncover that the number of people practicing coffee farming in Kenya which is predominantly made up of older people. More precisely, Ngeywo et al. (2015) indicate that Kenyan coffee farmers' average age is 51 years. The justification for the dwindling number of coffee farmers in the country was embedded in the fact that the Kenyan population is relatively young.

According to Meike and Bernhard's (2009) study, household head's experience and age are significant factors that affect efficiency in coffee cultivation. Efficiency tends to increase with experience but decreases with age. The number of adult household members has a negative impact on efficiency. This suggests that families tend to use available family labour more than hired labour. The study found that having additional family members decreases efficiency by 1.3 percentage points. Proper bookkeeping practices have a positive impact on efficiency, increasing it by 5.4 percentage points, indicating that efficient management of production relies on good accounting methods. Households that pursue other income-generating activities besides coffee tend to have higher efficiency levels, allowing farmers to invest in inputs even when coffee incomes are low. Farmers who work off-farm also have better access to relevant information. Additionally, if family members engage in other activities besides coffee, underemployment on the coffee plantation is less likely to occur. On average, households with additional income-generating activities display 6.5 per cent higher efficiency levels. Lastly, specialty coffee farmers located in the Western Valley have higher efficiency levels than those in the Brunca region. The findings are presented in Table 17.

Table 17

Relationship between Age of the Respondents and Coffee Productivity

How much did you get from the sale of Coffee?	Coef.	Std. Err.	Z	>z	[95% Conf.	Interval]
Frontier						
Less than 30 years	1	1	1	1	1	1
30 – 40 years	0.210	0.754	0.280	0.781	-1.267	1.687
41 – 50 years	-0.073	0.733	-0.100	0.921	-1.509	1.364
51 – 60 years	-0.018	0.732	-0.020	0.980	-1.453	1.417
61 – 70 years	0.515	0.734	0.700	0.483	-0.924	1.954
Above 70 years	0.872	0.745	1.170	0.242	-0.588	2.332
_cons	11.742	0.729	16.110	0.000	10.313	13.170

The first category was used as a reference category

Table 18

Anova Tests Presenting the Mean Difference between the age of the Respondents and the Use of Technology in Cultivation

	Analysis of Variance				
Source	SS	Df	MS	F	Prob>F (*Sig)*
Between groups	0.004	5	0.001	0.580	0.712
Within groups	0.475	333	0.001		
Total	0.479	338	0.001		

Dependent variable: use of improved cultivars, bio inputs and use mechanised implements.

DF= degree of freedom, F = calculated F statistic, Sig = significance level

The one-way analysis of variance indicated that there was no statistically significant impact between the use of improved cultivars, bio inputs and use of mechanised implements by young farmers and post youth farmers {(*F (5, 333)* =0.580*}*. Biam (2016) also measured the level of EE and its determinants using the Cobb-Douglas stochastic frontier and revealed that EE was negatively and significantly affected by the size of farms, the farmers' age, and household size (Biam, 2016). Other characteristics such as age, the number of crops grown by the family, the average size of plots farmed by the household, the mean distance across plots, and family involvement all had a negative impact on the overall factor efficacy and productivity (Fantu, 2015b). This is inconsistent with the current results.

Hypothesis Testing for age Category and Productivity among Coffee Farmers in Central Kenya

The null hypothesis for the study was that: H2o: Young farmers use improved cultivars, bio inputs and use mechanised implements than the post youth farmers H2a: Both young farmers and post youth farmers use improved cultivars, bio inputs and use mechanised implements. Therefore, given the results in Table 19 and Table 20, the study concludes that both young farmers and post youth farmers use improved cultivars, bio inputs and use mechanised implements since there was no statistically significant impact between the use of improved cultivars, bio inputs and use mechanised implements by young farmers and post youth farmers.

These findings are in line with Ngeywo et al. (2015) who hypothesised that age and the farm's size have a huge influence on an entity or individual's propensity to install farming techniques that instigate TE. More precisely, Ngeywo et al. (2015) indicate that a 31 farmer's age depicts his or her affinity towards farming methods that yield TE. This notion is also supported by Kamau et al. (2017) who uncovered that young-aged farmers are more likely to adopt specialised efficiency-boosting farming techniques as compared to their older counterparts.

The respondents were requested to indicate their marital status. The results indicated that 6.5% of the respondents are single, 70.3% of them are married, 0.9% of them are divorced and 22.4% of them are widowed. Likewise, according to Kimaro (2020), majority of the farmers (82.8%) were married an implication that community members of different marital statuses participated in coffee production among small-scale farmers, basically due to the importance of coffee for their daily livelihood requirements. Our findings concur with Ngeywo et al. (2015) who also indicated that marital status was critical in determining the level and magnitude of conflicts arising from hereditary process and which effect on the good agricultural practices in coffee farming. It was indicated that 74.3% of the farmers were married whereas 21% were widows while 4.7% were single or separated. Table 19 presents the summary of the statistics pertaining to the marital status of the respondents.

Table 19

Marital Status of the Respondents

Marital status	Frequency	Percentage (%)
Single	22	6.5
Married	239	70.3
Divorced	3	0.9
Widowed	76	22.4
Total	340	100

Education Level of the Respondents

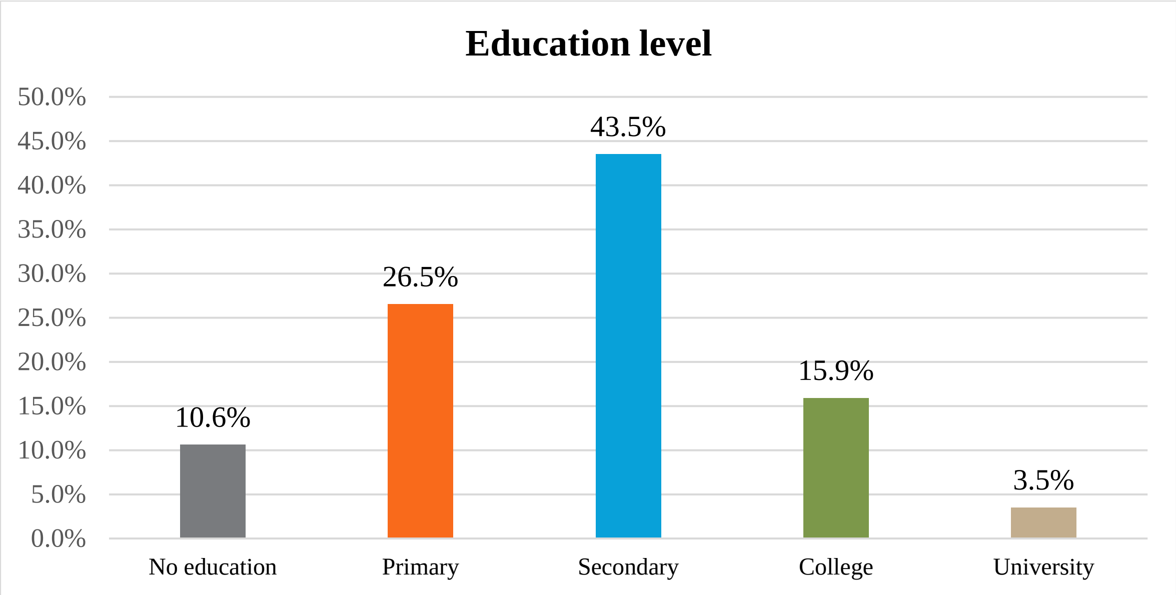
The respondents were requested to indicate their highest level of education. The results indicated that 10.6% of the respondents have no education, 26.5% of them have up to primary education, 43.5% of them have up to secondary education, 15.9% of them have up to college education while 3.5% of them have up to university education. The level of education of the farmer was found to have a considerable negative impact on TE, according to Ali and Khan (2014). Ahmed et al. (2015) also concurred that education positively impacted allocative and

EE. Additionally, their findings suggested that access to extensions had a beneficial effect on TE. Most smallholder coffee farmers in Kenya, according to Luusa (2019), lack the formal education required for better contemporary farming, with 97.6% of them having less than tertiary level education. The study's findings were modified to account for the policy irrelevance that emerges from regression models that consider education as a continuous variable even though it is an ordered variable. Education levels were reclassified into relevant ordinal divisions and added as dummy variables to the analysis to address this. This method made it easier to understand how incremental education levels affect important outcomes, which made the results more useful for policymakers who want to customise interventions according to educational thresholds.

The study found that there are various factors that can improve the TE of farmers, including access to credit, extension services, education level, land consolidation, improved coffee tree varieties, and cropping systems. According to the findings, farmers with greater levels of education typically had higher TE, which is consistent with other research from China, Bangladesh, Cote d'Ivoire, and Pakistan. The impact of education on TE, however, is only seen by Bangladesh's medium and big farmers, who frequently participate in off-farm income-generating activities (Tarek, 2019). Figure 10 presents the summary of the statistics about the Education level of the respondents.

Figure 10

Education Level of the Respondents



The Relationship between Education Level of the Respondents and Productivity among Coffee Farmers in Central Kenya

Table 20 indicated that there is a significant interaction between education level of the respondents and productivity among coffee farmers in Central Kenya (χ^2=38.223a, p= 0.008).

Table 20

The Relationship between Education Level of the Respondents and Coffee Productivity

Education level	Less than 5000	5,001 - 20,000	20,001 - 80,000	80,001 – 200,000	200,001 - 500,000	Over 500,000	(χ^2), P (χ^2)
No education	0.0%	0.0%	8.2%	11.0%	18.80%	18.20%	38.223, 0.008
Primary	33.30%	27.30%	20.30%	27.50%	35.40%	63.60%	
Secondary	66.70%	54.50%	51.30%	37.60%	33.30%	18.20%	
College	0.00%	0.00%	15.80%	22.00%	10.40%	0.00%	
University	0.00%	18.20%	4.40%	1.80%	2.10%	0.00%	

Household Size

The respondents were requested to indicate the number of members in their respective households. The results indicated that most of the households (29.7%) have up to 3 members, 25% of the households have up to 4 members, 18.8% of the households have up to 5 members, 11.2% of the households have up to 2 members, 0.3% of the households have up to 1 member while the rest of the households have more than 6 members. Chiona (2011) also revealed that EE was determined by the size of the household, seed variety, farm size, and accessibility to extension services. In contrast to inorganic nutrients, Ogada (2009) found that the household head's education level, gender, and non-crop income were factors influencing farm households' adoption of improved maize varieties. Better maize cultivars were more likely to be adopted by households with heads who completed high school or higher than by households with heads who had completed elementary school or less. This finding is like Gerhart's (1975) study, which found a favoruable relationship between education and technological adoption. However, as Rubas (2004) pointed out, the impact of education on technology acceptance is limited and not universal, which indicates that the coefficient of variation was statistically insignificant for inorganic cfertiliser acceptance but significant for enhanced maize variety adoption.

According to a study on the adoption of superior maize varieties in Kenya, families headed by men were 7% more likely to do so than households headed by women. The study also discovered that a one Kenyan shilling increase in non-crop income improved the likelihood of adopting superior maize varieties by 0.31D-06. This suggests that to enhance the likelihood of adopting superior maize varieties by 30%, a farmer's non-crop income must grow by one million Kenyan shillings. The study's results agree with those of an earlier study by Ouma et al (2022) which found that inorganic fertiliser required a higher income barrier for adoption compared to enhanced maize varieties. The study also found similar results regarding the association between gender and the adoption of enhanced maize cultivars. Table 21 presents the statistics of the household size of the respondents.

Table 21

Household Size

Size of your household	Frequency	Percentage (%)
1 member	1	0.3
2 members	38	11.2
3 members	101	29.7
4 members	85	25
5 members	64	18.8
6 members	33	9.7
7 members	13	3.8
8 members	4	1.2
10 members	1	0.3
Total	340	100

Land Size

The respondents were requested to indicate their land size. Table 22 indicated that 27.1% of the respondents have less than 2 acres, 59.1% of them have between 2 and 3.99 acres, 8.8% of them are between 4 and 5.99 acres, 2.4% of them have between 6 and 9.99 acres while 2.6% of them have 10 acres and above. These findings are consistent with Kamau et al. (2016) that large households produce more workers to work on coffee farms. They alluded to the significant positive influence on the fact that coffee farming is labour-intensive. In Murang' a, they indicated that large households benefited small scale farmers in the area. Machuka (2016) demonstrated a positive, significant relationship between farm size (in acres) and coffee output, with an increase of one acre leading to an increase of 1.781Kgs in productivity in 2013. Conversely, larger farms may be more prone to underutilising land by cultivating lower value crops or adopting land extensive practices rather than smaller farms due to the availability of land as a factor; this could result in negative impacts from increasing farm size for some farmers. However, according to Murimi et al. (2019), farm sizes are shrinking because of the increase in population and the sale of the land via informal land markets with emergency needs. The results of a study conducted in China and India indicate that land consolidation for the management of coffee plantations can effectively boost TE in production. This aligns with results from Chen et al. (2013), Wu et al. (2005), and Manjunatha et al. (2009), which all pointed out the efficacy of such measures as an applicable policy instrument to advance farmers' productivity and efficiency. This can be explained in that it allows farmers access to resources such as subsidies, credit facilities, marketing access, and rural infrastructure development which are available under consolidated plots, thus aiding these individuals in their efforts to increase production output and efficiency. The findings were tabulated in Table 22.

Table 22

Land Size

Size of your land	Frequency	Percentage (%)
10 acres and above	9	2.6
2 - 3.99 acres	201	59.1
4 - 5.99 acres	30	8.8
6 - 9.99 acres	8	2.4
Less than 2 acres	92	27.1
Total	340	100

The Relationship between Land Size and Coffee Productivity

Table 23 indicated that there is a significant interaction between land size and productivity among coffee farmers in Central Kenya (χ^2=274.448a, p= 0.000).

Table 23

The Relationship between Land Size and Coffee Productivity

	Land in acres	Less than 5000	5,001 - 20,000	20,001 - 80,000	80,001 – 200,000	200,001 - 500,000	Over 500,000	(χ^2), P (χ^2)
Size of your land	0	66.70%	9.10%	44.90%	14.70%	4.20%	0.00%	274.448a, 0.000
	0.69	0.00%	90.90%	53.80%	75.20%	47.90%	9.10%	
	1.1	33.30%	0.00%	0.00%	9.20%	37.50%	9.10%	
	1.39	0.00%	0.00%	0.00%	0.90%	8.30%	27.30%	
	1.61	0.00%	0.00%	1.30%	0.00%	2.10%	54.50%	

Period of Farming

The farmers were requested to indicate the period they have practiced farming. The findings indicated that most of the respondents (68.8%) have farmed for 11 and 30 years with (30.9%) of them having farmed for 11 and 20 years and (37.9%) of them having farmed for 21 and 30 years. Cherukut et al. (2016) observed noteworthy influences of land tenure on farm productivity. Wambua et al. (2021) uncovered that only 43.4% of the surveyed farmers have possession rights of land title deed, demonstrating that most respondents lack security in land tenure. The findings were tabulated in Table 24.

Table 24

Period of Farming

How long have you been farming?	Frequency	Percentage (%)
less than 5 years	11	3.2
5 - 10 years	30	8.8
11 - 20 years	105	30.9
21 - 30 years	129	37.9
31 - 40 years	61	17.9
Over 40 years	4	1.2
Total	340	100

The Relationship between Period of Farming and Coffee Productivity

Table 25 indicated that there is a significant interaction between period of farming and productivity among coffee farmers in Central Kenya (χ^2=51.976a, p= 0.001).

Table 25

The Relationship between Period of Farming and Coffee Productivity

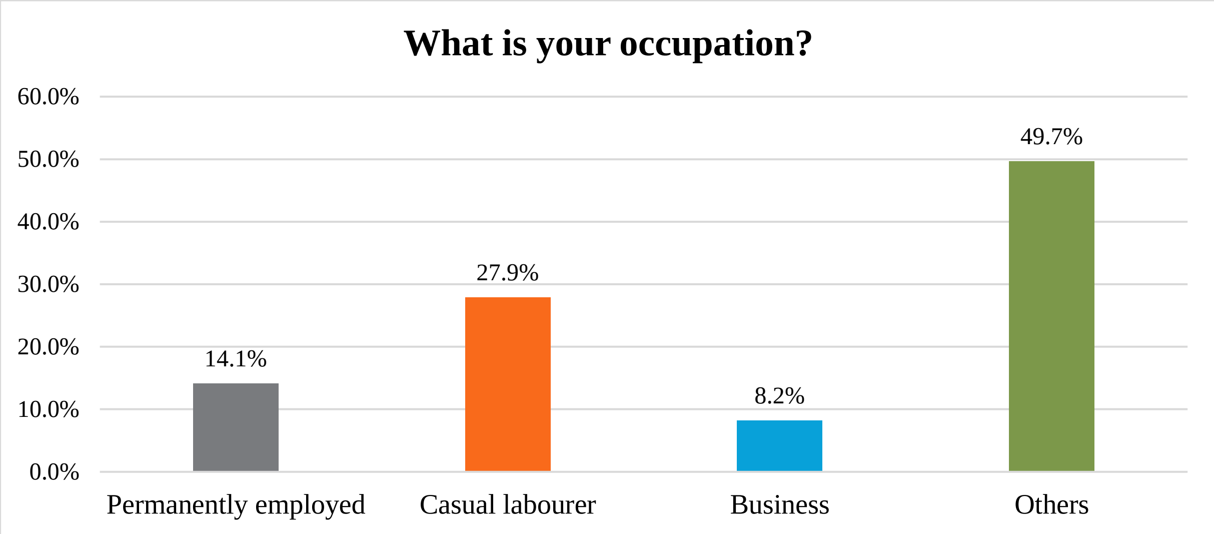
How long have you been farming? (Years)	Less than 5000	5,001 - 20,000	20,001 - 80,000	80,001 – 200,000	200,001 - 500,000	Over 500,000	(χ^2), P (χ^2)
less than 5 years	0.00%	0.00%	4.40%	2.80%	2.10%	0.00%	51.976a, 0.001
5 - 10	0.00%	0.0%	8.90%	11.9%	6.30%	0.00%	
11 - 20	0.00%	27.30%	39.20%	26.60%	18.80%	18.20%	
21 - 30	66.70%	45.50%	36.10%	42.20%	37.50%	9.10%	
31 - 40	33.30%	27.30%	10.80%	16.50%	31.30%	63.60%	
Over 40	0.00%	0.0%	0.60%	0.00%	4.20%	9.10%	

Occupation of the Respondents

The farmers were requested to indicate the main occupations besides coffee farming. The results indicated below that: (14.1%) of the respondents are permanently employed, 27.9% of them are casual labourers, (8.2%) of them are business owners and (49.7%) of them have other occupations. Khalil (2017) while conducting his study indicated that most subsistence farmers have other occupations that generate income for their family usually in the informal sector (Rapsomanikis, 2015). It also echoed the same, and according to Skouw-Rasmussen et al. (2014) also indicated that majority of the farmers practice mixed farming. The findings were presented in Figure 11.

Figure 11

Occupation of the Respondents



The Relationship between Occupation of the Respondents and Coffee Productivity

Table 26 indicated that there was a significant interaction between occupation of the respondents and productivity among coffee farmers in Central Kenya (χ^2=41.315a, p= 0.000).

Table 26

The Relationship between Occupation of the Respondents and Coffee Productivity

Type of employment	Less than 5000	5,001 - 20,000	20,001 - 80,000	80,001-200,000	20,000-500,000	Over 500,000	(χ^2), P (χ^2)
Permanent	0.00%	18.20%	12.70%	20.20%	8.30%	0.00%	41.35a, 0.000
Casual	66.7%	9.10%	31.60%	27.5%	22.90%	9.10%	
Business	0.0%	0.00%	7.60%	2.80%	16.70%	45.5%	
Others	33.3%	72.7%	48.10%	49.5%	52.10%	45.5%	

Annual Earnings from Coffee Farming

The farmers were requested to indicate their total annual earnings from coffee farming. The results indicated that (23.5%) of the respondents earn less than KES 100,000 annually, 55.3% of them earn between KES 100,000 and KES 300,000 annually, (15.9%) of them earn between KES 300,001 and KES 500,000 annually, 4.1% of them earn between 500,001 and KES 1,000,000 annually while (1.2%) of them earn over KES 1,000,000 annually. Table 27 presents the summary of the statistics about the annual earnings from coffee farming.

Table 27

Annual Earnings from Coffee Farming

How much do you earn annually (KES)	Frequency	Percentage (%)
Below 100,000	80	23.5
Between 100,000 - 300,000	188	55.3
Between 300,001 - 500,000	54	15.9
Between 500,001 -1,000,000	14	4.1
Over 1,000,000	4	1.2
Total	340	100

The Relationship between Annual Earnings from Coffee Farming and Coffee Productivity

Table 28 indicated that there was a significant interaction between annual earnings from coffee farming and productivity among coffee farmers in Central Kenya (χ^2=188.031a, p= 0.000).

Table 28

The Relationship between Annual Earnings from Coffee Farming and Coffee Productivity

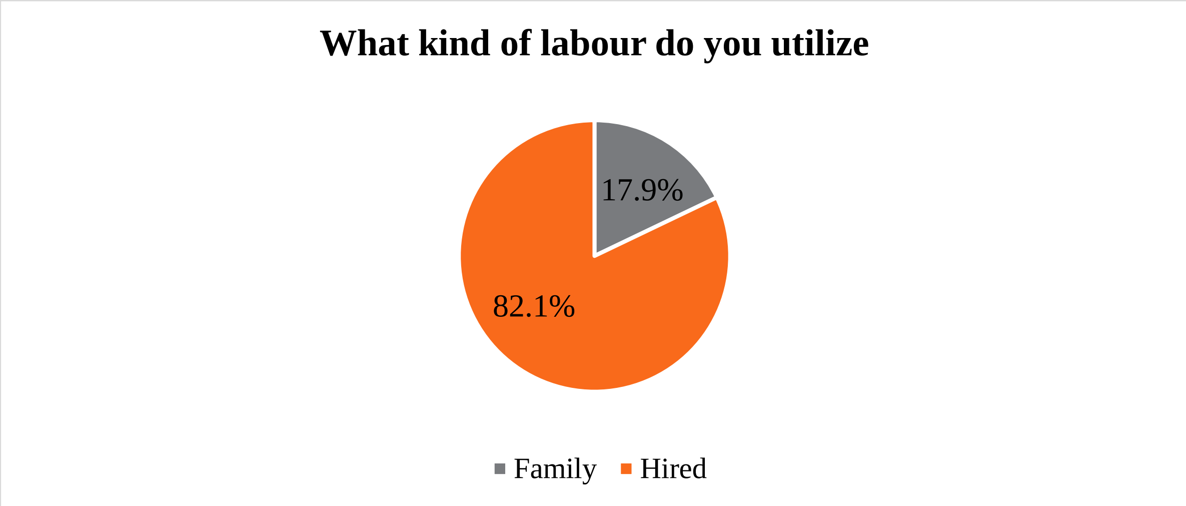
How much do you earn annually (KES)	Less than 5000	5,001 - 20,000	20,001-80,000	80,001-200,000	200,001-500,000	Over 500,000	(χ^2), P (χ^2)
Below 100,000	0.00%	27.30%	38.60%	13.80%	2.10%	0.00%	188.031 a, 0.000
100,000-300,000	66.70%	72.70%	54.40%	65.10%	43.80%	0.00%	
300,001-500,000	33.30%	0.00%	6.30%	20.20%	37.50%	27.30%	
500,001-1,000,000	0.00%	0.00%	0.60%	0.90%	12.50%	54.50%	
1,000,000	0.00%	0.00%	0.00%	0.00%	4.20%	18.20%	

Type of Labour Used in Coffee Production

The farmers were requested to indicate the type of labour used in coffee production. From Figure 12, (82.1%) of the respondents indicated that they use hired labour while (17.9%) of them use family labour on their farms. Family members according to Khalil (2017), are the main labourers in these farms. Subsistence farming is often characterised by minimal capital outlay, lack of modernised or mechanised farming practice and lack of access to market for selling their surplus produces. Figure 12 presents the summary of the statistics pertaining to the type of labour used in coffee production.

Figure 12

Type of Labour Used in Coffee Production



The Relationship between Type of Labour Used in Coffee Production and Coffee Productivity

Table 29 indicated that there was significant interaction between type of labour used in coffee production and productivity among coffee farmers in (χ^2=188.031a, p= 0.000).

Table 29

The Relationship between Type of Labour Used and Coffee Productivity

What kind of labour do you utilise?	Less than 5000	5,001 – 20,000	20,001 - 80,000	80,001 - 200,000	200,001 - 500,000	Over 500,000	(χ^2), P (χ^2)
Family	0.00%	54.50%	25.30%	9.20%	8.30%	9.10%	188.031a, 0.000
Hired	100.00%	45.50%	74.70%	90.80%	91.70%	90.90%	

Annual Cost of Cultivation

The farmers were requested to indicate the annual cost of coffee production. It was indicated by (1.5%) of the respondents that cultivation costs less than KES 2,500 annually, (0.3%) of them indicated that cultivation costs between KES 2,500 and KES 3,000 annually, (1.2%) of them indicated that cultivation costs between KES 3,501 and KES 4,000 annually, (95%) of them indicated that cultivation costs between KES 4,501 and KES 5,000 annually while 2.1% of them indicated that cultivation costs over KES 5,000 annually. According to GoK (2013) and ICO (2019), net revenues from coffee have been on a decline, which has been attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases. Table 30 presents the summary of the statistics pertaining to the annual cost of coffee production.

Table 30

Annual Cost of Cultivating Coffee

What is the annual cost of Cultivating? (KES)	Frequency	Percentage (%)
Up to 2500	5	1.5
2500 - 3000	1	0.3
3501 - 4000	4	1.2
4501 - 5000	323	95
Above 5000	7	2.1
Total	B	100

The Relationship between Annual Cost of Cultivating Coffee and Coffee Productivity

Table 31 indicated that there was no significant interaction between annual cost of cultivating coffee and productivity among coffee farmers in Central Kenya (χ^2=25.525a, p= 0.182).

Table 31

The relationship between annual cost of cultivating coffee and coffee productivity

What is the annual cost for Cultivating	Less than 5000	5,001–20,000	20,001-80,000	80,001-200,000	200,001-500,000	Over 500,000	(χ^2), P (χ^2)
Up to 2500	0.00%	0.00%	3.20%	0.00%	0.00%	0.00%	25.525a, 0.182
2500 - 3000	0.00%	0.00%	0.60%	0.00%	0.00%	0.00%	
3501 - 4000	0.00%	0.00%	1.90%	0.90%	0.00%	0.00%	
4501 - 5000	66.70%	100.00%	92.40%	98.20%	95.80%	100.00%	
Above 5000	33.30%	0.00%	1.90%	0.90%	4.20%	0.00%	

Annual Cost of Planting

The farmers were also requested to indicate the annual cost of coffee planting. It was indicated by (0.3%) of the respondents that planting costs KES 1,000 annually, (3.8%) of them indicated that planting costs KES 1200 annually, 1.8% of them indicated that planting costs KES 1300 annually, (2.9%) of them indicated that planting costs KES 1400 annually, (82.6%) of them indicated that planting costs KES 1500 annually, (5.6%) of them indicated that planting costs KES 1800 annually while (2.9%) of them indicated that planting costs are over 2100 annually. According to GoK (2013) and ICO (2019), net revenues from coffee have been on a decline, this has been attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases. Table 32 presents the summary of the statistics pertaining to the annual cost of coffee planting.

Potts et al. (2007) found that coffee producers had limited access to financing, with many only able to obtain loans at above-market rates. Similarly, Kalinda and Chibwe (2014) identified a lack of financing and high labour costs in Zambia's coffee chain, while Dahlman (2008) emphasised the need for cost-cutting strategies among small-scale coffee producers in

Peru. The findings of this study are consistent with the findings of the previous investigations, as access to productive inputs had a negative influence on economic gains in each of the provider institutional configurations. Kherallah and Kirsten (2002), on the other hand, stated that ratings and requirements are critical for delivering worldwide assurance of quality for an item, lowering knowledge and operational costs, and promoting international trade. They did, however, warn that if these requirements are not followed, they might be utilised as non-tariff trade barriers.

Table 32

Annual Cost of Coffee Planting

What is the annual cost of Planting? (KES)	Frequency	Percentage (%)
1,000	1	0.3
1200	13	3.8
1300	6	1.8
1400	10	2.9
1500	281	82.6
1800	19	5.6
2100	10	2.9
Total	340	100

Annual Cost of Fertiliser

The farmers were also requested to indicate the annual cost of fertiliser application in their farms. It was indicated by most of the respondents (98.8%) that fertiliser application costs less than KES 10,000 annually. According to GoK (2013) and ICO (2019), net revenues from coffee had been on a decline, which was attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases. Table 33 presents the summary of the statistics of the annual cost of fertiliser application.

It should be noted that these findings can be compared to previous studies on maize production, such as the study by Hassan et al. (1998), which showed a 30 percent increase in yield from adopting improved maize varieties and inorganic fertiliser, and the study by Duflo et al. (2003), which in western Kenya, applying inorganic fertiliser resulted in a wide range of output increases (between 28 and 134 percent). Furthermore, Alene et al. (2009) discovered that adopting enhanced maize varieties increased average production by 30% in West and Central African nations. The current study's finding that partial adoption had no effect on maize yields at 2004-2007 TE levels is consistent with the findings of De Groote et al. (2005).

Table 33

Annual Cost of Fertiliser

What is the annual cost of the Fertiliser application? (KES)	Frequency	Percentage (%)
0 - 10,000	336	98.8
10,001 - 30,000	3	0.9
30,001 - 60,000	0	0
60,001 - 90,000	1	0.3
Above 90,000	0	0
Total	340	100

Annual Cost of Manure Application

The farmers were also requested to indicate the annual cost of manure application. It was indicated by more than half of the respondents (85.0%) that manure application costs less than KES 10,000 annually with (14.4%) indicating that manure application costs between KES 10,001 and KES 30,000 annually. Governing body GoK (2013a) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. This falling output has been attributed to the costly fertiliser, inept management of cooperatives, climate change and declining global prices as reported by CBK (2012). In the Sri Lankan tea industry, where small-scale holders dominate, research informs us that they are vulnerable to high input costs and unable to bear the burden of expensive fertiliser (Wandeto, 2019). Table 34 presents the summary of the statistics on the annual cost of manure application.

Table 34

Annual Cost of Manure Application

What is the annual cost of the Manure Application? (KES)	Frequency	Percentage (%)
0 - 10,000	289	85.0
10,001 - 30,000	49	14.4
30,001 - 60,000	1	0.3
60,001 -90,000	0	0
Above 90,000	1	0.3
Total	340	100

Annual Cost of Weeding Labour

The farmers were also requested to indicate the annual cost of weeding labour. It was indicated by most of the respondents (86.0%) that weeding labour costs less than KES 10,000 annually with (12.4%) indicating that weeding labour costs between KES 10,001 and KES 30,000 annually. Governing body GoK (2013) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. This falling output has been attributed to the costly fertiliser, inept management of cooperatives, climate change and declining global prices as reported by CBK (2012). However, in a study conducted by Ogada (2009), it was found that manure application was lower among those who adopted the complete package compared to those who did not adopt it throughout the reference period, although the intensity decreased for both groups in 2007. Those that adopted the bundle had increased application of manure efficiency among intermediate users. In 2007, the intensity of application of manure dropped. To compensate for the decrease in manure application, complete package users raised the frequency of planting applying fertiliser. In 2007, however, the intensity of planting applying fertiliser among intermediate users reduced. Research in Ethiopia, on the other hand, discovered that the coefficient of weeding rate was positive and statistically substantial. This data reveals that increasing weeding frequency boosts a farmer's TE by thirteen percent. This suggests that one of the major factors affecting the coffee yield of smallholder farmers was weeds. These findings are consistent with those of Asten et al. (2011). Table 35 summarises the statistics pertaining to the annual cost of weeding labour.

Table 35

Annual Cost of Coffee Weeding

What is the annual cost for Weeding labour? (KES)	Frequency	Percentage (%)
0 - 10,000	294	86%
10,001 - 30,000	42	12%
30,001 - 60,000	3	1%
60,001 - 90,000	1	0%
Above 90,000	0	0%
Total	340	100

Annual Cost of Spraying Labour

The farmers were also requested to indicate the annual cost of spraying labour. It was indicated by most of the respondents (97.4%) that spraying labour costs between KES 10,001 and KES 30,000 annually. It has been suggested that the Sri Lankan tea industry is facing a significant issue due to the high production costs endured by the numerous small-scale holders in the industry. Research has found that these small-scale producers are particularly sensitive to high input prices and unable to cope with expensive fertilisers, as stated by Wandeto (2019). Table 36 presents the summary of the statistics on the annual cost of spraying labour.

Table 36

Annual Cost of Spraying Labour

What is the annual cost of Spraying labour (KES)	Frequency	Percentage (%)
0 - 10,000	7	2.1
10,001 - 30,000	331	97.4
30,001 - 60,000	1	0.3
60,001 - 90,000	1	0.3
Above 90,000	0	0
Total	340	100

Annual Cost of Coffee Pruning

The farmers were also requested to indicate the annual cost of coffee pruning. It was indicated by most of the respondents (82.4%) that coffee pruning costs less than KES 10,000 annually with (14.7%) indicating that coffee pruning costs between KES 10,001 and KES 30,000 annually. It has been suggested that the Sri Lankan tea industry is facing a significant issue due to the high production costs endured by the numerous small-scale holders in the industry. Research has found that these small-scale producers are particularly sensitive to high input prices and unable to cope with expensive fertilisers, as stated by Wandeto (2019). Table 37 presents the summary of the statistics pertaining to the annual cost of coffee pruning.

Table 37

Annual Cost of Coffee Pruning

What is the Annual cost of Coffee Pruning? (KES)	Frequency	Percentage (%)
0 - 10,000	280	82.4
10,001 - 30,000	50	14.7
30,001 - 60,000	7	2.1
60,001 -90,000	3	0.9
Above 90,000	0	0
Total	340	100

Annual Cost of Coffee Mulching

The farmers were also requested to indicate the annual cost of coffee mulching. It was indicated by most the respondents (99.1%) that mulching costs between KES 30,001 and KES 60,000 annually. Governing body GoK (2013a) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. This falling output has been attributed to the costly fertiliser, inept management of cooperatives, climate change and declining global prices as reported by Coffee Board of Kenya (2012). Table 38 presents the summary of the statistics about the annual cost of coffee mulching.

Table 38

Annual Cost of Coffee Mulching

What is the annual cost of Mulching? (KES)	Frequency	Percentage (%)
0 - 10,000	2	0.6
10,001 - 30,000	0	0
30,001 - 60,000	337	99.1
60,001 - 90,000	1	0.3
Above 90,000	0	0
Total	340	100

Annual Cost of Coffee Harvesting

The farmers were also requested to indicate the annual cost of coffee harvesting. It was indicated by most of the respondents (70.6%) that harvesting costs less than KES 10,000 annually while (26.8%) indicating that harvesting costs between KES 10,001 and KES 30,000 annually. Governing body GoK (2013a) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. This falling output has been attributed to the costly fertiliser, inept management of cooperatives, climate change and declining global prices as reported by CBK (2012). Table 39 presents the summary of the statistics of the annual cost of coffee harvesting.

Research has demonstrated that employing an improved type of coffee trees can substantially increase farmers' TE. Specifically, in the researched area, those growing the BM139 variety of Arabica coffee were found to be more technically efficient than those using lower-yielding varieties such as Jackson 2/1257. Studies from Pakistan, Zambia and Ethiopia by Fatima and Azeem (2018), Chiona et al. (2014) and Sorsie et al. (2015) highlighted the importance of modern and advanced crop varieties in raising production and efficacy. Furthermore, farming approaches emerged as factors affecting technical inefficiency, with mono-cropping schemes revealed to boost coffee growers' TE. This finding is consistent with Binam et al.'s (2003) findings that accentuated the merits of the mono-crop technique for growing coffee producers' efficiency in Cote d'Ivoire.

Table 39

Annual Cost of Coffee Harvesting

What is the annual cost of Harvesting? (KES)	Frequency	Percentage (%)
0 - 10,000	240	70.6
10,001 - 30,000	91	26.8
30,001 - 60,000	4	1.2
60,001 -90,000	5	1.5
Above 90,000	0	0
Total	340	100

Pilot Results

The researcher conducted a pilot analysis to assess the questionnaires' reliability and validity. It checked whether the question design was rational and if the questions were straightforward to understand. The pilot study helped to determine the time respondents took to complete the survey. The researcher used the pre-test to see whether the variables gathered could be efficiently processed and evaluated. The questionnaire was adjusted accordingly to suit the respondents in terms of comprehension and time taken. The pre-testing was done on a 5% subset of the total number of respondents. Since the study targets a total of 384 respondents, a total of 20 small-scale farmers were used in the pilot study. Since the study area is the Mount Kenya region, the respondents for the pilot test were selected from a different location. Nakuru area produced the participants for the pilot test. Its selection was because of proximity, it is near the area of study and two, it produces quite a significant amount of coffee in the region.

Test for Construct Validity

The results indicate that all the 32 statements included in the analysis have a significant KMO value. That is, the KMO of 0.642 was greater than 0.5 and the respective significance value of 0.000 was less than 0.05. Thus, it is viable to conduct a Confirmatory Factor Analysis for the study (Williams et al., 2010). The results are presented in Table 40.

Table 40

Factorial Test Results for Construct Validity

		Bartlett's Test of Sphericity			
Variable	MO	Approx. Chi-Square	df	Sig.	Conclusion
All the 32 statements	0.642	4173.707	96	0.000	Valid

Note:

- *Question 43 and Question 48 were not included since they both had 100% missing values.*
- *Factorial Test excluded the demographic variables.*

Communalities

As per Kaiser (1974), some of the statements were valid (given an extraction of greater than 0.5) while others were not valid (given an extraction of less than 0.5). This led to the confirmatory Factor Analysis to identify the various factor loadings. The results are presented in Table 41.

Table 41

Communalities

Statements	Initial	Extraction	Cut-off	Conclusion
Which of the following are you a member of?	1.0	0.2	0.5	Not accepted
Do you get visits from extension officers	1.0	0.7	0.5	Accepted
How often do extension officers' visit?	1.0	0.5	0.5	Accepted
Who are the providers of extension services in your area?	1.0	0.1	0.5	Not accepted
Are you certified	1.0	0.0	0.5	Not accepted
What kind of certifications have you complied with?	1.0	0.0	0.5	Not accepted
Do you get direct sales contracts	1.0	0.5	0.5	Accepted
How do you sell your coffee	1.0	0.8	0.5	Accepted
Did you have access to formal/informal credit last season?	1.0	0.2	0.5	Not accepted
From which institution do you get credit and how much	1.0	0.1	0.5	Not accepted
How much did you borrow in the previous season?	1.0	0.6	0.5	Accepted
Are you associated with the following groups?	1.0	0.6	0.5	Accepted

Do you receive any type of training?	1.0	0.0	0.5	Not accepted
How often do you receive training per year?	1.0	0.2	0.5	Not accepted
Which coffee varieties have you planted	1.0	0.0	0.5	Not accepted
Which other farming activity are you engaged in?	1.0	0.0	0.5	Not accepted
What fertiliser products do you use and what is the quantity used in a year?	1.0	0.0	0.5	Not accepted
How much does it cost you for the fertiliser?	1.0	0.3	0.5	Not accepted
Do you use herbicides	1.0	0.7	0.5	Accepted
How much does it cost you for the herbicide?	1.0	0.2	0.5	Not accepted
Do you use fungicides	1.0	0.8	0.5	Accepted
How much does it cost you for the fungicides	1.0	0.1	0.5	Not accepted
Are there biological methods you use?	1.0	0.2	0.5	Not accepted
Do you use technology in pruning	1.0	0.8	0.5	Accepted
How often is pruning done?	1.0	0.4	0.5	Not accepted
How much does it cost you in a year?	1.0	0.5	0.5	Accepted
Do you use technology in cultivation?	1.0	0.7	0.5	Accepted
Do you use technology in irrigation	1.0	0.8	0.5	Accepted
Do you use technology in pruning	1.0	0.3	0.5	Not accepted
Do you use technology in pruning	1.0	0.3	0.5	Not accepted
How much did you get from the sale of coffee in the last season?	1.0	0.7	0.5	Accepted
How much did you receive from other farming activities	1.0	0.5	0.5	Accepted

Extraction Method: Principal Component Analysis.

Confirmatory Factor Analysis

Confirmatory Factor Analysis CFA) was used in conjunction with Principal Component Analysis (PCA) to derive several components from the questionnaire's 32 statements. Because it is easier to comprehend three factors, this study chose to use the criteria of specifying the maximum number of factors rather than using Eigenvalues of one for efficient conceptualisation. The Varimax rotation result shows that, of the 32 components, the top four extracted factors accounted for 15.4%, 23.1%, 30.1%, and 35.6% of the total variance, meaning that these 32 assertions may be loaded into three factors. Exploratory Factor Analysis (EFA) has been used in previous research to study potential underlying variables influencing leadership (Willmer et al., 2019). The results are as shown in table 42 for the total variance explained and figure 13 for the scree plot.

Table 42

Total Variance Explained for the Statements

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.3	6.5	16.5	.3	16.5	16.5	.2	16.3	16.3
2	3.6	11.2	27.7	.6	11.2	27.7	3.3	10.4	26.8
3	1.7	5.4	33.1	.7	5.4	33.1	2.0	6.3	33.1
4	1.6	.0	38.0						
5	1.5	4.8	42.9						
6	1.4	4.3	47.2						
7	1.2	3.9	51.0						
8	1.2	3.7	54.7						
9	1.2	3.6	58.3						
10	1.1	3.3	61.7						
11	1.1	3.3	64.9						
12	1.0	3.2	68.2						
13	1.0	3.0	71.2						
14	0.9	3.0	74.1						
15	0.9	2.7	76.9						
16	0.8	2.6	79.5						
17	0.8	2.4	81.9						
18	0.7	3	84.2						
19	0.7	2.2	86.4						
20	0.6	2.0	88.4						
21	0.6	1.9	90.3						
22	0.5	1.7	92.0						
23	0.5	1.6	93.5						
24	0.4	1.4	94.9						
25	0.4	1.2	96.1						
26	0.4	1.1	97.2						
27	0.3	0.8	98.0						

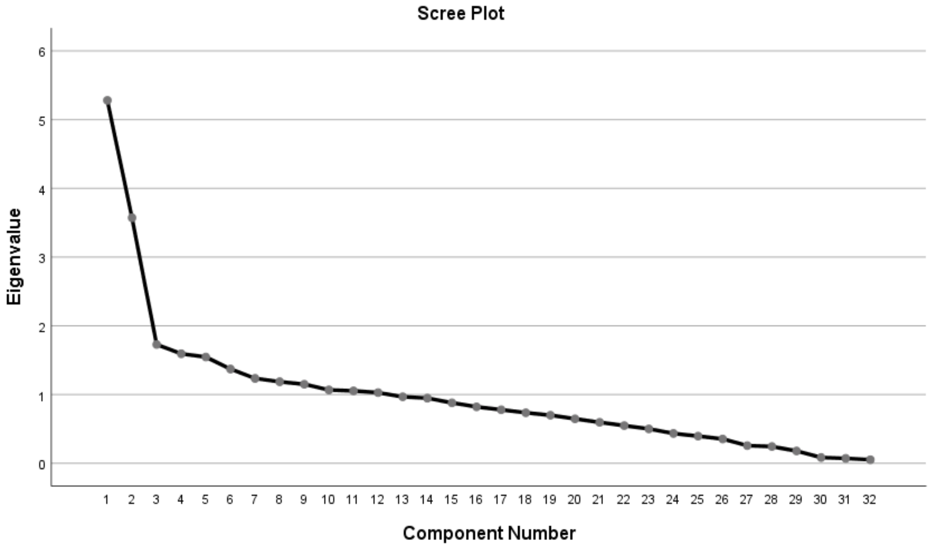
28	0.2	0.8	98.8
29	0.2	0.6	99.4
30	0.1	0.3	99.6
31	0.1	0.2	99.8
32	0.1	0.2	100.0

Extraction Method: Principal Component Analysis

The results of Figure 13 shows that the factors from the study can be extracted/loaded into 3 factors.

Figure 13

Item Scree Plot



Unrotated Factor Loadings

Table 43

Unrotated Factor Loadings

Component Matrix a	1	2	3
Which of the following are you a member of?	-0.37	0.11	-0.12
Do you get visits from extension officers	-0.16	0.63	-0.49
How often do extension officers’ visit?	-0.08	0.62	-0.37
Who are the providers of extension services in your area?	0.20	0.24	0.11
Are you certified	0.01	0.04	0.05
What kind of certifications have you complied with?	0.00	0.11	0.07
Do you get direct sales contracts	-0.70	-0.01	0.22
How do you sell your coffee	0.12	0.86	0.21
Did you have access to formal/informal credit last season?	-0.24	0.19	-0.36
From which institution do you get credit and how much	-0.06	-0.09	-0.23
How much did you borrow in the previous season?	0.62	0.07	0.01
Are you associated with the following groups?	0.73	-0.03	0.21
Do you receive any type of training?	0.03	0.12	-0.06
How often do you receive training per year?	0.30	-0.27	-0.03
Which coffee varieties have you planted	-0.07	-0.06	0.18
Which other farming activity are you engaged in?	-0.04	0.09	-0.17

What fertiliser products do you use and what is the quantity used in a year?	0.00	-0.10	0.19
How much does it cost you for the fertiliser?	0.47	0.07	0.26
Do you use herbicides	-0.82	0.10	0.12
How much does it cost you for the herbicide?	0.22	0.00	0.43
Do you use fungicides	-0.87	0.18	0.08
How much does it cost you for the fungicides	0.12	0.03	-0.28
Are there biological methods you use?	0.11	0.31	0.25
Do you use technology in pruning	-0.20	-0.83	-0.24
How often is pruning done?	0.19	0.61	0.03
How much does it cost you in a year?	0.70	0.02	-0.22
Do you use technology in cultivation?	-0.33	0.03	0.58
Do you use technology in irrigation	-0.12	0.11	0.07
Do you use technology in pruning	0.11	0.51	0.16
Do you use technology in pruning	0.05	0.53	0.08
How much did you get from the sale of coffee in the last season?	0.79	-0.15	-0.06
How much did you receive from other farming activities	0.66	0.23	-0.01

Extraction Method: Principal Component Analysis.

4 components were extracted.

Rotated Factor Loadings

The results were computed using SPSS to compare the variance explained and the rating results are presented in Table 44 The results confirm that based on the Rotated Factor Loadings, there are 3 distinctive variables/factors that can be extracted from the research questions. That is all the 32 factors can be loaded into 3 factors as shown by the highlighted columns. The results are as shown in table 4.31 below.

Table 44

Rotated Factor Loadings

Pattern Matrix a	1	2	3
Do you use fungicides	-0.886	0.073	0.023
Do you use herbicides	-0.830	0.020	-0.042
How much did you get from the sale of coffee in the last season?	0.807	-0.043	-0.032
How much does it cost you in a year?	0.713	0.031	0.184

Are you associated with the following groups?	0.711	0.158	-0.224
Do you get direct sales contracts	-0.711	-0.023	-0.180
How much did you receive from other farming activities	0.625	0.297	0.073
How much did you borrow in the previous season?	0.605	0.152	0.000
How much does it cost you for the fertiliser?	0.431	0.231	-0.227
Which of the following are you a member of?	-0.366	-0.002	0.164
How often do you receive training per year?	0.326	-0.219	-0.089
Who are the providers of extension services in your area?	-0.214	0.144	0.201
Do you use technology in irrigation	-0.139	0.107	-0.016
How do you sell your coffee	0.001	0.880	0.140
Do you use technology in pruning	-0.085	-0.875	-0.095
How often is pruning done?	0.114	0.598	0.205
Do you use technology in pruning	0.035	0.540	0.045
Do you use technology in pruning	-0.015	0.518	0.133
Are there biological methods you use?	0.053	0.393	-0.112
What kind of certifications have you complied with?	-0.019	0.129	-0.019
Are you certified	0.001	-0.052	0.028
Do you get visits from extension officers	-0.192	0.362	0.706
How often do extension officers' visit?	-0.122	0.406	0.588
Do you use technology in cultivation?	-0.383	0.207	-0.508
Did you have access to formal/informal credit last season?	-0.226	0.004	0.411
How much does it cost you for the herbicide?	0.184	0.196	-0.406
How much does it cost you for the fungicides	0.142	-0.066	0.263
What fertiliser products do you use and what's the quantity used in a year?	-0.003	-0.015	-0.208
Which other farming activity are you engaged in?	-0.032	0.014	0.196
Which coffee varieties have you planted	-0.080	0.000	-0.185
From which institution do you get credit and how much	-0.025	-0.174	0.177
Do you receive any type of training?	0.022	0.09	0.103

Extraction Method: Principal Component Analysis.

Rotation Method: Oblimin with Kaiser Normalisation.

a Rotation converged in 5 iterations.

Results of Findings; Research Question no. 1

The results of the findings are presented below based on the study research questions. The study Research Question no. 1 was how do relational agencies (Agro management services, extension officers, marketing agents) improve on TE in coffee farming in central Kenya? The answer to the research question is documented through the institutional membership as per below subsections.

Institutional Membership

The farmers were also requested to indicate their institutional membership. The findings indicated that 3.2% of the respondents are members of CMS/SMS, 4.7% of them are members of KF/OCML, 5.3% of them are members of Tropical/NKG, 1.2% of them are members of Kahawa bora, while 4.4% of them are members of Sasini. In this regard, the findings are in tandem with Bwabo et al. (2016) that cooperatives had a great contribution to the production of coffee as they enabled members (small scale holder farmers) to get inputs at reasonable prices, provide extension services, provide credits at reasonable interest rates, provide coffee processing as well as finding markets on behalf of farmers at regional, national and international levels. Sabari (2020) noted that effective management of coffee institutions can revive coffee production, resulting in better national income and economic growth. Additionally, cooperative societies enable coffee farmers to connect with government institutions and access farm inputs and seedlings, which encourages them to produce high quality coffee. The findings were tabulated in Table 45.

Table 45

Institutional Membership

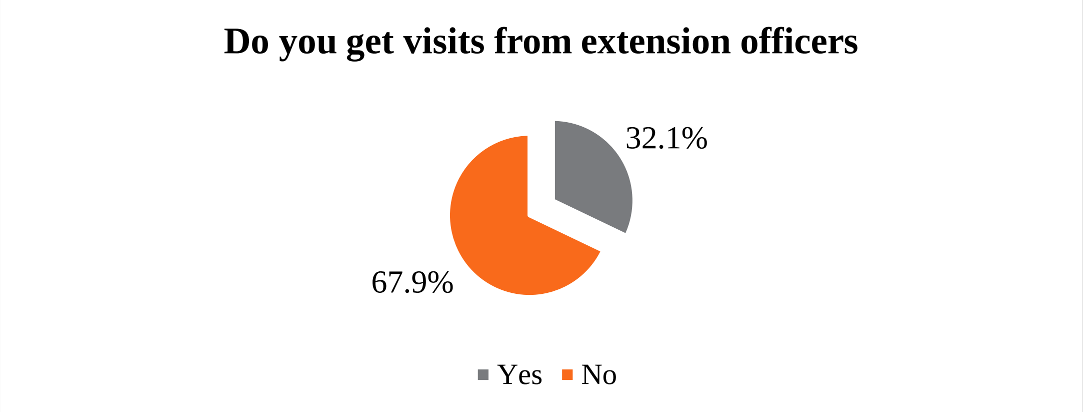
Which of the following are you a member of?	Frequency	Percentage (%)
CMS/SMS	11	3.2
KF/OCML	16	4.7
Tropical/NKG	18	5.3
Kahawa bora	4	1.2
Sasini	15	4.4
Others	276	81.2
Total	340	100

Visitation from Extension Officers

The farmers were also requested to indicate whether they get visits from extension officers. More than half of the respondents (67.9%) indicated that they do not get visits from extension officers while 32.1% of them indicated that they do get visits from extension officers. This is likely to lead to low productivity of coffee production since, extension services tend to lead to notable changes in attitudes and technology adoption and improved life quality as determined by housing, education, and health. The agricultural extension plays an imperative role in disseminating innovation to improve the harvest (Luusaa et al., 2018). The findings were presented in Figure 14.

Figure 14

Visitation from Extension Officers



Frequency of Visitation from Extension Officers

Farmers were requested to indicate how often they got visits from the extension officers. The results indicated that (12.8%) get visits from extension officers weekly, (9.2%) of them get visits from extension officers monthly, 44.0% of them get visits from extension officers on a quarterly basis, (23.0%) of them get visits from extension officers biannually, while (11.0%) of them get visits from extension officers annually. The findings were presented in Table 46.

Table 46

Frequency of Visitation from Extension Officers

How often do extension officers' visit?	Frequency	Percentage (%)	Valid Percentage (%)
Weekly	14	4.1	12.8
Monthly	10	2.9	9.2
Quarterly	48	14.1	44.0
Biannual	25	7.4	23.0
Yearly	12	3.5	11.0
Valid Total	109	32.1	100
Never	231	67.9	
Total	340	100	

Providers of Extension Services

The farmers were also requested to indicate who the providers of extension services were/are. The results indicated that (19.3%) of the respondents get extension services from NGOs, (12.8%) of them get extension services from the government, (19.3%) of them get extension services from Milling liason, (28.4%) of them get extension services from managing agents, while 20.2% of them get extension services from other providers. These extension services have been supported by Ahmed et al. (2015) to have a positive impact on TE. The extension services are customarily seen as methods for disseminating innovation from research stations to farmers (Luusaa et al., 2018). The findings were presented in Table 47.

Table 47

Providers of Extension Services

Who are the providers of extension services in your area?	Frequency	Percentage (%)	Valid Percentage (%)
NGO	21	6.2	19.3
Government	14	4.1	12.8
Milling liason	21	6.2	19.3
Managing agents	31	9.1	28.4
Others	22	6.5	20.2
Valid Total	109	32.1	100
Nil	231	67.9	
Total	340	100	

Certification of the Farmers

The farmers were also requested to indicate if they were certified coffee producers. The findings indicate that (92.9%) of the respondents are not certified coffee farmers while (7.1%) of them indicated that they are certified coffee farmers. According to Muriithi et al. (2018), multiple advantages are stemming from accreditation. Most importantly, the attainment of a coffee certificate opens new networking opportunities for small farmers. The lack of proper networks vital to sharing and learning new farming techniques and gaining access to vital agricultural supplies like seed and fertiliser has been a significant impediment to coffee farming. Kangile et al. (2021), indicated that the level of coffee certification is low, being constrained by unawareness and inaccessibility, the prevalence of coffee diseases, failure in realising price advantages, and certification not being cost effective. Therefore, economies of scale, experience, and participation in collective actions are significant factors affecting coffee farmers' decision to join certification schemes. The findings were presented in Figure 15.

Figure 15

Certification of the Farmers

Type of Certification complied with Common Code Certification

The farmers were also requested to indicate the type of certification they complied with common code certification. The findings indicate that more than half of the respondents (62.5%) indicated that they comply with common code certification while (37.5%) of them comply with Fairtrade certification. Likewise, according to a study on Indonesian coffee farmers, fair trade certification led to improved incomes because of technological transformation as noted by (Sarirahayu & Aprianingsih, 2018). In Kenya, the common code coffee certification or the 4C aims to create a standardised output; focusing on improving coffee quality, reducing farming costs, and uniting the coffee producers (Voora et al., 2019). It mainly focuses on large scale producers such as those producing over 20 tonnes of coffee. Another certification for Kenyan coffee is UTZ certified. The programme focuses on improving coffee growers' livelihoods together with their families by improving their living conditions. It, thus, aims at protecting the rights of the vulnerable in the community, wild lands, and wild animals (Voora et al., 2019).

According to the study, producers from certified coffee co-ops who had the capacity to select, decide, and hold accountable were more lucrative, with 0.27 units greater economic gains. This implies that producers in certified coffee co-ops can profit financially. However, the study discovered that in both certified and non-certified coffee co-ops, the ability to negotiate had a negative association with economic advantages. Farmers' signs of dialogue with coffee chain players such as milling companies, advertisers, and purchasers were used to assess their capacity to bargain. Respondents cited difficulties in discussions, such as verbal commitments not being honoured and millers bribing farmers for votes. The findings are in Table 48.

Table 48

Type of Certification

What kind of certifications have you complied with?	Frequency	Percentage (%)	Valid Percentage (%)
Common code certification	15	4.4	62.5
UTZ Certified	9	2.6	37.5
Valid Total	24	7.1	100
Nil	316	92.9	
Total	340	100	

Receipt of Direct Sales Contracts

The farmers were also requested to indicate whether they get direct sales contracts. The findings indicate that majority of the respondents (97.9%) indicated that they do not get direct sales contracts while (2.1%) of them get direct sales contracts. The findings were presented in Figure 16.

Figure 16

Receipt of Direct Sales Contracts

Coffee Marketing Agents

The farmers were also requested to indicate coffee marketing agents that facilitate their coffee marketing. The results indicated that (0.3%) of the respondents sell their coffee directly to exporters, (59.1%) of them sell their coffee via marketing agents, (2.4%) of them sell their coffee via millers while (37.6%) of them sell their coffee through cooperatives. The findings also corroborated with those of EPZA that marketing agents offer samples to buyers and assist producers in the auction process. CBK issues distinctive classification of licenses in marketing, such as warehouse license, roaster license, packaging license, auctioneering license (EPZA, 2005). The marketing agents with coffee auction permits are lawfully permitted to participate in the weekly auction. Many farmers feel that marketing agents promise the farmers an equitable share of the sale price and higher profit margins to land lucrative marketing contracts, but ultimately change very little (AFA, 2019). The findings were presented in Table 49.

Table 49

Coffee Marketing Agents

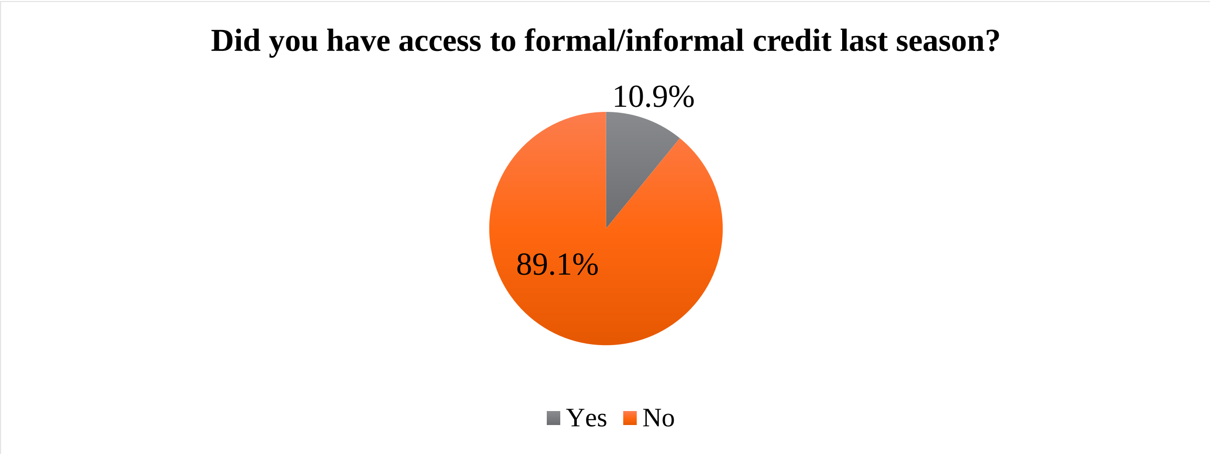
How do you sell your coffee	Frequency	Percentage (%)
Directly to exporters	1	0.3
Through marketing agents	201	59.1
Through millers	8	2.4
Through cooperatives	128	37.6
Others	2	0.6
Total	340	100

Access to Formal/Informal Credit in the Last Season

The farmers were also requested to indicate whether had access to formal/informal credit last season. The findings indicate that majority of the respondents (89.1%) have had no access to formal/informal credit last season while on the other hand (10.9%) of them indicated that they have never had have access to formal/informal credit last season. Access to credit was revealed by Nchare (2007) to be one of the greatest influencers of the TE of smallholder coffee farmers in Cameroon. Credit availability also impacts the TE of farming. According to Nyagaka et al. (2010), credit use significantly influenced TE. They noted that increasing credit to the Irish farmers would increase the TE of its production. Credit availability helped farmers acquire farm inputs such as seeds and fertilisers and make timely decisions about their farming. Kehinde and Ogundeji (2022) indicated that access to credit and cooperative services significantly influences the probability of farmers having higher productivity than farmers with no access to credit. The findings were presented in Figure 17.

Figure 17

Access to Formal/Informal Credit in the Last Season



Institution that Offered Credit

The farmers were also requested to state the institution that offered them the credit. The results indicated that (7.6%) of the respondents receive credit from commercial banks, (23.8%) of them receive credit from Saccos, (31.5%) of them receive credit from chamas, (21.2%) of them receive credit from factory/society while (12.4%) of them receive credit from friends/relatives. Kamau et al. (2016) also established that credit availability positively and significantly influenced TE. They clarified that the coffee farming sector is highly dependent on farm inputs such as fertiliser, pesticides, and seedlings, all of which must be purchased. Farmers, therefore, need to obtain credit from either the cooperatives or financial sectors to succeed in this venture. Thus, as credit access increases, so does the coffee productivity. Kamakia (2016) revealed that only (76.42%) of the farmers in Kirinyaga county Kenya had access to credit vouchers which they utilised for paying school fees thus it had no positive impact in increasing coffee production. The findings were presented in Table 50.

Table 50

Institution that Offered Credit

From which institution do you get credit and how much	Frequency	Percentage (%)
Commercial banks	26	7.6
Saccos	81	23.8
Chamas	107	31.5
Factory/society	72	21.2
Friends/relatives	42	12.4
Others/Own savings	12	3.5
Total	340	100

Amount Borrowed in the Previous Season

The farmers were also requested to state the amount they borrowed in the previous season. The results indicated that in the previous season, (13.5%) of the respondents borrowed up to KES 10,000, 54.1% of them borrowed between KES 10,000 and KES 50,000, (24.3%) of them borrowed between KES 50,001 and KES 100,000, (5.4%) of them borrowed between KES 100,001 and KES 200,000 while (2.7%) of them borrowed over KES 200,000. The Nigerian cassava farmers were found to have achieved higher productivity when access to credit was provided. Consequently, credit institutions should strive to extend their services to rural farming households, to further capitalise on the benefits of such credit (Awotide et al., 2015). The findings were presented in Table 51.

Table 51

Amount Borrowed in a Previous Season

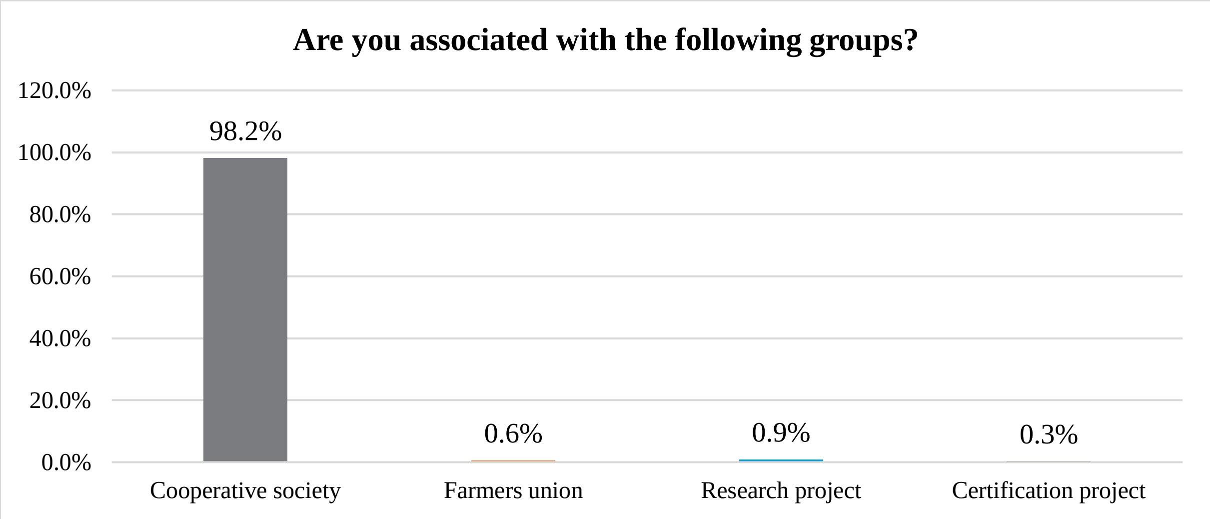
How much did you borrow in the previous season? (KES)	Frequency	Percentage (%)	Valid Percentage (%)
Up to 10,000	5	1.5	13.5
10,000 – 50,000	20	5.9	54.1
50,001 – 100,000	9	2.6	24.3
100,001 - 200,000	2	0.6	5.4
Over 200,000	1	0.3	2.7
Valid Total	37	10.9	100
Nil	303	89.1	
Total	340	100	

Association of the Farmers

The farmers were also requested to state whether they were associated with the following groups: cooperative society, farmers union, research project, training project, certification project, NGO project or any others. The results indicated that most of the respondents (98.2%) are associated with cooperative societies. Cooperatives offer various kinds of assistance to members and are key decision-makers on essential matters (Hasen & Mekonnen, 2017). Additionally, cooperatives lessen transfer fees and information disparity by reinforcing farmers' concession capacity (Trebbin, 2014). According to Chokera (2011), cooperatives are an autonomous union of people who have come together freely to run a business that satisfies their shared economic, social, and cultural needs and objectives. Such initiatives help farmers attain economies of scale by reducing their input costs or availing services such as storage and transport, as well as enhancing selling prices. However, Kenyan farmers have little market expertise, and existing member enterprises lack the necessary structural support to act as farmers' feedback channels (Chege, 2012). Figure 18 provided the findings.

Figure 18

Association of the Farmers

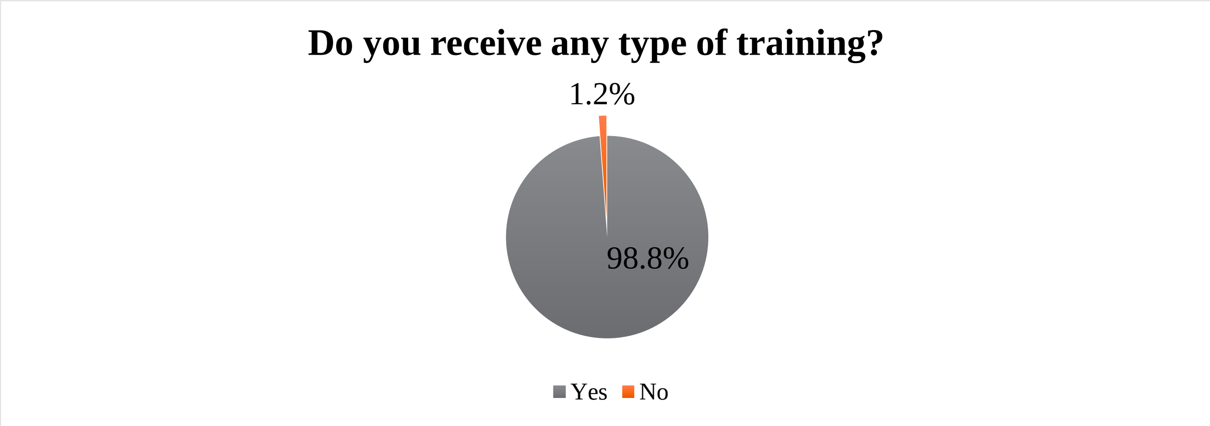


Receipt of Training in Coffee Production

The farmers were also questioned about any instruction they may have received. The findings showed that 99.8% of the respondents have training in coffee production. The degree of technical knowledge and skills among smallholder coffee producers in Kenya, according to Mati (2016), is extremely low. This hinders their efforts to raise the standard of the coffee and the effectiveness of production, thereby improving their method of generating cash. According to IFC (2022), a lack of agricultural training systems and insufficient public sector assistance for the sector, particularly in terms of material inputs like seeds and fertiliser and technical instruments, are to blame for poor performance and productivity. Figure 19 reported the findings.

Figure 19

Receipt of Training



Frequency of Training Per Year

The farmers were requested to state how often they receive training per year. The results indicated that most (83.8%) receive training pertaining to coffee production twice a year. In 2017, several coffee associations trained their staff on the importance of applying new technologies and have witnessed tremendous financial benefits. The cooperatives can produce high-quality coffee to attract higher prices in the international markets (McArthur & McCord, 2017). The findings were presented in Table 52.

Table 52

Frequency of Annual Training

How often do you receive training per year?	**Frequency**	**Percentage (%)**
Once	1	0.3
Twice	285	83.8
3 times	51	15
4 times	1	0.3
6 times	1	0.3
12 times	1	0.3
Total	340	100

Results of Findings; Research Question no. 2

The findings for the study research question no.2 which sought to get the difference in technology use (improved cultivars, mechanised, bio-inputs) between young coffee farmers and post-youth coffee farmers was elaborated by the findings on the coffee varieties planted, chemicals used and technical knowhow in operations. The subsections below elucidate the salient activities to address the research question no.2.

Type of Coffee Varieties Planted

The farmers were also requested to indicate the type of coffee varieties they planted. The results indicated that most of the respondents (83.8%) grow the Batian cultivars, (7.1%) grow the Ruiru 11 cultivar while 9.1% of them grow both varieties of coffee. These findings are in line with Kiwelu et al. (2021) showed that the yield potential for improved and traditional coffee varieties respectively has not yet been realised by farmers. That is, there is a large gap between the average coffee yield gained by smallholder farmers growing improved coffee varieties and farmers growing traditional coffee varieties respectively. As indicated by Ngango and Kim (2019), 82% of the Kenya farmers cultivate BM139 variety of Arabica coffee, while the remaining 18% grow Jackson 2/1257 variety. Furthermore, cultivation of improved variety of coffee trees, and the cropping system enhance farmers' TE. Their research also revealed that utilisation of an improved variety of coffee trees significantly boosts TE of the farmers. Moreover, it was observed that farmers cultivating BM139 are technically more efficient than those with low yielding varieties such as Jackson 2/1257 (Fatima & Khan, 2015). Similarly, Geffersa et al. (2019) suggested that selection of proper maize varieties is fundamental for production TE. Additionally, Anang et al. (2020) suggested adoption of proper varieties improves TE in maize production in Ghana. The findings were presented in Table 53.

Table 53

Type of Coffee Varieties Planted

Which coffee varieties have you planted	Frequency	Percentage (%)
Batian cultivar	285	83.8
Ruiru 11 cultivar	24	7.1
Both	31	9.1
Total	340	100

Other farming activity besides Coffee Planting

The farmers were also requested to indicate other farming activities besides coffee planting. Apart from coffee production, the findings indicated that (23.2%) of the respondents produce food crops, 20% of them keep livestock, (25.6%) of their practice, poultry while 31.2% of them practice mixed farming. According to Shumet (2012), off farming activities alongside the gender of the farmer, and the method of irrigation have no significant effect on TE. The findings were presented in Table 54.

Table 54

Other farming activity

Which other farming activity are you engaged in?	Frequency	Percentage (%)
Food Crops	79	23.2
Livestock keeping	68	20
Poultry rearing	87	25.6
Mixed farming	106	31.2
Total	340	100

Fertiliser Type Used in Coffee Production

The farmers were also requested to indicate the fertiliser products do you use and what is the quantity used in a year. The results indicated that (17.9%) of the respondents use DAP in coffee production, (30%) of them use CAN in coffee production, (16.2%) of them use SSP in coffee production and (17.9%) of them use mulch in coffee production. Some researchers have highlighted the use of fertilisers as a determinant of TE in farming. Widjaya et al. (2017)

indicated that organic and inorganic fertiliser was not efficient. The study found out that the commonly used inorganic fertilisers were urea, Ponska, and ZA. According to Ngoe et al. (2016), fertiliser increases significantly influenced the output. They noted that cocoa did well with a lot of fertiliser applications. Mesay et al. (2013) also revealed that the availability of inputs such as fertilisers and market availability increased the wheat production efficiency level. According to Capa (2015) although medium-high fertilisation rates recommended by experts gave high coffee yields and income, such treatments produced high N2O emissions and thus, led to low production/N2O emissions ratios of 208 for medium fertilisation, and of 188 for high fertilisation. Low fertilisation gave a high production/N2O ratio of 603, and an income of 7606 USD/ha higher than control, of 3524 USD/ha. The application of half the mineral fertilisation rates was thus recommended for coffee growers in Ecuador for a sustainable management of monoculture coffee plantations (Capa, 2015). The findings were presented in Table 55.

Table 55

Fertiliser Type Used in Coffee Production

What fertiliser products do you use?	Frequency	Percentage (%)
DAP	61	17.9
CAN	102	30
SSP	55	16.2
Others	61	17.9
Mulch	61	17.9
Total	340	100

Cost of Fertiliser in Coffee Production

The farmers were also requested to indicate the cost of fertiliser in coffee production. The results showed that (27.4%) of the respondents indicated that fertiliser costs less than KES 5,000, (35.3%) of them indicated that fertiliser costs between KES 5,000 and KES 10,000, (17.1%) of them indicated that costs between KES 10,001 and KES 20,000, (18.2%) of them indicated that fertiliser costs between KES 20,001 and KES 40,000, (1.5%) of them indicated that fertiliser costs between KES 40,001 and KES 80,000 while (0.6%) of them more than KES 10,0,000. Governing body GoK (2013a) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. This falling output has been attributed to the costly fertiliser, inept management of cooperatives, climate change and declining global prices as reported by Coffee Board of Kenya (2012). In the Sri Lankan tea industry, the issue of study has been provoked by smallholders, who dominate the industry, enduring high production costs. Being vulnerable to expensive input prices and unable to tolerate high fertiliser costs, they have been severely affected (Wandeto, 2019). The findings were presented in Table 56.

Table 56

Cost of Fertiliser

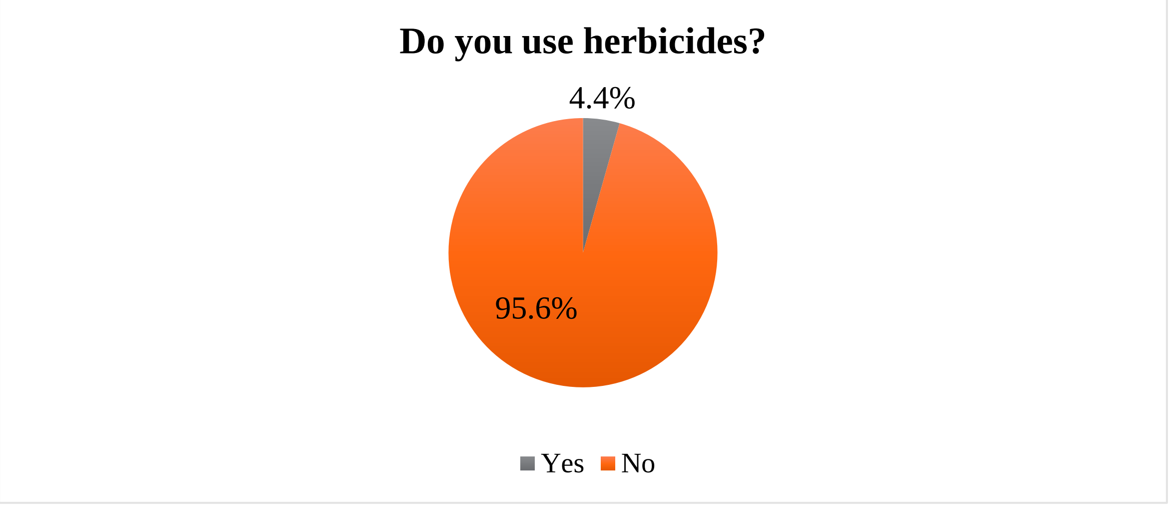
How much does it cost you for the fertiliser? (KES)	Frequency	Percentage (%)
Less than 5000	93	27.4
5000 - 10,000	120	35.3
10,001 - 20,000	58	17.1
20,001 - 40,000	62	18.2
40,001 - 80,000	5	1.5
Above 100,000	2	0.6
Total	340	100

Use of Herbicides in Coffee Production

The farmers were also requested to indicate whether they use herbicides in coffee production. The results revealed that most of the respondents (95.6%) do not use herbicides in coffee production while (4.4%) of them use herbicides in coffee production. The same has been seen in the case of Nigerian farmers where more than (80%) of the households relate their poverty status to problems in agriculture, of which lack of agricultural inputs and not being able to afford inputs (such as fertilisers and seeds) (Oseni and Winters, 2009). That' s why the huge gap in fertiliser use compared to recommended fertiliser levels is often given as one of the main reasons for low agricultural productivity in Nigeria (Amare et al., 2017). The findings were presented in Figure 20.

Figure 20

Use of Herbicides in Coffee Production



Cost of Herbicides in Coffee Production

The farmers were also requested to indicate the cost of herbicides in coffee production. The results show that many of the respondents (96.5%) indicated that herbicide costs between 10,001 and KES 20,000. Governing body GoK (2013) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. Meyo and Egoh (2020) also found that the estimated coefficients for the unit costs of fertiliser, herbicides, and labour were negative but not significant, whereas those for land and hybrid seeds were positive. Production response will greatly increase when input prices are low because of input subsidies. Improved non-labour determinants, such as hybrid and open-pollinated seeds, fertilisers, insecticides, fungicides, herbicides, and manure, have been categorised as improved variable inputs (Adesina & Zinnah, 1993). Only 30% of the 60 farmers used herbicides due to factors such as the high cost of herbicides (Meyo & Egoh, 2020). Table 57 presented the findings.

Table 57

Cost of Herbicides

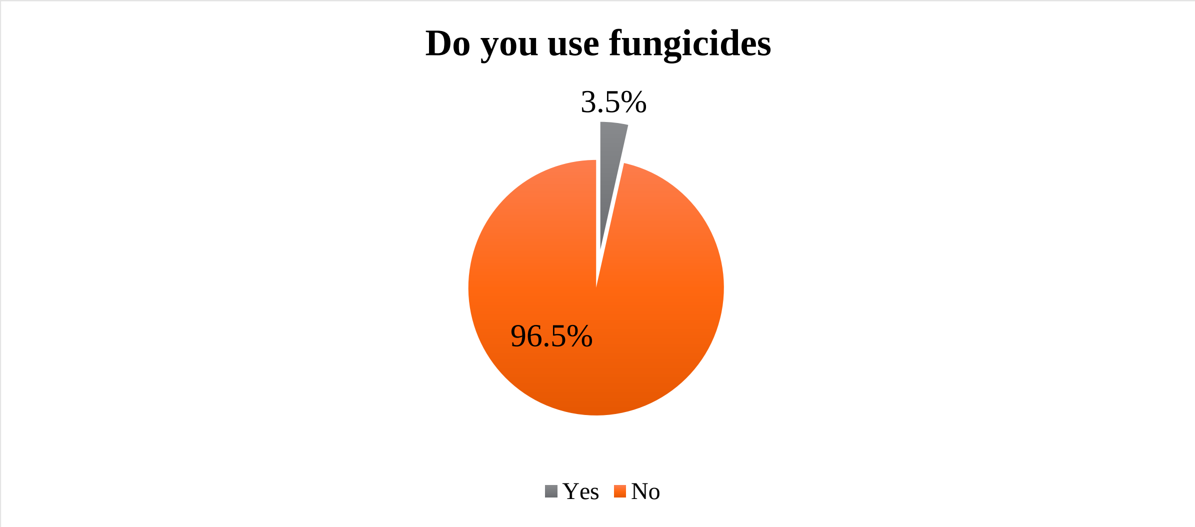
How much does it cost you for the herbicide? (KES)	Frequency	Percentage (%)
Less than 5000	5	1.5
5000 - 10,000	4	1.2
10,001 - 20,000	328	96.5
20,001 - 40,000	2	0.6
80,001 - 100,000	1	0.3
Total	340	100

Use of fungicides in Coffee production

The farmers were also requested to indicate whether they use fungicides in coffee production. The results show that many of the respondents (96.5%) do not use fungicides in coffee production while 3.5% of them use fungicides in coffee production. The same has been attributed to the case of farms in remote locations which tend to lack adequate access to roads and transportation. This increases transaction costs and hampers agricultural and economic growth (Thacker et al., 2019). While efficient use of fertilisers, pesticides, and human labour can increase yields (Devkota et al., 2019; Emran et al., 2019), many inputs may not be readily available in markets. In addition, rural agricultural labour availability is decreasing, with workers and youth. Households that applied fertiliser inputs as well as pesticides were positively high income (Yurie et al., 2017). The findings were presented in Figure 21.

Figure 21

Use of fungicides in Coffee Production



Cost of Fungicides in Coffee Production

The farmers were also requested to indicate the cost of fungicides in coffee production. The results show shows that many of the respondents (97.1%) indicated that fungicides costs between 10,001 and KES 20,000. Governing body GoK (2013) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. Meyo and Egoh (2020) also found that the estimated coefficients for the unit costs of fertiliser, herbicides, and labour were negative but not significant, whereas those for land and hybrid seeds were positive. Production response will greatly increase when input prices are low because of input subsidies. Improved non-labour determinants, such as hybrid and open-pollinated seeds, fertilisers, insecticides, fungicides, herbicides, and manure, have been categorised as improved variable inputs (Adesina and Zinnah, 1993). The findings were presented in Table 58.

Table 58

Cost of Fungicides

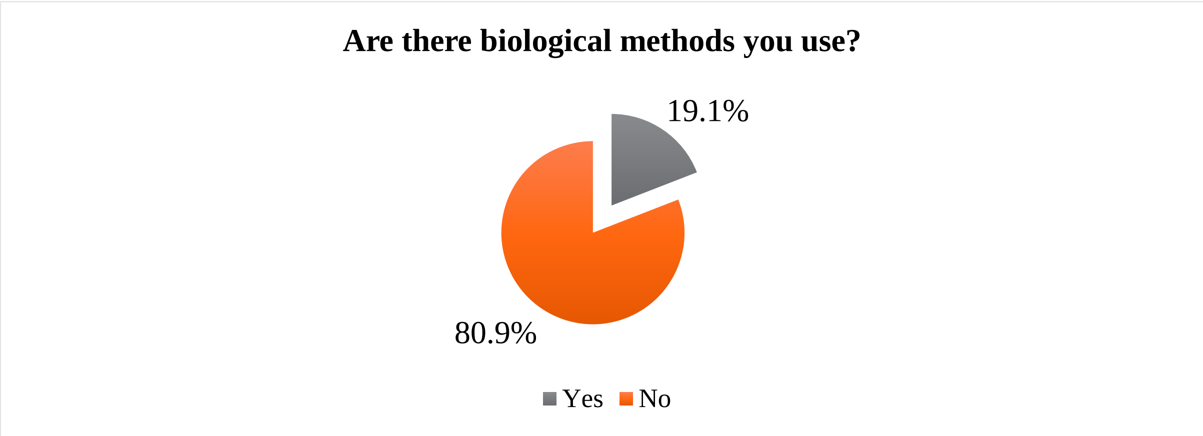
How much does it cost you for the fungicides? (KES)	Frequency	Percentage (%)
Less than 5000	4	1.2
5000 - 10,000	2	0.6
10,001 - 20,000	330	97.1
20,001 - 40,000	4	1.2
Total	340	100

Use of Biological Methods in Coffee Production

The farmers were also requested to indicate whether there are biological methods they use in coffee production. The results show shows that many of the respondents (80.9%) do not use biological methods in coffee production while (19.1%) of them use biological methods in coffee production. This is in line with Sarirahayu and Aprianingsih (2018) that technology adoption and serious coffee producers are the best answer to counter environmental changes. The acquisition of farming technology by farmers helps in increasing their adoption. The findings were presented in Figure 22.

Figure 22

Use of Biological Methods in Coffee Production

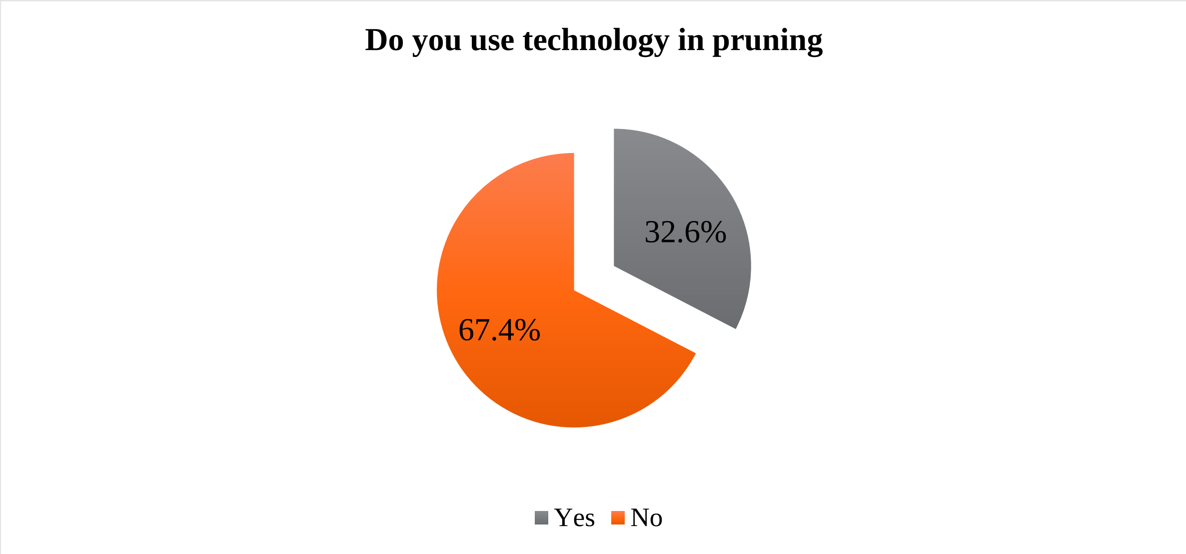


Use of Technology in Coffee Pruning

The farmers were also requested to indicate whether to use technology in the pruning of coffee. The results show that more than half of the respondents (67.4%) of the respondents do not use technology in coffee pruning while (32.6%) of them use technology in coffee pruning. This is in line with Sarirahayu and Aprianingsih (2018) that technology adoption and serious coffee producers are the best answer to counter environmental changes. The acquisition of farming technology by farmers helps in increasing their adoption. Application of new technology (e.g., using improved seeds and inorganic fertiliser) is important for increasing productivity of land as land scarcity increases. Low input use and farm technology, such as improved seed and fertiliser, are among the many reasons for low agricultural productivity in Nigeria (Amare et al., 2017). The findings were presented in Figure 23.

Figure 23

Use of Technology in Coffee Pruning



Frequency of Coffee Pruning

The farmers were also requested to indicate how often the coffee pruning is done. The results show that majority of the respondents (62.9%) indicated that pruning is done quarterly with (10.6%) of them indicating that pruning is done every month. Bertomeu and Roshetko (2007) likewise, show that high pruning intensity (retaining a live crown ratio of 20−30%) results in significantly higher maize grain yields but reduced tree diameter. Intensive pruning may enhance crop yield, but it is incompatible with commercial timber production because the growth rate and quality of the overstorey timber trees are severely reduced. The pruning of tree branches is effective in reducing light interception by the tree canopy, and thus prolonging the period of intercropping (Watanabe, 1992). Thus, in the Philippines, farmers often practice severe branch pruning every season before the planting of crops, to reduce tree-crop competition as well as to improve tree form (Bertomeu, 2004). In Indonesia, small scale timber farmers start severe branch pruning (live crown ratios of 40% or less) at six months to reduce tree-annual crop competition, ‘improve’ tree form, and reduce wind damage to trees (Roshetko et al. 2004). However, such intensive pruning slows tree growth Smith (1962), reducing tree diameter and final timber yields, resulting in lower timber value. The findings were presented in Table 59.

Table 59

Frequency of Coffee Pruning

How often is pruning done?	Frequency	Percentage (%)
Daily	31	9.1
Weekly	27	7.9
Fortnightly	32	9.4
Monthly	36	10.6
Quarterly	214	62.9
Total	340	100

Cost of Coffee Pruning

The farmers were also requested to indicate the cost of coffee pruning. The results show that more than half of the respondents (55.0%) indicated that the cost of pruning is less than KES 5000, (21.8%) of them indicated that the cost of pruning ranges between KES 5000 - KES 10,000, (12.1%) of them indicated that the cost of pruning ranges between KES 5000 - KES 10,000, (3.8%) of them indicated that the cost of pruning ranges between KES 20,001 - KES 40,000 while (2.1%) of them indicated that pruning costs between KES 40,001 and KES 80,000. Governing body GoK (2013) and independent organisation ICO (2019) noted a decrease in net returns generated from coffee due to its high production cost in Kenya. The findings were presented in Table 60.

Table 60

Frequency of costs in Coffee Pruning

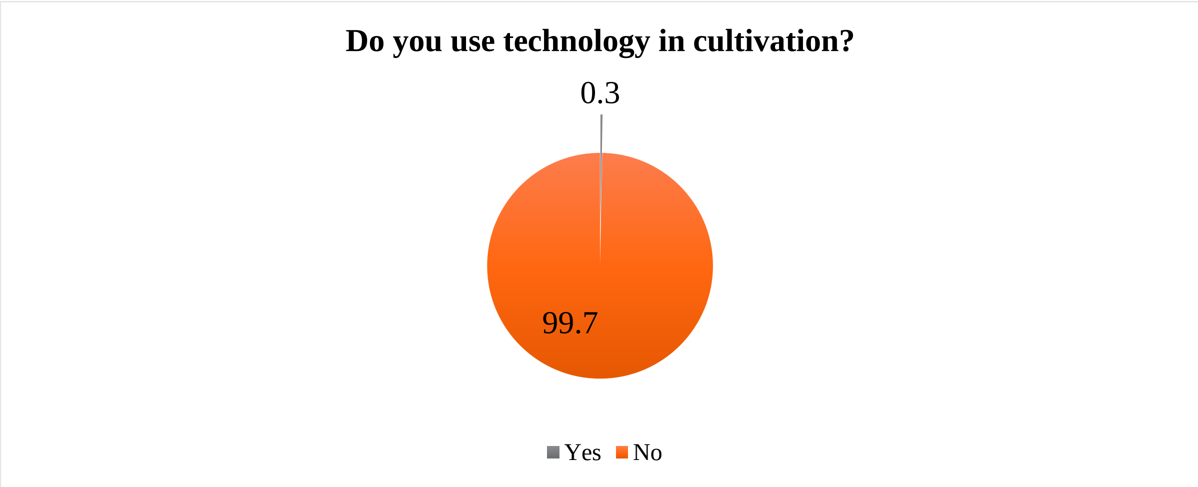
How much does it cost you in a year? (KES)	Frequency	Percentage (%)
Less than 5000	187	55.0
5000 - 10,000	74	21.8
10,001 - 20,000	41	12.1
20,001 - 40,000	13	3.8
40,001 - 80,000	7	2.1
Total	322	94.7
Missing System	18	5.3
Total	340	100

Use of Technology in Coffee Cultivation

The farmers were also requested to indicate whether to use technology in coffee production. The results show that many of the respondents (99.7%) do not use technology in coffee cultivation while (0.3%) of them use technology in coffee cultivation. This is in line with Sarirahayu and Aprianingsih (2018) that technology adoption and serious coffee producers can counter environmental changes. The acquisition of farming technology by farmers helps in increasing their adoption. The findings were presented in Figure 24.

Figure 24

Use of Technology in Coffee Cultivation

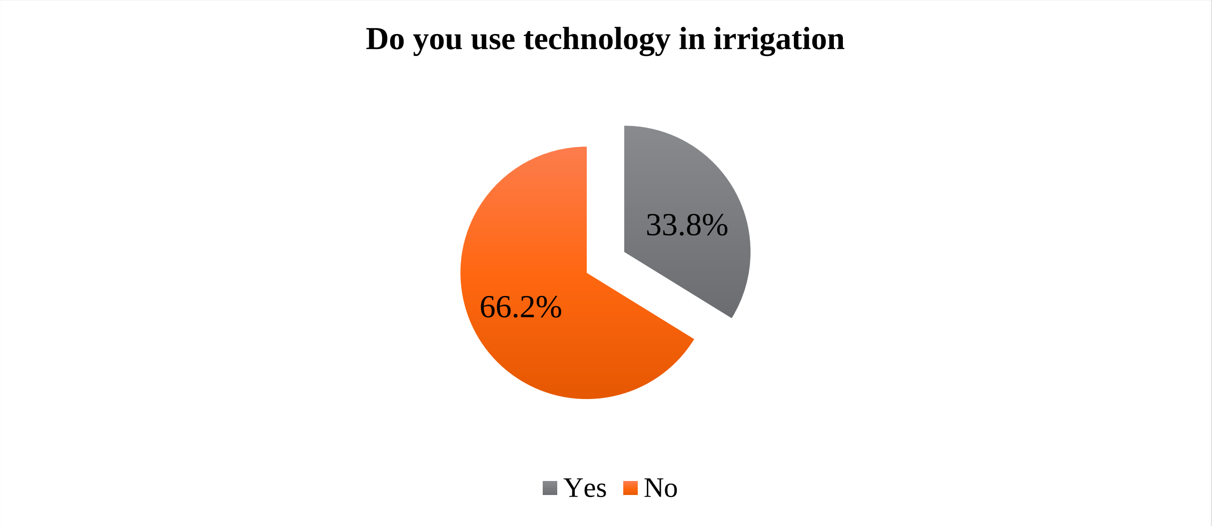


Use of Technology in Irrigation of Coffee

The farmers were also requested to indicate whether to use technology in coffee production. The results show that more than half of the respondents (66.2%) do not use technology in coffee irrigation while (33.8%) of them use technology in coffee irrigation. The findings are consistent with Bro and Clay. (2017) indicated that technology adoption in areas of seeds (cultivars), fertilisers, use of agro-equipment’s, pruning, harvesting, post-harvesting, and marketing impact positively on the coffee farmer earnings and TE (Lin et al., 2017 & Thompson et al., 2019). The findings were presented in Figure 25.

Figure 25

Use of Technology in Irrigation of Coffee



Results of Findings; Research Question no. 3

The third research question of the study was, what is the relationship between technology use (mechanised, improved variety), farm size, agency networks (management entity, extension and certification bodies) and productivity among coffee farmers in Central Kenya? To answer this question, the study used the trans-log ordinary regression based on the stochastic frontier model. In this study, the production function was determined by the SFA.

The relationship between technology use and productivity among coffee farmers

The study sought to establish the relationship between farm size and productivity among coffee farmers in Central Kenya. The model was statistically significant implying that technology use (mechanised, improved variety) significantly affects productivity among coffee farmers in Central Kenya (Prob > chi2 = 0.0003). This is in line with Sarirahayu and Aprianingsih (2018) that technology adoption and serious coffee producers are the best answer to counter environmental changes. The acquisition of farming technology by farmers helps in increasing their adoption. Administration assistance from planting to post-gather preparing, new land clearing, and restoring old and non-yielding coffee trees kick starts to start improvement. To adequately change cultivating practices, a more escalated approach is supported. By embracing current technology, coffee producers can build their efficiency. Gaviglio et al. (2021) also found a statistically significant difference between the crop and livestock farms' productivity indexes in South Milan Agricultural Park, suggesting that any difference between the level of TE between them relies on the technology farmers have at disposition and not on the farmers' decision-making.

From the Frontier regression model, the study indicates that there is a positive and insignificant relationship between the coffee varieties planted and the productivity among coffee farmers in Central Kenya ($\beta = 0.024$, $p = 0.832$). These findings are in line with Geffersa et al. (2019) who argued that it is important for farmers to consider the maize varieties before imposing technology for technical production efficiency. Like this, Anang et al. (2020) suggested that the adoption of the appropriate types of the crop would improve the TE of maize production in Ghana. According to Karuri (2020), the Tea Research Institute (TRI) is creating new technologies to solve climate change challenges, such as environmental conservation initiatives and the creation of enhanced tea cultivars. Producing climate-resistant tea cultivars like purple tea, which is more resilient to climate variability than green tea, could increase the revenue of tea producers as a form of climate adaptation. In 2019, Kachuwai investigated socioeconomic issues, barriers to the adoption of purple tea farming, and the function of purple tea farming in carbon sequestration. Compared to purple tea, green tea was produced at a lower rate and sold for less money. It exhibited greater resistance to drought, frost, hailstones, pests, and diseases.

However, there is a negative and insignificant relationship between the fertiliser products used and the productivity among coffee farmers in Central Kenya ($\beta = -0.098$, $p = 0.180$). The findings are inconsistent with Bro and Clay (2017) who indicated that technology adoption in areas of seeds (cultivars), fertilisers, use of agro-equipment's, pruning, harvesting, post-harvesting, and marketing impact positively on the coffee farmer earnings and TE (Lin et al., 2017; Thompson et al., 2019).

There is a positive and insignificant relationship between the cost of fertiliser and the productivity among coffee farmers in Central Kenya ($\beta = 0.080$, $p = 0.390$). The findings are not in line with GoK (2013) and ICO (2019) that net revenues from coffee have been on a decline, which is attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases.

There is also a negative and insignificant relationship between the use of herbicides and the productivity among coffee farmers in Central Kenya ($\beta = -0.968$, $p = 0.130$). Given the negative relationship between technology use and coffee production, the findings agree with Kamau et al. (2017) who concurred with the study that, the lack of sufficient TE in coffee farming can be attributed to specific socio-economic factors. Both studies argued that the farmers who lie in the Kenyan socio-economic spectrum's lower prisms are less likely to adopt coffee farming mechanisms that yield high TE.

There was a positive and insignificant relationship between the use of herbicides and the productivity among coffee farmers in Central Kenya ($\beta = 0.460$, $p = 0.180$). The findings are not in line with GoK (2013) and ICO (2019) that net revenues from coffee have been on a decline, which is attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases. Meyo and Egoh (2020) also found that the estimated coefficients for the unit costs of fertiliser, herbicides, and labour were negative but not significant, whereas those for land and hybrid seeds were positive. Production response will greatly increase when input prices are low because of input subsidies. Improved non-labour determinants, such as hybrid and open-pollinated seeds, fertilisers, insecticides, fungicides, herbicides, and manure, have been categorised as improved variable inputs (Adesina and Zinnah, 1993).

There was a negative and insignificant relationship between the use of fungicides and the productivity among coffee farmers in Central Kenya ($\beta = -0.100$, $p = 0.899$). The findings agree with GoK (2013) and ICO (2019) that net revenues from coffee have been on a decline, which is attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases. Likewise, there was a negative and insignificant relationship between the cost of fungicides and the productivity among coffee farmers in Central Kenya ($\beta = -0.243$, $p = 0.542$). According to GoK (2013) and ICO (2019), net revenues from coffee have been on a decline, which is attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases.

There was a positive and insignificant relationship between the use of biological methods and the productivity among coffee farmers in Central Kenya ($\beta = 0.063$, $p = 0.680$). The findings are consistent with Bro and Clay. (2017) indicated that technology adoption in areas of seeds (cultivars), fertilisers, use of agro-equipment’s, pruning, harvesting, post-harvesting, and marketing impact positively on the coffee farmer earnings and TE (Lin et al., 2017 & Thompson et al., 2019).

However, there was a negative and insignificant relationship between the use of technology in coffee pruning and the productivity among coffee farmers in Central Kenya (β = -0.357, p = 0.262). Given the negative relationship between technology use and coffee production, the findings agree with Runo (2009) and Kamau et al. (2017) who concurred with the study that the lack of sufficient TE in coffee farming can be attributed to specific socio-economic factors. Both studies argue that the farmers who lie in the Kenyan socio-economic spectrum's lower prisms are less likely to adopt coffee farming mechanisms that yield high TE.

There was however, a positive and significant relationship between the frequency of coffee pruning and the productivity among coffee farmers in Central Kenya (β = 0.253, p = **0.005**). Likewise, in the Philippines, farmers often practice severe branch pruning every season before the planting of crops, to reduce tree-crop competition as well as to improve tree form (Bertomeu, 2004). In Indonesia, small scale timber farmers start severe branch pruning (live crown ratios of 40% or less) at six months to reduce tree-annual crop competition, 'improve' tree form, and reduce wind damage to trees (Roshetko et al., 2004).

There was a positive and significant relationship between the annual cost of coffee pruning and the productivity among coffee farmers in Central Kenya (β = 0.263, p = **0.009**). However, there is a negative and insignificant relationship between the use of technology in coffee cultivation and the productivity among coffee farmers in Central Kenya (β = -0.236, p = 0.851). The findings are not in line with GoK (2013) and ICO (2019) that net revenues from coffee have been on a decline, which is attributed to the high cost of coffee production in the country because of the cost of purchased farm inputs, manpower and electricity supply, and the management of coffee diseases.

There was however, a positive and insignificant relationship between the use of technology in irrigation and the productivity among coffee farmers in Central Kenya ($\beta = 0.010$, $p = 0.932$). The findings are consistent with Bro and Clay. (2017) who indicated that technology adoption in areas of seeds (cultivars), fertilisers, use of agro-equipment's, pruning, harvesting, post-harvesting, and marketing impact positively on the coffee farmer earnings and TE (Lin et al., 2017; Thompson et al., 2019).

Therefore, given the mechanisation and the cultivation of improved varieties by farmers (where U_t represents the technical inefficiency), the study concludes that the farmers who grow the Batian cultivars are technically inefficient than those that grow the Ruiru 11 cultivar ($\beta = 0.024$). However, the farmers that use technology in coffee cultivation are more technically efficient than those that do not ($\beta = -0.236$). Kiwelu et al. (2021) also showed that the yield potential for improved and traditional coffee varieties respectively has not yet been realised by farmers. That is, there is a large gap between the average coffee yield gained by smallholder farmers growing improved coffee varieties and farmers growing traditional coffee varieties respectively. As indicated by Ngango and Kim (2019), 82% of the Kenya farmers cultivate BM139 variety of Arabica coffee, while the remaining 18% grow Jackson 2/1257 variety. Furthermore, cultivation of improved variety of coffee trees, and the cropping system enhance farmers' TE. The findings are presented in Table 61.

Table 61

The Relationship Between Technology Use and Productivity among Coffee Farmers

Model Summary						
					Number of obs	338
					Wald chi2(1)	31.24
					Prob > chi2	0.0003
How much did you get from the sale of Coffee?	Coef.	Std. Err.	z	P>z	95% Conf.	Interval
Frontier						
Which coffee varieties have you planted	0.024	0.113	0.210	0.832	-0.197	0.245
What fertiliser products do you use and what is the quantity used in a year?	-0.098	0.073	-1.340	0.180	-0.242	0.045
How much does it cost you for the fertiliser?	0.080	0.093	0.860	0.390	-0.103	0.264
Do you use herbicides	-0.968	0.640	-1.510	0.130	-2.221	0.286
How much does it cost you for the herbicide?	0.460	0.343	1.340	0.180	-0.212	1.132
Do you use fungicides	-0.100	0.791	-0.130	0.899	-1.651	1.451
How much does it cost you for the fungicides	-0.243	0.399	-0.610	0.542	-1.025	0.539
Are there biological methods you use?	0.063	0.152	0.410	0.680	-0.235	0.361
Do you use technology in pruning	-0.357	0.318	-1.120	0.262	-0.981	0.267
How often is pruning done?	0.253	0.091	2.780	0.005	0.075	0.431
How much does it cost you in a year?	0.263	0.101	2.600	0.009	0.065	0.461

Do you use technology in cultivation?	-0.236	1.259	-0.190	0.851	-2.705	2.232
Do you use technology in irrigation	0.010	0.122	0.090	0.932	-0.230	0.251
_cons	9.597	26.074	0.370	0.713	-41.507	60.700
Mu (Technical Inefficiency Model)						
Ut	Coef.	Std. Err.	z	P>z	95% Conf.	Interval
Gender	-0.115	0.136	-0.840	0.399	-0.382	0.152
Age	-0.019	0.209	-0.090	0.929	-0.429	0.391
Education level	-0.190	0.126	-1.500	0.133	-0.437	0.058
Size of your household?	0.595	0.121	4.930	0.000	0.359	0.831
What is your occupation?	0.052	0.111	0.470	0.641	-0.166	0.270
Which of the following are you a member of?	0.097	0.102	0.940	0.345	-0.104	0.298
Do you get visits from extension officers?	0.414	0.176	2.360	0.018	0.070	0.759
How often do extension officers' visit?	-0.184	0.107	-1.710	0.086	-0.394	0.026
Are you certified?	-0.100	0.234	-0.430	0.669	-0.558	0.358
What kind of certifications have you complied with?	-0.099	0.247	-0.400	0.688	-0.584	0.385
How do you sell your coffee?	-1.480	0.330	-4.490	0.000	-2.127	-0.834
Did you have access to formal/informal credit last season?	0.254	0.193	1.320	0.188	-0.125	0.633
Are you associated with the following groups?	1.106	0.372	2.980	0.003	0.377	1.834
_cons	2.824	26.063	0.110	0.914	-48.259	53.906

Note: *Dependent variable is the productivity among coffee farmers in Central Kenya – log of How much did you get from the sale of Coffee?*

Hypothesis Testing for Technology Use and Productivity among Coffee Farmers

The null hypothesis for the study was that: H_0: The technology use positively affects TE in Kenyan Coffee farming while the alternative hypothesis was that H_A: The technology negatively affects TE in Kenyan Coffee farming. Therefore, given the coefficient of -0.357 and -0.236 (for technical inefficiency), the study concluded that technology use positively affects TE in Kenyan Coffee farming, thus the null hypothesis was not rejected.

Similarly, the study's null hypothesis was that: H3: Among coffee producers in Central Kenya, there is no correlation between productivity and the usage of technology. H3a: Central Kenyan coffee growers' productivity and the usage of technology are related. The study indicated that there is a significant association between technology use and productivity among coffee growers in Central Kenya given the p-value of less than 0.05 (Prob > chi2 = 0.0003).

Theoretically, these findings also resonated with the elements of PEOU and PU used in the technology acceptance model (Davis, 2020). Since TAM is utilised in the prediction of behavioural intention concerning the acceptance of technology, Lee noted that an inadequate technology exposure before conducting an assessment (Lee et al., 2016). Therefore, the technology use (mechanised, improved variety) towards productivity among coffee farmers in Central Kenya validates the model in the current study since the study has found the model to have tested hypotheses of PU and PEOU, which can be used to predict productivity among coffee farmers in Central Kenya. This is likewise, validated since technology use in the current study has a significant relationship between technology use and productivity among coffee farmers in Central Kenya.

The Relationship Between Farm Size and Productivity among Coffee Farmers

The study was conducted to determine the relationship between farm size and productivity. The model's statistical significance suggests that farm size has a considerable impact on Kenyan coffee growers' production (Prob > chi2 = 0.0,000). From the Frontier regression model, the study indicates that there is a positive and significant relationship between the farm size and the productivity among coffee farmers in Central Kenya ($\beta = 0.869$, $p = 0.000$). Likewise, Ngeywo et al. (2015) indicated that coffee farmers with larger farms are more positively attuned towards the installation of farming approaches that yield higher levels of TE than their counterparts owning small farms. The capacity of larger coffee farm owners to install such methods is centred on having access to better networks. Most of them are financially capable, and the perceived return on investment derived from these ventures seems worthwhile. However, there was a negative impact on population pressure is greatly felt in medium and high agricultural areas of Embu County, where smallholder coffee farmers have intensified production of the crop to keep up with the demand for more land that is needed for farming (Ndirangu et al., 2017). There was an inverse relationship that could be observed between the size of the firm and its productivity.

Therefore, given the size of land used by farmers for coffee production (where U_t represents the technical inefficiency), the study concludes that the farmers who have between 2 and 3.99 acres are technically inefficient ($\beta = 0.869$). That is the smaller the size of the farm, the less technically efficient the farmers become. As a result, Sheng et al. (2019) contend that many small-scale farms continue to exhibit an inverse farm size-productivity relationship. According to Noack and Larsen (2019), agricultural earnings increase with farm size yet output per unit of land does fall as anticipated by earlier work as farm size increases. In other words, while the variance of agricultural revenues falls as farm size increases, the variance of locally produced food increases.

In a study conducted in Murang’a noted that, farm size and household characteristics are various indicators. The data suggest that farm size, coffee variety, loan availability, producers' age, and family size are all important predictors of TE in coffee growing. The age of a farmer had a negative and substantial impact on efficiency, but household size had a favourable impact on TE. This suggests that when farmers get older, their farm TE decreases. It is worth emphasising that coffee cultivation in Kenya has been transformed. Farmers, on the other hand, have embraced new coffee kinds to boost yield. Older farmers, on the other hand, are slower to accept or acknowledge utilising them (ACP, 2015). Murthy et al. (2009) evaluated TE of tomato production in India and discovered that farms managed by comparatively younger farmers were more efficient. These results suggest that farmers benefit from larger farms, earning higher and more stable incomes while consumers suffer from lower and more volatile food supply. The findings are presented in Table 62.

Table 62

The Relationship Between Farm Size and Productivity among Coffee Farmers

Model Summary						
					Number of obs	339
					Wald chi2(1)	56.25
					Prob > chi2	0.0,000
How much did you get from the sale of Coffee?	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Frontier						
Size of your land	0.869	0.1160	7.500	0.000	0.6420	1.0970
_cons	9.375	28.971	0.320	0.746	-47.407	66.156
Mu (Technical Inefficiency Model)						
Ut	Coef.	Std. Err.	Z	P>z	[95% Conf.	Interval
Gender	-0.052	0.128	-0.400	0.688	-0.303	0.200
Age	-0.167	0.197	-0.850	0.396	-0.554	0.219
Education level	-0.115	0.119	-0.970	0.334	-0.348	0.118
Size of your household?	0.402	0.118	3.430	0.001	0.172	0.633
What is your occupation?	-0.004	0.103	-0.040	0.967	-0.206	0.198
Which of the following are you a member of?	0.030	0.095	0.310	0.756	-0.157	0.216
Do you get visits from extension officers?	0.614	0.162	3.790	0.000	0.296	0.931
How often do extension officers’ visit?	-0.170	0.101	-1.690	0.092	-0.369	0.028
Are you certified?	-0.071	0.212	-0.330	0.738	-0.486	0.345
What kind of certifications have you complied with?	-0.138	0.239	-0.580	0.563	-0.607	0.330
How do you sell your coffee?	-0.747	0.127	-5.860	0.000	-0.997	-0.497
Did you have access to formal/informal credit last season?	0.103	0.181	0.570	0.571	-0.252	0.458

Are you associated with the following groups?	1.572	0.272	5.770	0.000	1.038	2.106
_cons	1.952	28.973	0.070	0.946	-54.835	58.739

Note: *Dependent variable is the productivity among coffee farmers in Central Kenya– log of How much did you get from the sale of Coffee?*

Hypothesis Testing for Farm size and Productivity among Coffee Farmers

The study's null hypothesis was that: H3o: Among coffee producers in Central Kenya, there is no correlation between farm size and productivity. H3a: There is a relationship amongst technology use, farm size, agency networks and productivity among coffee farmers in Central Kenya. Therefore, given the p-value of less than 0.05 (Prob > chi2 = 0.0,000), According to the study's findings, coffee producers in Central Kenya have a substantial association between farm size and productivity. The findings are consistent with Oerke et al. (2015), who found that land size is critical in production. They posit that there are varied inclinations between the size of the farm and the productivity in coffee farming.

The relationship between agency networks and productivity among coffee farmers

The goal of the study was to determine how agency networks affected the productivity of coffee growers in Central Kenya. The model was statistically significant implying that agency networks (management entity, extension, and certification bodies) significantly affect productivity among coffee farmers in Central Kenya (Prob > chi2 = 0.0290). From the Frontier regression model, the study indicates that there is a negative and significant relationship between the management entity (*Which of the following are you a member of?*) and the productivity among coffee farmers in Central Kenya (β = -1.107, p = 0.037). These findings are consistent with Voora et al. (2019) that most importantly, the attainment of a coffee certificate opens new networking opportunities for small farmers. Certification plans encourage farmers to know the best way to execute better-cultivating methods, set up conventions for managing ecological and social issues. They help actualise evaluating and third-party affirmation on these issues and communication with buyers about the coffee on the three backbones of manageability toward the end of trade chains (Hoebink et al., 2014). Darnhofer (2020) indicated that relational agencies in agriculture allows a more robust integration of the biological, ecological, social, cultural, and political aspects. Basing the relations on values and belief means that relational agency allows a better understanding of the drivers that shape farming diversity and shape changes in farming practices.

Producers who had more interaction with extension agents over the course of the growing season were found to be more effective than those who had less interactions, with the degree of contact with extension workers having a substantial and favourable influence on TE. The model's findings indicate that adding one unit more extension connections will increase the expected value of TE by 3%. The findings are consistent with earlier research by Getachew and Bamlak (2014), which all discovered that producers who received more visits from development organisations had access to better inputs and agricultural management techniques, which led to higher production effectiveness.

However, there is a negative and insignificant relationship between the extension bodies (*Do you get visits from extension officers?*) and the productivity among coffee farmers in Central Kenya ($\beta = -0.143$, $p = 0.841$). The study indicates that there is a negative and significant relationship between the extension bodies (*How often do extension officers' visit?*) and the productivity among coffee farmers in Central Kenya ($\beta = -0.143$, $p = 0.008$). The findings also corroborate those of EPZA where marketing agents offer samples to buyers and assist producers in the auction process. CBK issues distinctive classification of licenses in marketing, such as warehouse license, roaster license, packaging license, auctioneering license (EPZA, 2005). The marketing agents with coffee auction permits are lawfully permitted to participate in the weekly auction. Many farmers feel that marketing agents promise the farmers an equitable share of the sale price and higher profit margins to land lucrative marketing contracts, but ultimately change very little (AFA, 2019).

The study indicates that there was a negative and insignificant relationship between the certification bodies (*What kind of certifications have you complied with?*) and the productivity among coffee farmers in Central Kenya ($\beta = -0.111$, $p = 0.663$). The findings are inconsistent with Muriithi et al. (2018) who indicated that introducing a coffee certification programme promises to shift the affinity that most small-scale farmers construct towards coffee farming. The study concurred with the findings of Nyawira (2019), which demonstrated that there was a favourable association between Certified Coffee Cooperatives and economic benefits. By utilising a regression equation, the study revealed that participants from Certified Coffee Cooperatives who claimed to possess the Ability to Choose, Decide and Hold Accountable had a greater profitability, resulting in an increase of 0.27 units in Economic Benefits. Therefore, Nyawira's (2019) research concluded that Certified Coffee Cooperatives allowed farmers to become economically empowered by developing these abilities. More precisely, the researchers hypothesised that more and more farmers were willing to cultivate this crop if they receive accreditation from the relevant regulatory bodies.

Therefore, given the size of the management entity, extension, and certification bodies in coffee production (where U_t represents the technical inefficiency), the study concluded that the farmers who had institutional membership, those who get visits from extension officers, those who often get extension officers visits and those who have complied with certifications are technically efficient (β = -1.107, β = -0.143, β = -0.468, and β = -0.111). The findings are presented in Table 63.

Table 63

The Relationship Between Agency Networks and Productivity

Model Summary						
					Number of obs	339
					Wald chi2(1)	10.77
					Prob > chi2	0.029
How much did you get from the sale of Coffee?	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Frontier						
Ut	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Which of the following are you a member of?	-1.107	0.582	1.900	0.037	-2.247	0.033
Do you get visits from extension officers?	-0.143	0.714	-0.200	0.841	-1.542	1.256
How often do extension officers' visit?	-0.468	0.176	-2.660	0.008	-0.814	-0.123
What kind of certifications have you complied with?	-0.111	0.254	-0.440	0.663	-0.610	0.388
_cons	12.338	1.013	12.180	0.000	10.352	14.323
Mu (Technical Inefficiency Model)						
Gender	-0.243	0.134	-1.810	0.071	-0.506	0.021
Age	0.391	0.209	1.870	0.062	-0.020	0.801
Education level	-0.135	0.127	-1.060	0.288	-0.384	0.114
Size of your household	0.681	0.118	5.760	0.000	0.449	0.912
What is your occupation?	-0.044	0.111	-0.400	0.692	-0.261	0.173

Which of the following are you a member of?	1.256	0.615	2.040	0.041	0.051	2.461
Are you certified?	-0.108	0.226	-0.480	0.633	-0.551	0.335
How do you sell your coffee?	-0.900	0.135	-6.680	0.000	-1.164	-0.636
Did you have access to formal/informal credit last season?	0.007	0.196	0.040	0.970	-0.376	0.391
Are you associated with the following groups?	1.960	0.290	6.760	0.000	1.392	2.528
_cons	-0.945	1.105	-0.860	0.392	-3.111	1.220

Note: *Dependent variable is the productivity among coffee farmers in Central Kenya – log of How much did you get from the sale of Coffee?*

Hypothesis Testing for Agency Networks and Productivity among Coffee Farmers

The null hypothesis for the study was that: H1o: Existence of agency networks (Coffee management agents, marketing agents and extension) positively affects TE in coffee farming in central Kenya while the alternative hypothesis was that H1a: The presence of agency networks (Coffee management agents, marketing agents and extension) has a negative effect on TE in coffee farming in central Kenya. Therefore, given the negative coefficients of -1.107, -0.143, -0.468 and -0.111 (for technical inefficiency), the study did not reject the null hypothesis and concluded that the presence of agency networks (Coffee management agents, marketing agents and extension) positively affects TE in coffee farming in central Kenya.

Similarly, the study's null hypothesis was that: H3: In Central Kenya, there is no correlation between agency networks and production among coffee growers. H3a: In Central Kenya, there was a connection between agency networks and productivity among coffee growers. The study showed that there was a relationship between agency networks and productivity among coffee farmers in Central Kenya given the p-value of less than 0.05 (Prob > chi2 = 0.029). According to Nyawira (2019), who conducted the study, Farmer Agency substantially predicted Economic Benefits (= -0.255, p=0.002) in the entire model. However, the negative coefficient also demonstrates that Farmer Agency reduced model profitability overall by 0.255 units.

Theoretically, the findings agree with the activity theory which bridges the gap between the individual subject and the social reality. It provides a method of understanding and analysing a phenomenon, finding patterns, and making inferences across interactions - subject, object, and tool (Fjeld et al., 2002). In this case, the theory best informs the coffee farmers (subjects) who intend to improve the productivity of farm produce (object) by use and adoption of technology collaborative agency. Hill et al. (2002) analysed farmers' inspirations, tasks, and individuals or firms they interacted with and perceived the rules that guided the farmers to have both historical and cultural aspects. Among the tools that were thought to have a greater impact on farmers, actions were electronic gadgets. They concluded that activity theory offered a great framework for their analysis (Hill et al., 2002). Świergiel et al. (2018) used activity theory to examine organic farming development in Sweden and found that the organic farming concept was trying to break free from conventionalisation. The activity theory was used to categorise each stakeholder's needs. Thus, the theory has been found instrumental and validated in the current study since a relationship amongst agency networks and productivity among coffee farmers in Central Kenya was found to be significant. Therefore, coffee farmers can incorporate use of technology and assistance by the collaborative agency to improve their coffee production.

Research Question 4: What is the Production Yield of Coffee Farmers

To satisfy the research question, the study collected data in relation to revenue from the coffee sales as well as the coffee kilograms produced by the farmers as per the below subsection. Yield is the output produced from inputs combination. In coffee farming the major factor of production is land, labour and capital; Nyagaka et al. (2010). According to Rahaman et al. (2012) research in Bangladesh, small farmers have a higher level of TE in rice production in paddy fields. They are better at utilising limited resources to maximise farm production. As a result, inefficiency in rice production is responsible for the loss of approximately 12%, 7%, 9%, and 10% of the output. This loss can be attributed to either inefficiency in the rice production system, inefficiency among the sampled farmers, or a combination of both. However, the average allocative and economic efficiencies vary based on farm size categories.

Revenue Accrued from the Sale of Coffee in the Last Season

The farmers were also requested to indicate how much they got from the sale of coffee in the last season. The findings show that (0.9%) of the respondents indicated that coffee revenue in the last season was less than 5,000, (3.2%) of them indicated that coffee revenue in the last season was between KES 5,001 and KES 20,000, (46.5%) of them indicated that revenue in the last season was between KES 20,001 and KES 80,000, (32.1%) of them indicated that revenue in the last season was between KES 80,001 and KES 200,000, (14.1%) of them indicated that revenue in the last season was between KES 200,001 and KES 500,000, while (3.2%) of them indicated that coffee revenue in the last season was over KES 500,000. The findings are presented in Table 64.

The findings of the study are in tandem with the theory of production, which is used to explain the decision-making process of producers in bundling/combining various inputs of production (fixed capital and labour) to produce an optimum highest level of output for consumption. As illustrated by Cohen et al. (2019), the economic production theory indicates that proprietors or business entities typically determine the quantity of a product to be manufactured, and the magnitude of raw materials and other production factors channelled into the development process based on a set of principles stemming from various internal and external environmental factors. Also, there shall be an enrichment to the production theory of economics by showing the social aspect of synergy in production. This theory has been used to validate the TE (the measure of how inputs are successfully transformed into the right outputs through the interplay of technology and suitable economic conditions) of coffee farmers in in Central Kenya. TE is realised when the producer achieves the highest output with minimal inputs, the findings validate the principles of the production theory where the farmer intends to maximise output with least cost of production as possible.

Table 64

Revenue Accrued from the Sale of Coffee in the Last Season

How much did you get from the sale of coffee in the last season? (KES)	Frequency	Percent
Less than 5000	3	0.9
5,001 - 20,000	11	3.2
20,001 - 80,000	158	46.5
80,001 - 200,000	109	32.1
200,001 - 500,000	48	14.1
Over 500,000	11	3.2
Total	340	100

Revenue Accrued from Other Farming Activities

The farmers were also requested to indicate how much they got from other farming activities in the last season. The findings show that (0.3%) of the respondents indicated that another revenue was less than 5,000, (3.5%) of them indicated that non-coffee revenue in the last season was between KES 5,001 and KES 20,000, (29.1%) of them indicated that non-coffee revenue in the last season was between KES 20,001 and KES 80,000, (32.6%) of them indicated that non-coffee revenue in the last season was between KES 80,001 and KES 200,000, 30.6% of them indicated that non-coffee revenue in the last season was between KES 200,001 and KES 500,000 while 3.8% of them indicated that non-coffee revenue in the last season was over KES 500,000. The findings were presented in Table 65.

Table 65

Revenue Accrued from other Farming Activities

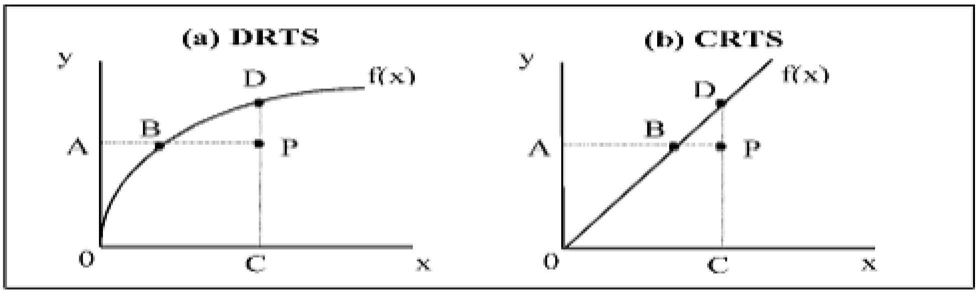
How much did you receive from other farming activities? (KES)	Frequency	Per cent
Less than 5000	1	0.3
5,001 - 20,000	12	3.5
20,001 - 80,000	99	29.1
80,001 - 200,000	111	32.6
200,001 - 500,000	104	30.6
Over 500,000	13	3.8
Total	340	100

The Technical Efficiency of Coffee Farmers in Central Kenya

The yield is the product (kg) divided by the area of the land (acres). How much output may be proportionally increased without changing the input used, according to output-oriented theory (TE). How much may inputs be lowered proportionally without changing the output produced? is an example of an input-oriented TE.

Figure 26

Input and Output Orientated Technical Efficiency Measures and Returns to Sale



Therefore, in the current case, TE = Y_i / Y_i^* Where; Y_i = relative measure (actual yield) and Y_i^* = absolute measure (optimum yield). In Kenya as at 2018/19, the average /yield (Kg/ha) stands at 890.6 metric tonnes (543.2 from Estates and 347.4 from Cooperatives) (KNBS, 2020). Some of the estates can produce at optimum at 2,000 metric tonnes per hectare (Eaagads, 2019). Therefore, the TE of coffee farmers in Central Kenya is indicated by 0.5243 (see Table 66).

Therefore, TE given its mean value is given as 0.5243. The null hypothesis H_0: Production yield of coffee farmers in Central Kenya is greater than zero was accepted since the TE is factor of yield and the land. This implies that the coffee farmers in Central Kenya are averagely (TE= 0.5243) given the type of labour used, the size of land used, technological use and relational agency. These findings are, however, not consistent with Kamau et al. (2017) on yield management who alluded to the fact that small scale coffee farmers are less efficient at 54 per cent. Also, other recommendations on this subsector incline to adoption of new technology (Wambua et al, 2019; Kamau et al., 2017), management of farms (Kamau et al., 2017; Rijsbergen 2016; Wambua et al, 2019), training farmers (Ngweyo et al., 2015) and agency relationship for certifications (Muriithi et al., 2018). A study conducted in Rwanda showed that the average TE score for all households in the sample was 0.64, indicating a potential to improve maize output by 36% without increasing the proportion of farm inputs used.

This conclusion was consistent with prior African research on the TE of the agricultural output sector. The study also discovered that large-scale farms were technically more efficient than medium and small-scale farms on average. Maize farmer training and education were found to be positively related to TE, as they provided access to innovative and up-to-date production techniques and increased the pioneer spirit in agricultural technology adoption, resulting in better production decision-making. The study also revealed a positive relationship between extension contacts frequency and TE, indicating that visits of extension officers to maize farmers contributed to TE in maize production. This relationship was consistent with previous studies on TE among maize farmers in Nigeria and Arabica coffee production in Cameroon, but some studies found an unexpected negative relationship between extension contact and TE, warranting further investigation. The findings were presented in Table 66.

Table 66

Technical Efficiency of coffee farmers in Central Kenya

Descriptive Statistics	N (Obs)	Range	Minimum	Maximum	Mean	Std. Deviation
TE (Input oriented)	340	7.49	0.01	7.5	0.524 3	0.57707

N/B:

i. *TE = Yi/ Yi* where; Yi = relative measure (actual yield) and Yi* = absolute measure (optimum yield)*

ii. *Optimum yield is set at 2,000 metric tons per hectare.*

iii. *Average /yield (Kg/ha) stands at 890.6 metric tons (543.2 from Estates and 347.4 from Cooperatives).*

Summary of the Chapter

Through stochastic production frontier, the study sought to understand the driving forces behind relational agency, technology, and TE Kenyan coffee cultivation. The questionnaire was used to collect data, and the study response rate was 88.54%. The KMO test revealed that, KMO of 0.5 and above is significant. The study KMO value was 0.642 was greater than 0.5. Thus, it was viable to conduct a Confirmatory Factor Analysis for the study (Williams et al., 2010). The results of the varimax rotation recognised the first four extracted factors out of 32 components explained 15.4%, 23.1%, 30.1% and 35.6% of the total variations respectively.

Demographic analysis of the respondents, the study revealed that 72.9% of the respondents are males while 27.1% of them were females. The findings about the age of the respondents were that 0.3% of the respondents were of less than 30 years, 4.4% of them were between 30 and 40 years, 25% of them were between 41 and 50 years, 35.6% of them were between 51 and 60 years, 25.6% of them were 61 and 70 years while 9.1% of them were above 70 years. The study found that there was a positive and insignificant relationship between those farmers who are between 41 and 50 years and productivity compared to those who are less than 30 years ($\beta = 0.515$, $p = 0.483$). There is also a positive and insignificant relationship between those farmers who are above 70 years and productivity compared to those who are less than 30 years ($\beta = 0.872$, $p = 0.242$). The results of this study align with those of Woretaw (2020) who found that inputs such as capital, labour, land, and seed have a positive impact on output. According to the study, increasing the utilisation of capital, labour, and land inputs by one percent boosts grain production by 0.18 percent, 0.23 percent, and 0.56 percent, accordingly, while agrochemical input has a negative influence on output. Gender and educational attainment improve technological efficiency, while age, occupation, district, and incentives enhance technical inefficiency, according to the technical inefficiency paradigm. Producers' TE varied from twenty-three percent to one hundred percent, with an average TE of 71.7 percent. The report suggests stepping up efforts in adult and ongoing education.

The study findings rejected the null hypothesis number 2, which stated that young farmers use improved cultivars, bio inputs and mechanised implements than the post youth farmers. The one-way analysis of variance indicated that there was no statistically significant impact between the use of improved cultivars, bio inputs and use of mechanised implements by young farmers and post youth farmers {(F (5, 333) =0.580}. The study found out that 74.3% of the respondents were married; and 86% of the study sample had a formal basic education qualification. This enables the farmers to implement the information shared by the agency actors. In central Kenya, the family size composition of above three was 54% of the study group. The result agreed with Ogada (2014) conducted a study and discovered that decisions regarding adoption of related technologies were interconnected and were affected by various factors such as farmer characteristics, plot level factors and market imperfections. The study also revealed that smallholder farmers were not efficient in terms of technicality and were able to produce only 60 percent of the maximum possible output. The amount of TE differed between households and was impacted by the farming environment, production hazards, and farmer characteristics. The study also showed that adopting inorganic fertilisers and improved maize varieties together could lead to increased yields, particularly when done by efficient farmers.

Arable land is a major component of production. In the study area, the findings were that 86% of the respondents owned less than 4 acres of land. Many of the respondents had farming experience of 68.8% and a good number (57%) had other occupations which supplemented coffee farming. On labour productivity, it was found that 17.9% of the respondents engaged in family labour, and 82.1% used hired labour. Seasonal costs of coffee planting were pegged at KES 5,000 by 95% of the respondents. Due to the land sizes, the cost of fertilisers was found to be KES 10,000.00, the same costs were also attributed to the costs of the green manure.

All farmers were found to be affiliated to an agency such as a farmer's cooperative, marketing agency membership or even a managing agency. Extension visits were low in the sample group accounting to a population of 32.1%. It was found that 80% of the visits emanated from the managing agents, milling liaison, Government officers and non-governmental field support team. Certification penetration was found to be a low of 7.1% of the study sample. Out of which 4C and UTZ were the certification practices which were observed by the complaint group of 7.1 %. On coffee marketing, it was found that 98% of the farmers used cooperatives and registered marketing agent's entities. The respondents had little penetration to credit access, whereby only 10.9% of the respondents had access to financing. Pruning technology also had a low penetration too accounting for 32.6% of the study sample. The findings of this study align with research conducted in Tanzania and Rwanda, which highlight the importance of inorganic fertilisers, agrochemicals, and labour as key inputs for crop production. The study found that farmers were technically inefficient, with a mean TE index of 68%, indicating a potential scope for improvement of 32%. The number of coffee trees and farmer experience were identified as primary determinants of TE. Similarly, a study in Rwanda found that the average TE of maize farms was 0.64, with room for improvement of roughly 36%. The study also discovered a link between farm size and technological efficiency in maize production, indicating the necessity for land consolidation to boost output. Both studies found that education, group affiliation, services for extension, credit, off-farm revenue, tenure of land, and ownership of livestock are important determinants influencing TE. Another research of small-scale coffee producers found a mean TE of eighty-two percent implying that existing resources and technology might improve coffee production by eighteen percent. According to the study, education, access to financing, services for extension, a wider diversity of coffee plants, cropping systems, and land consolidation all have a favourable impact on TE.

The null hypothesis number 3 on there is no relationship between technology use, farm size, agency networks, and productivity among coffee farmers in Central Kenya was rejected. The model was statistically significant implying that technology use (mechanised, improved variety) significantly affects productivity among coffee farmers in Central Kenya (Prob > chi2 = 0.0003), in this case the alternate hypothesis was accepted, in that there is a relationship between technology use, farm size, agency networks, and productivity among coffee farmers in Central Kenya. In furtherance to this, an inline hypothesis H0: The technology use positively affects TE in Kenyan Coffee farming was accepted, since the inefficiency coefficients -0.357 and -0.236 (for technical inefficiency) were negative. The study concluded that technology use positively affects TE in Kenyan Coffee farming consequently, the null hypothesis was not disproved. In Central Kenya, a study was conducted to determine the relationship between farm size and productivity. The findings based on the SFA were significant (Prob > chi2 = 0.0,000). Another inline hypothesis on the relationship between agency networks and productivity among coffee farmers in Central Kenya, was found to be significant (Prob > chi2 = 0.0290).

The null hypothesis no 1 for the study was that: H1o: Existence of agency networks (Coffee management agents, marketing agents and extension) positively affects TE in coffee farming in central Kenya. The hypothesis was accepted since the technical inefficiencies were negative (-1.107, -0.143, -0.468 and -0.111).

The coffee revenue income band of KES 20,000 to KES 80,000 had 46.5% of the respondents, while the income band of KES 80,001 to KES 200,000 had 32.1% of the respondents. The null hypothesis H0: Production yield of coffee farmers in Central Kenya is greater than zero was accepted. This suggests that given the sort of labour utilised, the amount of land used, the use of technology, and the relational agency, coffee producers in Central Kenya are technically efficient on average (TE= 0.5243). The results corroborated a study carried out in Ethiopia by Woretaw (2020), which shown that inputs of capital, labour, land, and seed had a favourable impact on output. Yield was shown to be responsive, with increases in grain output of 0.18 percent, 0.23 percent, and 0.56 percent, respectively, for every one percent increase in capital, labour, and land input. The agrochemical input, on the other hand, had a detrimental influence on production. The study also discovered that gender and levels of education had an impact on TE, with age, occupation, district, and subsidies having a negative impact. Producers' TE ranged from 23 percent to one hundred percent, with an average of 71.7 percent.

CHAPTER 5: IMPLICATIONS, RECOMMENDATIONS, AND CONCLUSION

Introduction

This chapter gives the results summary of each research question and develops a linkage between how the findings have improved on the theory, consistency to the problem statement and its implication to the management practice.

The aim of the study was to examine the relationship between the various interrelated subjects which are involved on the coffee value chain. Ideally TE is an agricultural engineering where, cost of producing a given output is as low as possible. A farmer applies anew technique that boosts crop yield and reduces wastes thereby offer growers and farmers with precise forecasting, data driven decision making among others. These changes positively impacted on the bottom line of farmers which led to the improved food production at reasonable prices. These technologies may include irrigation, fertilisers, high yielding variety of seeds, insecticides/pesticides, farm machineries and financial institutions.

Regrettably, coffee farmers and smallholder growers in Murang'a County encounter difficulties including substandard agricultural practices, inadequate quality inputs, and limited access to information, finance, and markets, which are intensified by new issues such as climate change, evolving patterns of pests and diseases, and changing demographics. The conventional methods of reducing the disparities in productivity, such as providing more fertilisers and pesticides and educating farmers on proper agricultural practices, are inadequate.

The text discusses various studies conducted by scholars on farm technology adoption, TE, and productivity in smallholder food crop agriculture in different countries such as Kenya, Ghana, Rwanda, and Northern Ghana. The studies found that several factors such as farm size, access to credit, seed type, fertiliser, and production systems can positively influence TE, while others such as land size can have a negative impact. Education, credit, and modern inputs are recommended to improve efficiency. The scholars suggest a two-pronged approach by technology developers and development partners to scale up yields among smallholders. Overall, efficient use of available resources and existing technology can help farmers increase their output.

Yetagesu (2022) estimates that smallholder coffee producers in Southwest Ethiopia's Jimma zone have a southwest efficiency of 74.27%, meaning that they are producing about 25.73% less than the maximum output level. The study found that technical inefficiency was responsible for 99.9% of the variation in matured coffee output, while random noise accounted for the remaining 0.1%. The amount of land owned, the frequency of weeding, and extension services, for example, all had a large and favourable impact on TE, whereas the number of animals in the herd and off-farm revenue had a negative effect. The study suggests institutional services to boost smallholder coffee producers' productivity.

Meanwhile, Woretaw (2020) discovered that capital, labour, land, and seed inputs positively affect grain production in Northwest Ethiopia, while agrochemical input negatively influences it. Age, employment, district, and subsidies factors enhance technical inefficiency, the study indicated, whereas gender, degree of education, and subsidies factors increase TE. Technical efficiencies for the producers range from 23 to 100%, with a mean of 71.7%. Based on the above review, none has done a study on relational agency, technology, and TE in Kenyan coffee farming. With the active theory guiding this study with collaborative nature of the value of the actors, this study therefore will fulfil the gap by examining relational agency, technology, and TE in Kenyan coffee farming: a stochastic production frontier approach in Murang'a County Kenya.

The study was conducted based on collaborative agency relationships. The study was under pinned by the activity theory which focuses on how the subjects interact and relate to make rational decisions. Technology adoption model was also used in the study, the diffusion, and acceptances a formulated the framework on the individual adopt new innovations. Productivity was analysed through the production theory of economics; a Cobb Douglas trans-log regression model was used to measure the variable relationships.

The study's aim was to identify TE among coffee farmers following the adoption of constructed relationships and technology. Study evaluated the relational agency, technology, and TE in Kenyan coffee farming using a stochastic production frontier approach through the quantitative approach. The study utilised a cross-section design in collecting data. Primary data from farmers under marketing agents was collected at a specific period. The unavailability of information on a periodical basis limited the use of the longitudinal design in this study. This study employed both stratified sampling and simple random sampling methods. Since the number of small-scale farmers in all the counties was known, the researcher grouped the population as per the county administrative units and simple random sampling was used in identifying the respondent to take part in the study.

The researcher obtained permission before embarking on the data collection process. Approval granted by the national government was enough for the region under study. First and foremost, the researcher obtained approval from UNICAF University. In addition, a confirmatory letter was issued to ascertain the researcher was a student from the institution. Another important document that was obtained was the NACOSTI permit. It is a document issued by the government of Kenya through the ministry of education to regulate and authorise the research process in the country. Due to the COVID-19 pandemic, the researcher followed several measures to contain the spread. The researcher ensured that all the enumerators were aware of the health hazards associated with the pandemic. COVID-19 personal protective equipment was provided. We obtained informed consent, the researcher educated all research participants on study purpose, their participation in the study, what happens to the data gathered from them, and what they consented to do. Informed consent normally specifies how the data will be stored and disposed of and how the requisite secrecy will be maintained. It also states how the participant can withdraw their consent at any point, if you would stop using their data.

Discussion of the Findings

The discussions of the study were made based on the research questions of the study. The discussions are shown below:

Summary of the Background Information: Social Economic Information

From the background information, it was noted that more than half of the respondents are males. Given their marital statuses, many of them were married. It was also noted that most of them have up to secondary education. The findings indicate that most households have up to 3 members. Given the size of land they own, more than half of them have between 2 and 3.99 acres of land while many of the respondents have farmed for 11 and 30 years. Occupation-wise, it was revealed that most of the respondents have other occupations with a third of them being casual labourers. Likewise, most of the respondents indicated that they use hired labour. The findings indicate that more than half of the respondents earn between KES 100,000 and KES 300,000 annually from coffee farming. Furthermore, majority of them indicated that cultivation costs between KES 4,501 and KES 5,000 annually, planting costs KES 1,500 annually, fertiliser application costs less than KES 10,000 annually, manure application costs less than KES 10,000 annually, weeding labour costs less than KES 10,000 annually and that spraying labour costs between KES 10,001 and KES 30,000 annually.

Likewise, it was indicated by most of the respondents that coffee pruning costs less than KES 10,000 annually, most of the respondents indicated that mulching costs between KES 30,001 and KES 60,000 annually, while many of the respondents indicated that harvesting costs less than KES 10,000 annually. The study found that the coffee farmers in Central Kenya are technically inefficient given the type of labour used, the size of land used, technological use and relational agency.

The study also showed no significant interaction between the gender of the respondents and the annual cost of cultivating coffee and productivity among coffee farmers in Central Kenya. However, there is a significant interaction between education level of the respondents, land size, period of farming, occupation of the respondents, annual earnings from coffee farming and the type of labour used in coffee production and productivity among coffee farmers in Central Kenya. The findings were in line with Ngango (2019) research, which indicated that education, credit access, extension services, improved coffee tree varieties, cropping systems, and land consolidation have a positive and meaningful impact on TE. Therefore, coffee sector development policies could concentrate on improving farmers' access to credit and extension services. In addition, the use of disease-resistant, high-yielding coffee cultivars, enhanced cropping techniques, and better management of coffee plantations through land consolidation could aid in lowering technical inefficiency among coffee farmers in Northern Rwanda.

How Relational Agencies Improve on Technical Efficiency

The findings indicated that more than half of the respondents do not get visits from extension officers. Of those who get the visits from extension officers, most of the respondents get visits from extension officers on a quarterly basis. Most of them were, however, not certified coffee farmers while more than half of the certified farmers indicated that they comply with Common code certification. Many of the respondents indicated that they do not get direct sales contracts.

The findings indicate that most of the respondents had had no access to formal/informal credit last season. For those who accessed credit, most of the respondents receive credit from Saccos. More than half of the farmers borrowed between KES 10,000 and KES 50,000. The findings also note that many of the respondents are associated with the following groups, most of the respondents receive training about coffee production while most of the respondents receive training of coffee production twice every year.

The null hypothesis for the study was that: H1o: Existence of agency networks (Coffee management agents, marketing agents and extension) positively affects TE in coffee farming in central Kenya while the alternative hypothesis was that H1a: The presence of agency networks (Coffee management agents, marketing agents and extension) has a negative effect on TE in coffee farming in central Kenya. Therefore, given the negative coefficients of technical inefficiency, the study did not reject the null hypothesis and concluded that the presence of agency networks (Coffee management agents, marketing agents and extension) positively affects TE in coffee farming in central Kenya. The outcome of this study was consistent with the research conducted by Kamau et al. (2017) who concurred with the study that the lack of sufficient TE in coffee farming can be attributed to specific socio-economic factors. Both studies argue that the farmers who lie in the Kenyan socio-economic spectrum's lower prisms are less likely to adopt coffee farming mechanisms that yield high TE.

The study is consistent with the activity theory in that it is in consistent with findings of Karlsson and Wistrand (2017) who had examined the Activity Theory with method engineering as a theoretical framework for analysing systems development. In this study, activity theory perspective was separated through a collective of actors (Coffee management agents, marketing agents and extension) following different rules and activities for the coffee value chain. In synergy, they helped guide and further improvements in coffee farming to remove inefficiencies. Collaborative agency eliminated delays and leads to a potential improvement of the TE by 10%. This study results are in inconsistency with the findings of Kundu and Ngigi (2018), whose study findings were that cash payout from the agency due to a poor relationship led farmers to delay applying for agricultural inputs, consequently leading to low yield. Collaborative agency through the activity theory, has mapped a new dispensation on the yield’s improvement.

Economic inefficiency and extension visits have a negative association, according to Mahmuda et al. (2018). Small and marginal farmers that get assistance from Extension can reduce financial inefficiencies by 18 percent and seventeen percent, respectively. It is a key policy instrument for increasing peasant farmer production. Other researchers, including Beyan et al. (2013), Getachew and Bamlak (2014), Chilot et al. (1996), Freeman et al. (1996), Asfaw et al. (1997), and Kedir (1998), found that farmers who had more visits with development agents had better access to inputs and farming management practices, which led to increased production efficiencies.

In management, coffee subsector plays a vital role in export earnings, agricultural sector ranks third in the Kenyan economy, the inefficiencies in this sector are depicted on the primary producing units, the coffee subsector (Varga, 2020). The study recommends that since the relation agency actors improve on the TE positively, coffee growers should partner with other value chain stakeholders for better yields. In the past coffee wars have been labelling the managing agent actors as cartels who impede yields. Every farmer who collaborates with the agency actors had had an opportunity for direct sales markets. This is consistent with the literature review that certification (offered by managing agents) involves giving honest information to the buyers. It permits the fair-trade association to separate its item. The item separation permits the fair-trade association to market their coffee overseas (Potts et al., 2014).

Difference in Technology Use Between Young and Post-Youth Coffee Farmers

The findings also indicated that there is a positive and insignificant relationship between those farmers who are 30 and 40 years and productivity compared to those who are less than 30 years. There is, however, a negative and insignificant relationship between those farmers who are between 41 and 50 years and productivity compared to those who are less than 30 years. There was also a negative and insignificant relationship between those farmers who are between 41 and 50 years and productivity compared to those who are less than 30 years. There is a positive and insignificant relationship between those farmers who are between 41 and 50 years and productivity compared to those who are less than 30 years. There was also a positive and insignificant relationship between those farmers who are above 70 years and productivity compared to those who are less than 30 years. The one-way analysis of variance indicated that there was no statistically significant impact between the use of improved cultivars, bio inputs and use of mechanised implements by young farmers and post youth farmers.

The model was statistically significant implying that technology use mechanised, improved variety significantly affects productivity among coffee farmers in central Kenya. The null H2o: Young farmers use improved cultivars, bio inputs and use mechanised implements than the post youth farmers were rejected and the alternate hypothesis, H2a: Both young farmers and post youth farmers use improved cultivars, bio inputs and use mechanised implements was accepted.

The study findings contribute to the technology diffusion in that coffee farmers were aware of the existence of various innovations to help them manage their coffee farms. Both young and post youth farmers were the same in use of technology, since farmers keenness is to produce higher yields which promise better returns. Therefore, given the coefficient for technical inefficiency, the study concluded that technology use mechanised, improved cultivars) positively affects TE in Kenyan Coffee farming. Cultivation of the enhanced cultivars (Ruiru 11) that are disease-resistant coffee berries and offer superior yields. The findings are consistent with several researchers who had shown that technology adoption improves the efficiency of farms. Alene and Zeller (2005) concluded that crop production in farming improved by 21% when the appropriate technology was adopted. The study indicated that the TE of 79% was realised through the adoption of the right technology. Similarly, Anang et al. (2020) advised that the TE of maize production in Ghana was improved by the adoption of the right varieties of the crop. The findings were consistent with Temesgen et al., (2018) study which found a positive correlation between production efficiency and land size, as well as a negative correlation between production efficiency and fertiliser usage. Additionally, the study found significant second-order parameters of interaction between livestock and labour, seed and land, and land and fertiliser. The mean levels of production efficiency suggest that coffee farmers in the study region could increase their production by 22% by reducing inefficiencies and utilising existing technology and inputs effectively.

In the management practice, the study finding alluded to the use of the improved cultivars as promoted by the extension officers. The research agency in the coffee subsector should continue investing in producing other strains of cultivars that will be drought resistant.

The youth have no access to the land since the study findings show that only 4.7% of the study population were below the age of 40 years. This is consistent with previous research findings on the primary reason (youth lacking land) is that land is seen as a man's asset and the eldest man in the land who is the father does not like to give control or decisions of agriculture to the youth (Oerke et al., 2015). Moreover, Parabathina et al. (2017) indicated that the household head's age played a great role in influencing both the technical and EE of coffee farming. Ngeywo et al. (2015) hypothesise that age and the farm's size have a huge influence on an entity or individual's propensity to install farming techniques that instigate TE. More precisely farmer's age depicts his or her affinity towards farming methods that yield TE.

The study was inconsistent with the findings by Kamau *et al.* (2017), who uncovered that younger farmers are more likely to adopt specialised efficiency-boosting farming techniques as compared to their older counterparts. In this study, youth and elderly farmers were found to have the same technology implementation. The major limitation to the youth obtaining the land was due to the landowners (elderly) having some sentiments value thus not yielding to youth request.

Relationship Between Technology Use, Farm Size, Agency Networks and Productivity

Given the technology use (mechanised, improved variety), the Frontier regression model indicates that there is a positive and insignificant relationship between the coffee varieties planted and the productivity among coffee farmers in Central Kenya. However, there was negative and insignificant relationship between the fertiliser products used and the productivity among coffee farmers in Central Kenya. There was a positive and insignificant relationship between the cost of fertiliser and the productivity among coffee farmers in Central Kenya. There is also a negative and insignificant relationship between the use of herbicides and the productivity among coffee farmers in Central Kenya. There was a positive and insignificant relationship between the use of herbicides and the productivity among coffee farmers in Central Kenya. There was a negative and insignificant relationship between the use of fungicides and the productivity among coffee farmers in Central Kenya.

The findings also indicated that there was a negative and insignificant relationship between the cost of fungicides and the productivity among coffee farmers in Central Kenya. There is a positive and insignificant relationship between the use of biological methods and the productivity among coffee farmers in Central Kenya. However, there was a negative and insignificant relationship between the use of technology in coffee pruning and the productivity among coffee farmers in Central Kenya. There is, however, a positive and significant relationship between the frequency of coffee pruning and the productivity among coffee farmers in Central Kenya. There was a positive and significant relationship between the annual cost of coffee pruning and the productivity among coffee farmers in Central Kenya. However, there was a negative and insignificant relationship between the use of technology in coffee cultivation and the productivity among coffee farmers in Central Kenya. There was, however, a positive and insignificant relationship between the use of technology in irrigation and the productivity among coffee farmers in Central Kenya.

Given the size of the farm, the Frontier regression model indicates that there was a positive and significant relationship between the farm size and the productivity among coffee farmers in Central Kenya.

Likewise, given the agency networks (management entity, extension, and certification bodies), the Frontier regression model indicates that there is a negative and significant relationship between the management entity (*Which of the following are you a member of?*) and the productivity among coffee farmers in Central Kenya. However, there was a negative and insignificant relationship between the extension bodies (*Do you get visits from extension officers?*) and the productivity among coffee farmers in Central Kenya. The study indicates that there is a negative and significant relationship between the extension bodies (*How often do extension officers' visit?*) and the productivity among coffee farmers in Central Kenya. The study indicates that there is a negative and insignificant relationship between the certification bodies (*What kind of certifications have you complied with?*) and the productivity among coffee farmers in Central Kenya.

The study model was thus significant. This was in line with Sarirahayu and Aprianingsih (2018) that technology adoption and serious coffee producers are the best answer to counter environmental changes. This has anchored the activity theory, that the observed agency relationship has its initiative from activity theory, which advances the subjects' interactive nature. In the conceptual framework, the significance of the models supports the framework that institutional factors, social-economic factors, and technological factors under the government policy framework are work together to increase the coffee productivity. This is still in line with the management call for coffee growers to partner with other value chain stakeholders for better yields.

The results were in line with those of Abate et al. (2006), who found that large-scale grain farmers had a mean TE of 74% and were more productive than smallholders, who had a mean TE of 68%. This could be explained by the fact that large-scale farmers have an advantage in gaining and utilising larger market shares, having access to resources, and reaping the rewards of economies of scale and capacity brought on by huge farm sizes. Therefore, compared to small producers, large-scale producers can improve their TE.

This study backs up the findings of Nyawira (2019), who found that registered coffee unions had a good relationship with economic advantages. Farmers who belonged to registered coffee unions acknowledged having the power to make decisions, judgments, and hold others accountable had enhanced economic viability, with economic advantages being 0.27 points higher, pursuant to the econometric model. This implies that certified coffee cooperatives enable growers to profit financially. The capacity to bargain, on the other hand, was shown to have a substantial and negative link with economic gains in both certified and non-certified coffee cooperatives, which was surprising. bargaining with coffee chain participants such as millers, marketers, and purchasers was used to assess bargaining abilities. Respondents cited challenges such as verbal guarantees not being fulfilled and millers bribing farmers for votes, resulting in exaggerated milling losses. This led to reduced profitability for coffee farmers, particularly in non-certified cooperatives. The disparate power dynamics may be explained by the farmers' lack of empowerment compared to other participants in the coffee chain, such as millers and marketers.

Production Yield of Coffee Farmers in Central Kenya

From the findings, most of the farmers indicated that coffee revenue in the last season was between KES 20,001 and KES 80,000 while the minority indicated that coffee revenue in the last season was between KES 80,001 and KES 200,000. Likewise, revenue accrued from other farming activities between KES 20,001 and KES 80,000 according to a third of the farmers. A third of them indicated that non-coffee revenue was between KES 80,001 and KES 200,000 in the last season while a third of them indicated non-coffee revenue between KES 200,001 and KES 500,000 in the last season.

The null hypothesis H_0: Production yield of coffee farmers in Central Kenya is greater than zero was accepted. This suggests that considering the sort of labour utilised, the amount of land used, the use of technology, and the relational agency, the coffee producers in Central Kenya are technically averagely efficient. The findings are in line with Haggar et al.'s (2017) study, which discovered that the adoption of innovative agricultural practice has increased crop yield as well (Haggar et al., 2017). Using a two-step process, Kamau et al. (2016) calculated the TE of coffee farming in Murang'a. The study calculated the TE measures using DEA. The average TE was discovered to be 54%. This nevertheless demonstrates that there is opportunity for advancement. According to Muriithi (2016), the underlying economic theory explaining the variables thought to affect Kenyan coffee producers' decisions is to adopt new technologies is based on the knowledge that Kenyan coffee farmers are rational.

In the management practice, the following factors should be emphasised because they affect TE, size of the household extension visits, marketing agents and membership affiliation. Moreover, the Frontier regression model indicates that there is a negative and significant relationship between the management entity (Which of the following are you a member of?)

and the productivity among coffee farmers in Central Kenya. These results support Voora et al. (2019), who found that obtaining a coffee credential paves the way for new networking opportunities for small producers.

Contributions to Theory

The findings contribute to the activity theory which bridges the gap between the individual subject and the social reality. In collaboration, they provide a method of understanding and analysing a phenomenon, finding patterns, and making inferences across interactions - subject, object, and tool. In this case, the theory best informed the coffee farmers (subjects) who intend to improve the productivity of farm produce (object) by use and adoption of technology collaborative agency. Hill et al., (2002) concluded that activity theory offered a great framework for their analysis. Świergiel et al. (2018) also found that the organic farming concept was trying to break free from conventionalisation. Thus, the theory has been found instrumental and validated in the current study since a relationship amongst agency networks and productivity among coffee farmers in Central Kenya was found to be significant. Therefore, the coffee farmers could incorporate the use of technology and could be assisted by the collaborative agency to improve their coffee production.

Managerial Implications

Based on the above findings and given the mechanisation and the cultivation of improved varieties by farmers (where U_t represents the technical inefficiency), the study concluded that the farmers who grow the SL 28 cultivars were technically inefficient than those that grow the Ruiru 11 cultivar. However, the farmers that use technology in coffee cultivation are more technically efficient than those that do not. Likewise, given the size of land used by farmers for coffee production (where U_t represents the technical inefficiency), the study concluded that the farmers who have between 2 and 3.99 acres are technically inefficient. That is the smaller the size of the farm, the less technically efficient the farmers become. Lastly, given the size of the management entity, extension, and certification bodies in coffee production (where U_t represents the technical inefficiency), the study concluded that the farmers who have institutional membership, those who get visits from extension officers, and those who have complied with certifications are technically efficient.

The study also concluded that both young farmers and post youth farmers use improved cultivars, biological inputs and use mechanised implements since there was no statistically significant impact between the use of improved cultivars, bio-inputs and use mechanised implements by young farmers and post youth farmers. Likewise, the study concluded that technology use positively affects TE in Kenyan Coffee farming, thus the null hypothesis was accepted.

The study also concluded that among coffee growers in Central Kenya, there was a substantial correlation between technology utilisation and productivity. In Central Kenya, there was a connection between farm size and production among coffee farmers. The study also concluded that the presence of agency networks (Coffee management agents, marketing agents and extension) positively affects TE in coffee farming in central Kenya. Likewise, the study concluded that there was a significant relationship between agency networks and productivity among coffee farmers in Central Kenya.

However, based on the input-oriented TE, the study concluded that the coffee farmers in Central Kenya are technically inefficient given the type of labour used, the size of land used, technological use and relational agency. This shows that the coffee production in Central Kenya was yet to be optimised, and farmers are not able to efficiently allocate the farm inputs to achieve maximum output. This has been evidenced by majority of the farmers having limited size of land under coffee; majority of them using hired labour; more than half of them who do not get visits from extension officers; majority of them who are not certified coffee farmers and majority who do not access to formal/informal credit last season. Lack/shortage of such input variables negatively impacts on the optimisation of coffee output and thus resulting in technical inefficiencies.

Recommendations for Applications

Given that the farmers who grew the improved cultivars (Ruiru 11) are technically more efficient than those that grow the SL-28 cultivar, the current study recommended the farmers to seek extensional advice on which coffee products to grow and a possible switch to the production of Ruiru 11 cultivar for TE.

Likewise, the farmers that use technology in coffee cultivation were found to be more technically efficient than those that do not. Therefore, the study recommended that farmers to continuously adopt and use technological methods in coffee production (like the use of improved cultivars, use of herbicides, biological methods, fertiliser products and technologically enhanced irrigation methods) for TE.

The study found that smaller farms have lower TE levels, and as a result, recommended that the National Land Commission work with county governments to establish secure land tenure systems for farmers in Central Kenya. On-farm investments should also be promoted to enhance TE and increase access to agricultural credit and extension services. To benefit from institutional membership, extension services, and credit access, the Coffee Board of Kenya and the National Land Commission should ensure that all coffee producers in Central Kenya are

100% certified. To ensure that agricultural credit is used effectively, county governments and credit providers should establish monitoring mechanisms.

The study also recommended that coffee farmers register with institutional groups or cooperatives to access extension services. Contract farming should be allowed at the farm level, with quality differentiation and payment commensurate with quality. To protect farmers from price instability, the government should set up a guaranteed minimum price and a revolving fund. It should also investigate other marketing strategies including internet sales and collaborations with well-known global companies. Certification costs should be subsidised by the government, and adherence to international labour and environmental standards facilitated. Finally, the study suggested that farmers or their representatives should be allowed to observe coffee chain processes and transactions to increase transparency and accountability. Additionally, the study found that seed, labour, land size, and capital inputs have a statistically significant positive effect on the TE level of large-scale grain production.

Improved agricultural practices and yields, access to new cultivars, and an extension outreach programme for coffee farmers can facilitate higher yields in the longer term. However, there are challenges such as high operating costs, governance-related inefficiencies, and input supply systems that need to be addressed.

Ministries of agriculture at national and county levels should allocate resources to support capacity-building activities for all actors along the coffee value chain. The availability and quality of the extension officers to provide knowledge and training on the SCP practices to coffee producers is essential for implementing the practices. Some of the critical knowledge includes information on the best SCP practices and their benefits for specific land conditions and how farmers can maintain sustainable practices. SCP training is also required to create more skilled labourers. Thus, it is important for the county-level minister to ensure the effectiveness of these extension officers.

At national and county levels, the Ministries of agriculture should allocate financial resources to support coffee producers by providing subsidy programmes for sustainable technology improvements and incentive programmes for SCP integration. This will encourage more farmers to improve their current practices and switch to sustainable practices. In addition, this will motivate more farmers and youth to stick with coffee production.

At the county level the ministry of agriculture should consider creating institutional platforms for farmers to explore both local and international coffee markets, allowing them to gain access to information on the market conditions and bargaining powers on the pricing and product marketing. This will help farmers better understand market demands and produce quality coffee that fits the market with the potential to sell at a higher price.

The report makes recommendations for raising coffee farmers' educational levels and providing possibilities for female farmers to oversee large-scale coffee farming. To lessen technological inefficiency, the county government could offer guidelines for appropriate input application and set up a pilot research institution in the study areas. To increase the TE of large-scale coffee growers in Murang'a County, there is currently a high level of inefficiency in the coffee production process that needs to be addressed by policymakers and researchers.

Efforts should be made to enlist experienced farmers capable of leading large-scale agriculture, and young adults ought to be urged to join. To improve their coffee growing skills and expertise, they need to have improved access to required production inputs such as fertilisers, land, and agricultural chemicals, as well as educational opportunities and seminars.

These measures can lead to enhanced production and profitability by making better use of existing farm technologies.

The study recommends improving extension services to reach all farmers in Murang’a County, regardless of their location, to enhance their managerial skills and TE. The government should also make it possible for small-scale farmers to acquire finance. The study also highlights the need for enhanced coffee variety research and development. Extension professionals should be entrusted with assisting and enticing farmers to adopt high-yielding and disease-resistant varieties like BM139. The study also reveals that land consolidation and mono-cropping could aid in reducing technical inefficiencies among coffee growers in Murang'a County. Despite challenges such as difficult terrain and the high cost of machinery, introducing mechanisation could improve the maintenance, efficiency, and productivity of coffee plantations.

Recommendations for Future Research

Stochastic production function permits for the thorough investigation of the determinants of TE, further research is recommended for the other determinants which did not form part of this study such as the effect of climate change on coffee production; block-chain technology adoption and its impact on coffee farming.

The study recommended further research on the TE for the large coffee estates, an area where it had little research and see how the findings would be compared with the small-scale farmers. Most of the large coffee estates production level per hectare was publicly available through their annual report, however the level of TE could not be statically ascertained. It was the large estates whose volumes influence the auction market.

Kenya and other countries in east Africa are well known for their prowess in the production of coffee. However, the COVID-19 pandemic has taken its toll on coffee production in the country as it has done to several other sectors. As reported by the Coffee Directorate of Kenya, the number of metric tons of coffee produced in the country fell from 50,600 in 2019 to 46,162 in 2020. Again, the coffee imported into the country also witnessed a 17.1% decline in September 2020 as compared to September 2019 (Coffee Directorate, 2020). The underlying reason behind this decline is ultimately the COVID-19 pandemic. However, fluctuations in the dollar exchange rate also influenced the decline. Further study in this area would also aid in the formulation of disaster preparedness in coffee farming.

The outcomes of this study point to a few significant conclusions. To start, expanding coffee crops is essential for raising TE. There can be a considerable improvement in TI 1 with more coffee trees. This is in line with the Tanzania Coffee Hoard's interim plan, which is a component of the Tanzania Coffee Industry Development Strategy 2011-2021, to give 20 million seedlings to farmers by 2021. Additionally, efforts should be made to encourage youth engagement and give them access to critical input and training, as well as to support seasoned farmers who can take the lead in business-oriented agriculture. Without raising input levels, coffee production might be boosted by 25% by boosting the effectiveness of already used farm methods. For greater productivity, farming experience is also essential, and training in optimal agricultural practices can help farmers advance their abilities. The NGOs can assist farmers in learning how to use inputs properly to maximise output and advance towards the production frontier.

To investigate how the efficiency and productivity of the coffee farming industry are impacted by land and labour market inefficiencies. The study suggests various ways to improve

TE in coffee production. One of the recommendations is to increase contact between extension officers and farmers by deploying participatory methods like the lead-farmer model, group training, and farmer-driven extension demand. Access to credit is also crucial for TE, and the government should consider influencing borrowing rates to make credit more accessible for farmers. Formal and informal education can also improve efficiency, and non-formal agricultural education could supplement formal education for farmers who have not acquired formal education.

The study only evaluated TE and recommends an assessment of allocative efficiency to determine optimal levels of input use. Furthermore, the study suggests that policy makers should develop strategies to improve the performance of the coffee sector and consider the needs of large-scale coffee producers in Kenya.

Therefore, future researchers must consider a broader sample of farmers that spans more than counties in Murang'a, Nyeri, Kiambu, Embu, Kitui, and Kisii, respectively. Our findings on the level of improving TE among coffee growers in Murang'a County, Kenya, may not be generalizable as such.

Limitations

Under this study, the researcher acknowledged the deficiency or deficiencies by stating a need for future researchers to revise their specific methods for collecting data that includes these missing elements. Under this study, 44 despondences never returned their questionnaires, it could have been that because of one of the following problems; Not everyone received an invitation, the study does not seem interesting, there are too many questions, questions are too complex, the language is not suitable for your respondents, Personal questions at the beginning, Logic flaws, Seasonality.

Under this study the researcher realised that, relying only on open-ended questions to collect certain data may not provide you with useful insights since not everyone can articulate their ideas or opinions if asked about them generally, so it is important to follow up with a question that presents an aided list that respondents select from.

In this work, the frontier was estimated using an SFA, although this methodology cannot accommodate numerous outputs. Due to a lack of precise information from coffee farmers and cooperative societies, certain output, such as the output of dry coffee beans, was excluded from the study. Comparing the DEA approach to the frontier approach would have made it possible to evaluate multiple input, multiple output technologies. Because the farmers were unable to offer precise information on man hours or for different categories of work performed in the coffee farms, this study used the assumption that worker productivity in the coffee farms was the same.

This study did not consider every variable that might have been included in the technical inefficiency model, including risk, market flaws, worker age, coffee experience, and others. The physical measurements used in this study to assess physical inputs made it impossible to compare differences in input quality, such as the quality of the labour force, the quality of the pesticides and fertilisers, etc. Researchers have utilised monetary input values to address the issue of heterogeneity of inputs, or variances in quality; however, it was hard to achieve uniform monetary values for this study since coffee fans had a wide range of varying costs. The growth in total factor productivity was not examined in this study to determine if technological change is the result of increased efficiency or innovation. It is also possible to investigate the consequences of prices that the coffee producers deem to be high and how they affect coffee exports on TE.

From the finding under this study, the researcher realised that majority of the farmers do not get access to credit facilities due to technicalities involved while acquiring credit facilities.

Also, young farmers who do not own land were not able to expand their coffee plantation practices and therefore were disadvantaged especially in the coffee sector and, they are looking for other avenues since they do not consider coffee farming as a source of income.

Areas for Further Research

The results of this study point to the need for additional research on the evaluation of TE of small-scale coffee agricultural operations in Murang'a County, Kenya. Additional investigation could focus on TE in resource use: Evidence from small-scale coffee producers in the Kenyan counties of Nyandarua and Kisii.

To identify the external factors that would indirectly affect coffee production in Nyeri such as linkages to market and policy environment. Future research should also analyse the coffee value chain to identify the gaps in the coffee farming in Murang’a.

Conclusion

In this study, we examined the relational agency, technology, and TE in Kenyan coffee farming: a stochastic production frontier approach in Murang’a County Kenya. Who is technically inefficient? That means, farmers need to increase coffee production by adopting TE in their farms. From the result, there was a significant variation in yield per coffee tree except for organic fertiliser whose coefficient was not significantly different from zero. This implies that farmers in Murang’a were applying inputs below the optimum level. Hence coffee production could be increased by improving the inputs use and subsequently TE. The farmers' experience and the number of coffee trees are very important in improving TE. The study revealed that the coffee farmers in Murang'a Kenya are technically inefficient given the type of labour used, the size of land used, technological use and relational agency.

The study also showed no significant interaction between the gender of the respondents and the annual cost of cultivating coffee and productivity among coffee farmers in Murang'a Kenya. However, there was a significant interaction between education level of the respondents, land size, period of farming, occupation of the respondents, annual earnings from coffee farming and the type of labour used in coffee production and productivity among coffee farmers in Central Kenya.

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APPENDICES

Appendix A: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 443081

Date of Issue: 25/June/2021

RESEARCH LICENSE

This is to Certify that Mr.. George Waweru Mwangi of UNICAF, has been licensed to conduct research in Embu, Kiambu, Kirinyaga, Muranga, Nyeri on the topic: RELATIONAL AGENCY, TECHNOLOGY AND TECHNICAL EFFICIENCY IN KENYAN COFFEE FARMING: A STOCHASTIC PRODUCTION FRONTIER APPROACH for the period ending : 25/June/2022.

License No: NACOSTI/P/21/11416

443081

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendix B: UREC's Decision

UNICAF UNIVERSITY

UREC's Decision

Student's Name: George Waweru Mwangi

Student's ID #: R1806D5508566

Supervisor's Name: Wajdi Ben Rejeb

Program of Study: UUZ: DBA Doctoral of Business Administration

Offer ID /Group ID: O16468G15817

Dissertation Stage: 1

Research Project Title: Relational agency, Technology and Technical efficiency in Kenyan coffee farming: A stochastic production frontier approach

Comments:

Decision: A. Approved without revision or comments

Date: 15-Apr-2020

Appendix C: Introduction Letter

UNICAF UNIVERSITY

Date: 22 June 2021

Licensing & Monitoring
The National Commission for Science Technology and Innovation off
Waiyaki Way, Upper Kabete,
P. O. Box 30623, 00100
Nairobi, KENYA

Object: INTRODUCTION OF GEORGE WAWERU MWANGI (UNICAF PHD STUDENT)

Dear Sir,

George is a doctoral student at Unicaf University Zambia (UUZ). As part of the degree program he will be carrying out a study on Relational agency, Technology and Technical efficiency in Kenyan coffee farming: A stochastic production frontier approach.

The study will be using a questionnaire to collect data from coffee farmers in Central Kenya counties. Unicaf University Research Ethics Committee has approved the proposal for the data collection to be done.

The information collected will remain strictly confidential and will never be used for commercial purposes. This survey is part of an academic work, which, with your precious collaboration, would have the desired influence for the improvement of the agricultural sector in Kenya.

Any assistance accorded to George will be highly valued.

Kindly, let us know if you require any further information or need any further clarifications.

Yours Sincerely,

For and on Behalf of Unicaf University

Dr. Wajdi Ben Rejeb
Doctoral Research Supervisor

Appendix D: Informed Consent

UNICAF UNIVERSITY

UU_IC - Version 2.1AP

Informed Consent Form

Part 1: Debriefing of Participants

Student's Name: George Waweru Mwangi

Student's E-mail Address: georgewaweru@gmail.com

Student ID #: R1806D5508566

Supervisor's Name: Dr. Wajdi Ben Rejeb

University Campus: Unicaf University Zambia (UUZ)

Program of Study: UUZ: DBA - Doctorate of Business Administration

Research Project Title: Relational agency, Technology and Technical efficiency in Kenyan coffee farming: A stochastic production frontier approach

Date: 28-Mar-2021

Provide a short description (purpose, aim and significance) of the research project, and explain why and how you have chosen this person to participate in this research (maximum 150 words).

This study aims to identify technical efficiency among coffee farmers following the adoption of constructed relationships and technology. Coffee exports lead to dollar inflows to the economy to alleviate poverty (KNBS, 2019); it is imperative to implore on various ways to boost productions amidst glaring evidence of low yields. This will be identified by how coffee farmers adapt and utilize technology, variations in disease-resistant measures, and best coffee farming practices. The research aim for this study is to evaluate the impact of relational agency, technological adoption, and technical efficiency in the dialect of how it impacts Kenyan farmers and their farming endeavor through the adoption of the frontier approach. All actors (stakeholders) in the production (Coffee sub-sector) should work in sync to ensure all desired outcomes are attained.
You have been chosen as a participant to help identify the existing agency relationships, technology adoption level and how government policies shape coffee farming. Besides, your recommendation on the institutional support you may require to improve on your farming activities.

The above named Student is committed in ensuring participant's voluntarily participation in the research project and guaranteeing there are no potential risks and/or harms to the participants.

Participants have the right to withdraw at any stage (prior or post the completion) of the research without any consequences and without providing any explanation. In these cases, data collected will be deleted.

All data and information collected will be coded and will not be accessible to anyone outside this research. Data described and included in dissemination activities will only refer to coded information ensuring beyond the bounds of possibility participant identification.

I, George Waweru Mwangi **, ensure that all information stated above is true and that all conditions have been met.**

Student's Signature: ______________________

UNICAF UNIVERSITY

UU_IC - Version 2.1

Informed Consent Form

Part 2: Certificate of Consent

This section is mandatory and should to be signed by the participant(s)

Student's Name: George Waweru Mwangi

Student's E-mail Address: georgewaweru@gmail.com

Student ID #: R1806D5508566

Supervisor's Name: Dr. Wajdi Ben Rejeb

University Campus: Unicaf University Zambia (UUZ)

Program of Study: UUZ: DBA - Doctorate of Business Administration

Research Project Title: Relational agency, Technology and Technical efficiency in Kenyan coffee farming: A stochastic production frontier approach

I have read the foregoing information about this study, or it has been read to me. I have had the opportunity to ask questions and discuss about it. I have received satisfactory answers to all my questions and I have received enough information about this study. I understand that I am free to withdraw from this study at any time without giving a reason for withdrawing and without negative consequences. I consent to the use of multimedia (e.g. audio recordings, video recordings) for the purposes of my participation to this study. I understand that my data will remain anonymous and confidential, unless stated otherwise. I consent voluntarily to be a participant in this study.

Participant's Print name:

Participant's Signature: ______________________

Date:

If the Participant is illiterate:

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had an opportunity to ask questions. I confirm that the aforementioned individual has given consent freely.

Witness's Print name:

Witness's Signature: ______________________

Date:

Appendix E: Gate Keeper Letter

UNICAF UNIVERSITY

UU_GL - Version 2.0AP

Gatekeeper letter

Address: National Com. for Science Techn. & Innov

Date: 16-May-2021

Subject: APPLICATION FOR A RESEARCH LICENSE

Dear Prof. Walter,

I am a **doctoral** student at **Unicaf University Zambia (UUZ)**

As part of my degree I am carrying out a study on **Relational agency, Technology and Technical efficiency in Kenyan coffee farming: A stochastic production frontier approach.**

I am writing to seek research license and permission to administer questionnaire to farmers in Kenya. The Counties of interest are Kiambu, Muranga, Nyeri, Kerugoya and Embu.

Subject to approval by Unicaf Research Ethics Committee (UREC) this study will be using a **questionnaire to collect data from coffee farmers in Central Kenya counties.**

The purpose of this study is to investigate the nexus of constructed relationships and technology adoption on technical efficiency in coffee farming. The study fills this knowledge gap on coffee farming construed relationships in the coffee value chain. Moreover, the study examines the effectiveness of government interventions in improving technical efficiency in coffee farming. The research aim for this study is to evaluate the impact of relational agency, technological adoption, and technical efficiency in the dialect of how it impacts Kenyan farmers and their farming endeavor through the adoption of the frontier approach.

Study hypothesis to be testes are;
(i)Existence of agency networks (Coffee management agents, marketing agents, and extension) positively affects technical efficiency in coffee farming in central Kenya;
(ii)There is no relationship between technology use, farm size, agency networks, and productivity among coffee farmers in Central Kenya
(iii)Production yield of coffee farmers in Central Kenya is greater than zero.

Thank you in advance for your time and for your consideration of this project. Kindly please let me know if you require any further information or need any further clarifications.

Yours Sincerely,

Student's Name: George Waweru Mwangi
Student's E-mail: georgewaweru@gmail.com
Student's Address and Telephone: 12025-00100, Nairobi; +254722465145
Supervisor's Title and Name: Dr. Wajdi Ben Rejeb
Supervisor's Position: Supervisor & Lecturer
Supervisor's E-mail: w.rejeb@unicaf.org

Appendix F: Farmers Questionnaire

Date	
Location	
Enumerator’s name	

SECTION ONE: SOCIO-ECONOMIC FACTORS

1	Gender	Male [ ]		Female [ ]
2	Age(years)			
3	Marital status	Single [ ] Married [ ]		Divorced [ ] Widowed [ ]
4	Education level	No education [ ] Primary [ ] Secondary [ ]		College [ ] University [ ] Others (specify) ....
5	Kindly indicate the size of your household	....		
6	What is the size of your land (in acres)	....		
7	How long have you been farming?	....		
8	What is your occupation?	Permanently employed [ ] Casual labourer [ ] Business [ ] Others (specify) ………………………		
9	How much do you earn annually (in Kenyan shillings)	Below 100,000 [ ] Between 100,000-300,000 [ ] Between 300,001-500,000 [ ] Between 500,001-1,000,000 [ ] Over 1,000,000 [ ]		
10	a. What kind of labour do you utilize	Family [ ] Hired [ ]		
			Family	Hired

11	b. What is the annual cost?	Activity	No. of persons	Cost/day	Total cost	No. of persons	Cost/day	Total cost
		Cultivating						
		Planting						
		Fertiliser application						
		Manure application						
		Weeding labour						
		Spraying labour						
		Coffee pruning						
		Mulching						
		Harvesting						
		Other						

SECTION TWO: INSTITUTIONAL FACTORS

Coffee management experts					
11	Which of the following are you a member?	Kenya Coffee Traders Association [ ] Kenya Coffee Producers Association [ ] Kenya Coffee Producers and Traders Association [ ] Others (specify)..			
Extension workers					
12	Do you get visits from extension officers	Yes [ ] No [ ]			
13	How often do extension officers visit?	Weekly [ ] Monthly [ ] Quarterly [ ]	Biannual [ ] Yearly [ ] Biennial [ ]		
	Who are the providers of extension services in your area?	NGO [ ] Government [ ] Farmers [ ] Others (specify)..			
Certification agencies					
14	Are you certified	Yes [ ] No [ ]			
15	What kind of certifications have you complied with?	Type of certification	Year certified	Cost	Benefits of certification
		Common code coffee certification			
		UTZ certified			
		Fairtrade certification			
		Rainforest			
		CAFÉ practices			
		Others			
Direct sales contracts					
16	Do you get direct sales contracts	Yes [ ] No [ ]			
17	How do you sell your coffee	Directly to exporters [ ] Though marketing agents [ ] Trough millers [ ] Through cooperatives [ ] Others (specify)..			
Access to credit					
18	Did you have access to formal/informal credit last season?	Yes [ ] No [ ]			
19	From which institution do you get credit and how much	Institution Commercial banks Saccos Chamas	Amount (KES)		

		Factory/society .... Friends/relatives .... Others ....
20	How much did you borrow in previous season?	KES …………………………..
Social capital		
21	Are you associated with the following groups?	Cooperative society Yes [ ] No [ ] Farmers union Yes [ ] No [ ] Research project Yes [ ] No [ ] Training project Yes [ ] No [ ] Certification project Yes [ ] No [ ] NGO project Yes [ ] No [ ] Others (specify)..
22	Do you receive any type of training?	Yes [ ] No [ ]
23	How often do you receive training from either of the following per year?	Type of group ……………………… Number of trainings ……………………… Coffee meetings ……………………… Agricultural groups ……………………… Groups that you are a leader ……………………… Agricultural shows ……………………… Extension visits ……………………… Course or seminar on coffee farming ………………………

SECTION THREE: TECHNOLOGY FACTORS

Coffee varieties and cultivars					
24	Which coffee varieties have you planted	Arabica [ ] Robusta [ ] Both [ ] Others (specify) ………………………			
25	Which other farming activity are you engaged in?	Banana farming Maize farming Dairy farming Poultry keeping	Tea farming Pineapple farming Vegetables growing Others (specify) ………………………		
Fertilisers					
26	What fertiliser products do you use and what's the quantity used in a year?	Type	Amount (kg/year)	Unit cost	Total cost
		DAP			
		CAN			
		SSP			
		Manure			
		Others			
		Mulch			
Pesticides					
27	Do you use herbicides	Yes [ ] No [ ]			
28	If you use, indicate the type, quantity the cost	Type of herbicides (commonly used brands)	Amount (kg/year)	Unit cost	Total cost
29	Do you use fungicides	Yes [ ] No [ ]			
30	If you use, indicate the type, quantity the cost	Type of fungicides (commonly used brands)	Amount (kg/year)	Unit cost	Total cost
31	Do you use fungicides	Yes [ ] No [ ]			
32	If you use, indicate the type, quantity the cost	Type of fungicides (commonly used brands)	Amount (kg/year)	Unit cost	Total cost
Biological controls methods					
33	Are there biological methods you use in place of insecticides	Yes [ ] No [ ]			
34	If yes, indicate them	....	....		

		....	....
35	How much do you incur per year using these methods	KES …………………………..	
Pruning method			
36	Do you use technology in pruning	Yes [ ] No [ ]	
37	If yes, name them	....	
38	How often is pruning done?	Daily [ ] Weekly [ ] Fortnightly [ ]	Monthly [ ] Quarterly [ ] Yearly [ ]
39	How much does it cost you in a year?	KES ………………………….	
Cultivation			
40	Do you use either of the following in farming?	Hoes Plough Tractors Pangas	
41	Do you use technology in cultivation?	Yes [ ] No [ ]	
42	If yes, name them	....	....
Irrigation			
43	What is the main type of irrigation do you use?	Flooding [ ] Dripping [ ] Sprinkling [ ] Others (indicate)	
44	Do you use technology in irrigation	Yes [ ] No [ ]	
45	If yes, name them	....	....
Weeding			
46	Do you use technology in pruning	Yes [ ] No [ ]	
47	If yes, name them	....	....
Spraying			
48	Do you use technology in spraying	Yes [ ] No [ ]	
49	If yes, name them	....	....

		....	....

SECTION FOUR: TURNOVER

	Type	Quantity	Units	Unit cost	Total cost
How much did you get from sale of coffee in the last season?	Fresh cherry				
	Dried cherry				
	Dried bean				
How much did you receive from other farming activities	Dairy				
	Banana farming				
	Tea farming				
	Maize farming				
	Pineapple farming				
	Poultry farming				
	Vegetable farming				
	Other activities				