

**ANALYSIS OF SOCIO-ECONOMIC CHARACTERISTICS, AGRONOMIC
PRACTICES AND COOPERATIVE DIVERSITY ON COFFEE YIELD GAP
AMONG SMALLHOLDER FARMERS IN NYERI CENTRAL SUB-COUNTY,
KENYA**

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**A Thesis Submitted to the Graduate School in Partial Fulfilment of the
Requirements for the Award of the Degree of Master of Science in Agricultural
Economics of Chuka University**


CHUKA UNIVERSITY

OCTOBER, 2023

DECLARATION AND RECOMMENDATION


Declaration


This thesis is my original work and has not been presented for an award of a diploma or conferment of a degree in any other institution.

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Recommendation

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DEDICATION

This thesis is dedicated to my late father: Sammy Ndung'u, Loving mother: Agnes Muthoni, siblings: Simon Munyi, Elly Elvins, Tracy Njoki and Daughter: Blessing Muthoni for their immeasurable support: morally and financially.

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I give God all the glory for the strength, inspiration and chance to further my education. Truly, I am grateful for He has been faithful.

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ABSTRACT

Coffee significantly aids in the reduction of poverty in households, increases the gross domestic product (GDP) of Kenya and generates tax revenue. However, the coffee yields have been declining over the last two decades which is revealed by the reduction in acreage by 30% from 170,000 ha in the 1980s to 108,199 ha in 2021. This has resulted to decrease in production by 70% making it hard for smallholder coffee farmers to benefit from the sector. The ultimate result is a large yield gap between farmers' actual yields and the potential productivity of the coffee varieties from the KALRO-Coffee Research Institute, Ruiru. This study aimed at identifying factors (socio-economic characteristics, agronomic practices and cooperative diversity) influencing coffee yield gap among smallholder coffee farmers in Nyeri Central sub-county, Nyeri County. A cross-sectional research design was used and through the systematic random sampling technique, a sample of 175 smallholder coffee farmers was drawn from the target population of approximately 7000 coffee farmers. A semi-structured questionnaire was used for the study with its validity determined by the academic supervisors and the experts in the coffee sector. The reliability of the research instrument was also determined using the split half method. Primary data on coffee farmers' socio-economic characteristics, agronomic practices and cooperative diversity were collected. The data on socio-economic characteristics, agronomic practices and cooperative diversity were analyzed as descriptive statistics using SPSS version 29 and their effect on coffee yield gap was determined using the fractional logit regression model in STATA version 17. The findings noted that the average farmers' yields per hectare for Ruiru 11, Batian and SL 28 was 8,593.920 kg/ha, 3,545.277 kg/ha and 1,722.423 kg/ha, respectively. The yield gap estimated was 66,406.080 kgs, 53,454.722 kgs and 38,177.577 kgs for Ruiru 11, Batian and SL 28, respectively. Further, the yield gap index per farmer ranged between 84.99% to 96.90% and the yield gap index per variety was 88.54% for Ruiru 11, 93.78% for Batian and 95.68% SL 28. The model parameters indicated that gender of the household head, schooling years, household size, labour, weed management, disease management, extension, training as well as production and market information were negative but significant independent variables at $p < 0.05$. The insect-pest management was found to have a positive and significant effect on coffee yield gap at $p < 0.05$. The independent variables omitted in the model analysis were found to be insignificant and hence did not affect the outcome in this study. Moreover, negative coefficients indicated that an increase in each of the explanatory variables resulted in a decrease in the coffee yield gap, holding other factors constant. The marginal effect showed the number of units that the independent variable contributed to either increase or decrease the coffee yield gap. The study concluded that the smallholder coffee farmers' age was 60 years which contributed to increased yield gap while households led by male individuals resulted to minimized yield gaps. Also, the smallholder coffee farmers were producing below their potential as depicted by the large yield gap estimate. Hence, this study suggests that farmers should fully implement the recommended agronomic practices fully and adopt the improved varieties especially Ruiru 11. Also, the Government and other stakeholders should support the extension services so as to increase coffee yields which would result in reduced coffee yield gap.

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LIST OF ACRONYMS

| | |
|--------------|--|
| AFA | Agriculture and Food Authority |
| CBD | Coffee Berry Disease |
| CBK | Coffee Board of Kenya |
| CDA | Coffee Development Authority |
| CLR | Coffee Leaf Rust |
| CRI | Coffee Research Institute |
| ETL | Economic Threshold Level |
| ICO | International Coffee Organisation |
| KALRO | Kenya Agriculture, Livestock and Research Organisation |
| KPCU | Kenya Planters Cooperative Union |
| SDGs | Sustainable Development Goals |
| SL | Scott Laboratories |
| USDA | United States Department of Agriculture |

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Coffee (*Coffea arabica*) contributes significantly to various Countries' GDP, creates tax income, and aids in the elimination of household poverty (Tamru & Minten, 2023; Behuria, 2019). It is grown in over 70 countries worldwide, with Brazil producing 39.7 million 60 kg bags of arabica coffee in 2023 (ICO, 2023). It is the world's third-most consumed beverage, trailing after water and tea (Bank, 2020), and the second-most traded commodity after crude oil, accounting for more than \$100 billion in commerce (Balgain, 2019). The European Union and Asia are the world's major coffee consumption and importing markets, with an average of 55.388 million 60 kg bags and 44.162 million 60 kg bags in 2023 (ICO, 2023). Coffee being a global commodity, it provides many developing nations with foreign currency as they produce over 90% of world's coffee production (Nsabimana & Tirkaso, 2020). Further, the world coffee sector has expanded dramatically over the last decade, with coffee demand increasing by 65% (ICO, 2019).

Coffee is grown in 25 African counties including Ethiopia, Kenya, Uganda, Tanzania, Madagascar, and Côte d'Ivoire (Lu *et al.*, 2022). In Africa, coffee production accounts for an average of 30% of all the export profits of producing countries with smallholder farmers generating 95% of the coffee (Onwusiribe *et al.*, 2022; Behuria, 2019). Despite its economic importance, coffee yields in Africa are unstable, with annual production dropping by 0.1% on average while global yield increase by 1.3% (Gather, 2022). As a result, the yield gap has increased at a rate of 3.8% per year on average, with the present realized yield being six times lower than the prospective yields (ICO, 2020).

Coffee is one of Kenya's most important agricultural exports, accounting for up to 40% of total export value (Otieno *et al.*, 2019). However, the situation has changed considerably since the height of coffee output in 1988. Coffee output in the crop year 2022/2023 was 750 thousand 60kg bags, down from an approximated 860 thousand 60kg bags in the 2021/2022 crop year (USDA, 2023). However, farm level production remains below its potential of more than 30 kg per tree (Solidaridad, 2022; KARLO, 2019), which can be associated with different factors including: drop in global coffee

prices, outdated farming practices, poor cooperative operation, the impact of coffee value chain features, climate change, delays between coffee cherry delivery and payment of small-scale growers, and conversion of coffee farms to more profitable enterprises and real estate projects, among others (MoA, 2022).

The fall in coffee yields has affected production resulting in a substantial yield gap that has a severe consequence on the smallholder farmers' livelihoods (AFA, 2021). Actual coffee yields continue to lag behind farm trial and station trial yields, resulting in a large gap between smallholder farmers' potential productivity and the actual productivity achieved in different agro-ecological zones (Minai *et al.*, 2014). Biophysical factors, soil management factors, sub-optimal agronomic methods, socio-economic position, climate variability, and cooperative operation among others, may have contributed to the substantial yield difference. As a result, there is potential to boost coffee yields and improve food security (Karatunga, 2022).

In an effort to increase coffee production, the Government has created interventions targeted at recovering the sub-sector to full capacity, allowing it to contribute more to the national economy (Kuguru, 2016). These include the establishment of a coffee development fund, farmers' debt relief from banks' non-performing loans, removal of outstanding grower arrears, the introduction of improved coffee varieties, and the minimization of coffee marketing restrictions through the initiation of direct coffee auction and sales (Chang'alwa & Kimaku, 2022). In addition, the Government introduced the Coffee Bill in 2020 as part of changes aimed at building an efficient, and successful coffee industry that benefits coffee producers (Coffee Act, 2020). Furthermore, County Governments have undertaken efforts to revitalize the industry, but these efforts are yet to bear fruit.

The Nyeri County Government has recognized the importance of coffee players in the livelihoods of smallholder farmers and has come up with strategies for coffee revival, policy discussion, and the implementation of the Coffee Bill of 2020 (Mugambi, 2021). Despite substantial efforts to enhance the coffee sector in the County, particularly in the Nyeri Central sub-county, average farm yields as well as general production remains low. As a result, there is a significant exploitable gap between the present farmer yields

and potential yields from KARLO-Coffee Research Institute (CRI) station trials. Hence, to sustain farmers' average yields and minimize the existing yield gap, a significant difference between farm level yields and potential yields is necessary (Assefa *et al.*, 2020).

A household's socio-economic characteristics determine its ability to practice high agricultural production (Marie *et al.*, 2020). Adequate information on farmers' socio-economic characteristics may aid in estimating smallholder farmers' ability to produce optimal yields from utilization of a set of inputs (Silva *et al.*, 2023). However, majority of agronomic yield gap estimations focus on environmental and farm management aspects, while farmer traits and socio-economic characteristics are rarely considered (Beza *et al.*, 2016). Therefore, to make informed recommendations to lower the coffee yield gap, this study focused on a few socio-economic characteristics including age, schooling years, land size, gender, farming experience, labour and household income.

Agronomic practices are commonly used in coffee field production, where they have a substantial impact on the volumes and quality of coffee generated by a farmer and are critical in determining yield per unit area (Naik *et al.*, 2021). Propagation, soil and water conservation, soil enrichment and nutrition, weed control, shade management, bush management, pest and disease control, and harvesting are some of the coffee cultivation practices (Naik *et al.*, 2021). Therefore, poor agronomic practices may be the result of insufficient resources and extension services (Rossenbourg *et al.*, 2018). However, yields are expected to be high with good agricultural practices (Njoki *et al.*, 2023). This study concentrated on specific agronomic practices such as pruning, weed management, insect-pest and disease control, integrated cropping systems, coffee varieties, and fertilizer application.

Further, cooperative societies account for more than 72% of coffee sales in Kenya (Otieno, 2019). Smallholder coffee producers form cooperatives to strengthen their bargaining power and obtain access to markets (Mugo *et al.*, 2019). The coffee sub-sector in Kenya is well-known for its cooperative milling, auctioning, and marketing structures, as well as the dominance of smallholder farmers in production (Ndirangu, 2020). Cooperatives are known to supply crucial services such as agro-inputs, training,

extension services and credit to enhance farmers' yields per unit area (Ahmed *et al.*, 2017). Cooperative diversity entails integration of cooperative services to boost production, such as farmer training, credit provision, input provision, quality control and improvement, coffee value addition, marketing information, production information and extension support (Wairegi *et al.*, 2018). However, there exists insufficient information on the role of cooperative services in coffee production. Therefore, this study considered the effect of the services provided to smallholder cooperative members on the coffee yields and resultant yield gap.

Therefore, the large yield gap indicates significant challenges faced by smallholder coffee farmers. It also reveals the enormous potential for yield improvement in Kenya's coffee production and the necessity to close the gap for the purpose of maintaining growth in average farmer yields (Wang *et al.*, 2015). Despite the existence of numerous studies on factors influencing yield gaps conducted at the global, regional, and national levels, the findings are general, making it difficult to develop site-specific crop and management strategies applicable to smallholder farmers for narrowing yield (Boullouz *et al.*, 2022). Furthermore, there exists insufficient information on coffee yield gaps based on direct farm management activities. As a result, understanding factors influencing smallholder coffee farmers' yield gap is critical in efforts to close the existing yield gap, increase coffee yields, and enhance household food security.

1.2 Statement of the Problem

Coffee farming is a valuable enterprise for smallholder farmers in Kenya. It contributes to poverty reduction, income creation and provision of livelihoods to its farmers. However, the coffee sub-sector in Kenya has been characterised by declining and low productivity at farm level. The result is actual farm yields being far below potential yields of over 30 kgs per tree from KARLO-CRI station trials. Hence, a large yield gap is realised that reveals enormous potential for yield improvement in coffee production. The large yield gap may be attributed to several factors yet there is limited quantitative information on site-specific factors and the yield gap attributed by the factors. This study informs the knowledge gap by analysing the effect of socio-economic characteristics, agronomic practices and cooperative diversity on coffee yield gap in Nyeri County using a case study of smallholder farmers in Nyeri Central sub-county.

1.3 Objectives of the Study

1.3.1 Broad Objective

To analyse the socio-economic characteristics, agronomic practices, and cooperative diversity that contribute to the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County.

1.3.2 Specific Objectives

- i. To estimate the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County.
- ii. To determine the effect of socio-economic characteristics on the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County.
- iii. To determine the effect of agronomic practices on the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County.
- iv. To determine the effect of cooperative diversity on the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County.

1.4 Research Questions

The research was guided by the following questions:

- i. What is the coffee yield gap level among smallholder farmers in Nyeri Central sub-county in Nyeri County?
- ii. What are the effects of socio-economic characteristics on the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County?
- iii. What are the effects of agronomic practices on the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County?
- iv. What are the effects of cooperative diversity on the coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County?

1.5 Significance of the Study

The key participants in Kenya's coffee industry will extremely benefit from the findings, conclusions and recommendations of this study in the following ways: smallholder farmers will benefit from increased awareness of factors that contribute to the yield gap in order to direct efforts to improve coffee production more efficiently. The findings will also be valuable to policymakers and the County administration of

Nyeri in developing suitable policies, particularly regarding coffee yields, in order to alleviate poverty among smallholder coffee producers and improve food security. The study will also provide useful information to scholars as a foundation for further research into the interests of coffee production and its impact to Kenya's economy. Further, this study will contribute to achievement of the Big Four Agenda that would result in higher sustainable incomes to the smallholder coffee farmers and in the long-run, the Government would generate increased GDP and realization of job creation through additional coffee processing factories. The study will also provide recommendations to reduce yield gaps as a tactical undertaking to realizing Vision 2030 and sustainable development goals (SDGs), particularly SDG 1 on no poverty, SDG 2 on zero hunger, SDG 3 on good health and well-being, and SDG 4 on quality education, all of which will have a significant impact on turning around the fortunes of smallholder farmers in Nyeri Central sub-county.

1.6 Scope of the Study

This study assessed the effects of three factors on the coffee yield gap among smallholder coffee farmers: socio-economic characteristics, agronomic practices and cooperative diversity. The study was carried out in Nyeri Central sub-county, Nyeri County, where primary data was collected. Nyeri Central sub-county was chosen because of its favorable ecological conditions for coffee cultivation.

1.7 Limitations

This study was limited to the information provided by respondents, some of whom overstated the information and others may have concealed critical information. Hence, the information provided was cross-checked with the assistance of field extension officers from the cooperatives. Farmers who expected benefits from the research demonstrated strategic bias. Such farmers' data was dropped as it did not represent the reality of coffee production in Nyeri Central sub-county. The respondents in Nyeri Central sub-county had different educational backgrounds, which influenced their reasoning of the questions. This required interpretation of the questions to the local language in the best way to ensure that the quality of the information was not altered.

1.8 Assumptions

The study assumed that the cooperative society's office had access to updated farmers' output records. This study also assumed that the variables of interest remained constant the entire period of the survey.

1.9 Operational Definition of Terms

| | |
|---------------------------------------|--|
| Actual Coffee yields | It is the amount of a cherry harvested per hectare of land per year by the smallholder coffee farmers in Nyeri Central sub-county. |
| Potential coffee yield | It is the highest amount of crop yield achieved under optimal management in long term experiments at the KARLO-CRI. |
| Coffee yield gap | It refers to the difference between the farmers' actual coffee yields and the KARLO-CRI station trials' potential yields. |
| Smallholder coffee farmer | It is a farmer whose land under coffee cultivation ranges between 0.10 ha to 2.2 ha either owned or leased. |
| Socio-economic characteristics | It refers to the quantitative factor of a household that determine its ability to practise improved agricultural production. |
| Agronomic practices | Agricultural practices generally associated with field coffee production including pruning, weed control, insect-pest control, fertiliser application, integrated cropping system and disease control. |
| Cooperative diversity | It is the integration of a range of services for improving coffee production to the members of the cooperative including farmer training, credit provision, input provision and extension. |
| Improved coffee varieties | This refers to coffee species that have been improved using plant breeding techniques to provide increased resistance to pest, diseases and other environmental condition as well as increase yields. They include; Ruiru 11 and Batian in Nyeri Central sub-county. |
| Traditional coffee varieties | This refers to coffee species that have been existing or originating in Kenya where it is extensively grown such as SL 28, SL 34 and K7. Specifically, in Nyeri Central sub-county it refers to SL 28 coffee variety. |

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Coffee Production

Coffee is grown in over 70 countries mostly in South America, Africa and Southeast Asia which makes it a prominent global product (Bacsi *et al.*, 2023). It is a substantial source of revenue for many underdeveloped countries, which produce 90% of the world's coffee (Sanger, 2018). However, the consumption levels in majority of the coffee-producing countries is low, hence they end up selling their coffee in international markets which is limited with quotas (Rhiney *et al.*, 2021). World coffee consumption has expanded at a 4.2% annual rate and is estimated to be 175.6 million bags in 2021/22 (ICO, 2023). On the other hand, consumption is predominantly concentrated in established markets of Western Europe and North America, with expansion into emerging markets of Eastern Europe and Asia (ICO, 2019).

Despite its strong performance, the coffee industry is faced with several challenges, including massive overproduction in some countries, inequality within the value chain, fluctuating and collapsing coffee prices, poor coffee quality and increased pests (Kundu & Ngigi, 2018). In the last decade, climate change has been a major source of concern not only for general agriculture but also in coffee production which has been characterised by changing or unpredictable rainfall patterns, high temperatures, droughts and heavy rainfall or storms. As a result, output has been low, disease frequency has been high, and production shortages in key sectors have become more frequent (Grabs, 2020). Despite this, most countries' coffee value chains, which include farmers, processing cooperatives, market actors and Government organizations, have also influenced coffee production, processing and marketing (Kabeta, 2021).

Kenya is acknowledged as a prominent specialty coffee origin and ranks 16th among the coffee producers by volume (Chemura *et al.*, 2021). Kenya mostly grows Arabica coffee (99%) with the main varieties being Ruiru 11, SL 28, K 7, Batian and SL 34 (Ngare, 2021). Arabica coffee has an inherent advantage due to its geographical location. In Kenya, the Mount Kenya region and the highlands of Kisii, Nyanza, Bungoma, Nakuru, and Kericho have acidic soils that are perfect for coffee production (Esilaba *et al.*, 2023).

French missionaries introduced coffee to Kenya for the first time in 1893. The first planting took place in Bura, Taita Hills, and thereafter in 1900 and 1904, it was expanded to Kibwezi and Kikuyu, respectively where it was cultivated through irrigation (Chelangat, 2019). During this time, crop management, production, processing, grading, and sales were not subject to any defined restrictions. Between 1900 and 1933, the coffee trade was governed by specific individuals and informal institutions (Ndirangu, 2020). At that time, Kenyans were not allowed to own or manage coffee farms, and the majority of the coffee output was generated by a small number of huge estates. Following the Devonshire White Paper report in 1923, the colonial government approved controlled coffee growing outside of European-established territory in Kisii and Meru, in the 1930s (Ndirangu, 2016).

Moreover, a 'Local Growers Experiment' was launched in 1934 by the British Colonial Board to assess Kenyans' ability to run small coffee estates. However, to control the natives' smallholder production, the Government enacted the Coffee Producers Act (Thuku *et al.*, 2013). Small African farms were developed apart from existing white estates and were limited to less than a quarter acre of land with less than 100 bushes. Due to restrictions, smallholders were unable to benefit from services such as training, banking institutions, and the Coffee Board of Kenya (Ndirangu, 2016). Small farmers were also prohibited from competing for labour with British estates by the colonials (Thuku *et al.*, 2013).

During the year 1944, all smallholder growers were required by law to be part of the local growing cooperatives under the coffee board. This was done so that the large estate farmers can gain leverage over smallholders because they dominated the boards (Condliffe *et al.*, 2008). Following independence, the government made significant efforts to enhance smallholder output by giving financial assistance for coffee cultivation, farmland, and technical assistance to farmers and cooperatives (ICO, 2019). Thereafter, the Coffee Development Authority (CDA) was founded in 1964 by the government to support cooperatives and small farmers by offering technical assistance and providing financial support to the cooperatives for development of new coffee processing and milling units from local financial institutions.

However, the smallholder output overtook estate production, which were owned and controlled by indigenous Kenyans white farmers and who had acquired huge tracks of land in 1978 (Kanyinga, 2013). Further in the 1980s, Kenya's coffee production had reached a peak of 129,000 metric tons, accounting for 40% of the total exports. However, in the recent decade, coffee exports and its earnings have been surpassed by those of tea, tourism and horticulture (Bathfield *et al.*, 2013). Prior to liberalization, the only controlling authority and marketing agent was Coffee Board of Kenya (CBK) , with Kenya Planters Cooperative Union (KPCU) as the only processing institution (Mitchell, 2013).

In 1986 the liberation process began with release of market policies after the government realized it controlled majority of the sectors in the economy. Further, the Finance Act of 2005 permitted marketing agents to sell coffee directly to buyers rather than channelling it to the central auction system (Gitau *et al.*, 2008). Also, other millers, such as Thika Coffee Millers, were licensed to process and mill coffee to lessen KPCU's monopoly. However, coffee milling cooperative societies were only to market their coffee through the auction system. Moreover, the Government has also continued to come up with strategies to boost the coffee value chain and further stimulate coffee industry activities over the years (Ndirangu, 2020).

Despite Kenya's opportunities in coffee, diminishing production have been reported over the years with coffee acreage declining from 170,000 hectares in the early 1980s to 108,199 hectares in 2020/21 (AFA, 2021). The reduced acreage could be attributed to coffee tree uprooting to make way for real estate development especially for urban centers within the traditional coffee growing areas (MoA, 2022). This output increased dramatically to a high of 129,000 metric tons in 1987/88 (Ndirangu, 2020), but after the International Coffee Agreement collapsed in 1989, coffee production began to diminish progressively, along with other major barriers (Vorlaufer, 2012). Currently, coffee production is approximated to be 45,000 metric tons, which has resulted to lower revenue for many smallholder coffee growers and majority ignoring the crop (USDA, 2023). On average, the volumes of the smallholder farmers is 300–400 kg/ha of clean coffee (KARLO, 2019).

2.2 Yield Gap Concept

Crop yields have stagnated in many Countries globally with average yields approaching a ceiling in some locations as crop response to inputs demonstrate a decrease in marginal yield benefits. This has resulted in considerable agricultural yield difference (Silva *et al.*, 2019). The yield gap is defined as variation between the benchmark potential yields and average yield achieved by farmers within a certain regional and temporal context, providing all other crop parameters remain constant (Zheng *et al.*, 2019). The concept of yield gap is based on the evaluation and quantification of yield potential. Yield potential is the highest feasible yield attainable under specific environmental conditions, assuming adequate water and fertilizer availability, as well as good insect-pest, disease and weed management (Wang *et al.*, 2023). Hence, understanding yield potential and detecting yield gaps allows for the development of long-term strategies to increase agricultural output (Salam & Sarker, 2023).

Yield gap analysis provides a foundation for discovering the optimal management techniques for increasing agricultural yield by closing the yield gap (Zhang *et al.*, 2022). It also allows the assessment of the potential to boost yields on existing arable lands by providing information on aspects that limit present farmers' yields (Sun *et al.*, 2022). Furthermore, yield gap evaluation is employed at the regional level to explore the important aspects restricting crop production and farmer yield (Jha *et al.*, 2022).

Depending on the level of estimation, many types of yield gaps can be found, such as model-based, farmer-based, experimental and exploitable yield gaps (Devkota, 2021). Input data relating to crop management, weather and soil are incorporated in crop growth models which can be used to estimate yield gaps (Monzon *et al.*, 2021; Rahn *et al.*, 2018). Comparing the maximum yields obtained in research trials under regulated agronomic constraints with yields obtained by farmers in their fields reflects the experimental yield gap (Asante *et al.*, 2022).

Farmer-based yield gaps are assessed at the farm level by analyzing and recording farmers' yields, with the highest yield serving as a baseline for which other yields are compared (Abdulai *et al.*, 2020). The exploitable yield gap denoted the discrepancy between farmers' potential production in a particular environment and their actual

yields (Figure 1). Although there are other methods for measuring yield gaps, experimental yield gaps are the most common (Tseng *et al.*, 2021).

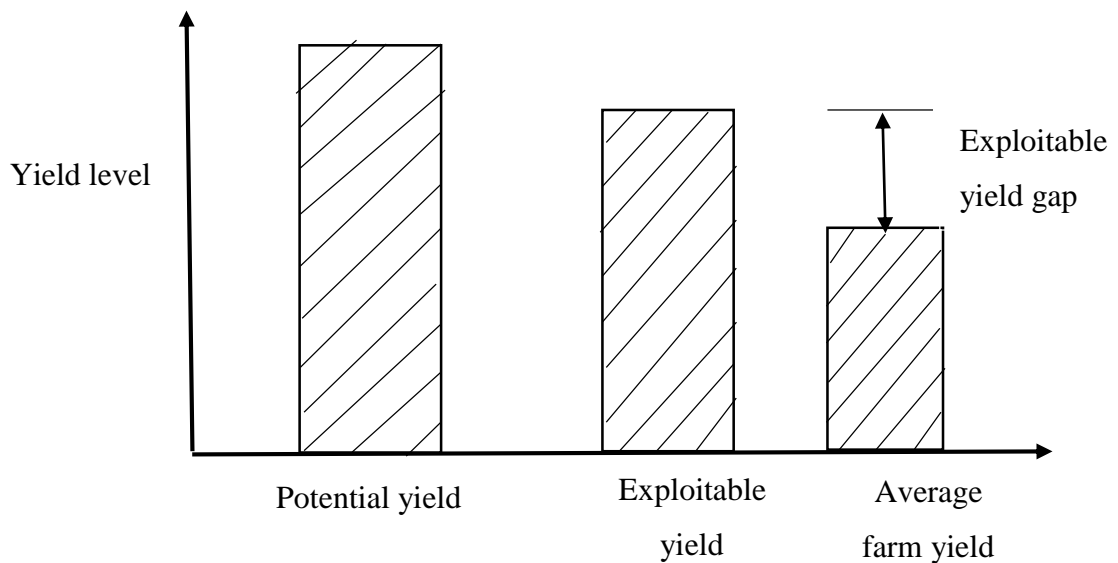


Figure 1: Exploitable Yield Gap

Source: Adopted from Van Ittersum *et al.* (2013)

However, farmers' maximum yields are used, particularly in intensively managed agricultural systems in the absence of experimental growth trials. These maximum yields are based on the assumption that some farmers use appropriate management strategies capable of achieving or approaching yield potential (Abdulai *et al.*, 2020). Efforts to understand the yield gap requires established methods and novel approaches such as remote sensing for conclusive and accurate data for facts driven decisions among the agronomists, soil scientists, and socio-economists (Monzon *et al.*, 2021).

2.3 Effect of Socio-economic Characteristics on the Coffee Yield Gap

Socio-economic characteristics are concerned with the social and economic situations of communities rather than their cultural and biophysical surroundings. They assess a smallholder farmer's ability to improve agricultural production and accept new technologies (Marie *et al.*, 2020). Sufficient knowledge about farmers' socio-economic features can aid in the improvement of their agricultural production capacity (Abdul-Kareem & Sahinli, 2018). Gender, education level, household income, age, farm experience, and size of land are some of the socio-economic characteristics that can influence coffee output inequalities.

2.3.1 Gender

Gender is probably a determinant in production due to the roles of the different members of the community. Munialo (2020) reported that maize yield gap declined for male-headed families among the smallholder farmers in Western Kenya. This was due to the fact that males made the decisions in the households and had control over the farm operations which contributed to increased yields. However, Bjournlund *et al.* (2019) noted that households with male heads as the only decision authority had poor incomes, resulting in delays in land preparation and cultivation and reduced fertilizer application hence low outputs obtained. This suggests that male-headed households may produce less, resulting in poorer income and, as a result, decreased welfare among farmers. Further, Ojo *et al.* (2023) reported that the average groundnut output and land size of the male gender was higher than that of their female counterparts. This imply that males had better access to resources and were actively involved in groundnut production resulting to a large gender yield gap. However, determining the effect of gender on coffee output is critical since it may help narrow the yield gap. As a result, it is necessary to access the influence of gender on the coffee yield gap in Nyeri Central sub-county, Nyeri County.

2.3.2 Age

The age of farmers has been found to determine farmers' adoption of recommended practices and technologies and also the scale of operation. This is most probably due to their ease in understanding and implementing the information acquired as well as provision of labour for their production. Abdulai *et al.* (2020) observed that elderly farmers were unwilling to intensify cocoa management in the marginal climate zone of Ghana despite the potential for production improvement to close the yield gap through sustainable intensification. Wairegi *et al.* (2018) found that increase productivity was notable among the younger farmers as the aged were less inclined to coffee production. This is because coffee cultivation requires more labor and the elderly farmers are considered weak to perform intensive tasks. This means that agronomic practices may be ineffective, resulting in low coffee production per unit area. Also, Tabe- Ojong *et al.* (2023) noted that 54 years was the mean age for cassava farmers in Thailand where 54% were males. The findings imply that cassava farming was mostly done by the

elderly which affected their soil conservation measures because the aged farmers were reluctant to take up the new technologies.

Coffee Research Foundation (2010) reported that age had the potential to decrease productivity where a large proportion of the farmers were aged 50 years and above had low coffee production. This was due to the fact that most farm operations are manual, and as farmers age, their output declines. Tesfayohannes *et al.* (2022) discovered that the elderly population may have awareness of soil improvement and water preservation activities, however, their ability to implement these techniques to improve soil nutrient abundance and crop yields is restricted. As a result, farmers' output in agricultural production may drop as they age, necessitating the use of hired labor to assist in production operations in order to maintain yield volume. However, there exist a knowledge gap to determine the extent of age and its effect on coffee production and resulting coffee yield gap.

2.3.3 Education Level

Education has proven to be an essential component of agricultural output. Minai *et al.* (2014), noted that the more educated a farmer was, the more efficient producer they became. As a result, poor literacy levels can hinder coffee output. Eric *et al.* (2015) found that the farmer's educational background was essential in acquiring and implementing current technologies such as improved maize varieties as well as recommended fertilizer use that may result in increased production. Furthermore, Munialo (2020) reported that when the farm operator is educated, yield gaps narrow. This could be because they have a better understanding of agricultural production and can thus source more agricultural information for their output. Tafesse *et al.* (2023) observed that the schooling years determined farmers' ability to evaluate and implement information received and further adopt recommended technologies in effort to increase the allocative, technical and economic efficiency in onion production.

Wambua (2020) noted that on average farmers had secondary school education, meaning that would be more receptive and embrace innovative agricultural strategies due to their diverse knowledge. Risk management, risk reduction measures, and long-term production decisions all required a high degree of education. Akamin *et al.* (2017)

observed similar results, reporting that education level influenced the technical efficiency of Cameroon's vegetable farmers where farmers with secondary level outperformed those with only a primary and informal education. Furthermore, Bidogeza *et al.* (2009) observed that a high degree of education increases farmers' capacity and likelihood of uptake of new production concepts and techniques. As a result, education may be a critical component in enhancing crop output, perhaps resulting in smaller yield disparities. However, there is an inadequate information in Nyeri County about the impact of education on the coffee yield difference.

2.3.4 Household Income

Household income is essential to meeting the household needs, enhancing family business and implementing of household investment decisions. Wairegi *et al.* (2018), noted that the poor old household heads in coffee production had limited diversification in revenue sources. Also, the stable and wealthy household found coffee as less essential owing to their efforts to diversify and enhance their non-farm revenue streams. This suggests that engaging other high-valued income-generating activities could have a favorable and considerable result on coffee yield. Tabe-Ojong *et al.* (2023) observed that 80% of the households depended on farm income that was low and hence affected the assets owned by the household and further its investment in soil conservation measures. This implied that majority of rural families rely on farming for their survival hence determining the household ability to meet different needs. Challa and Talihun (2014) noted that off-farm income boosts farmers' ability to get essential agricultural commodities at the needed period and also increasing farmers' risk-bearing capacity during production. However, there is a knowledge vacuum in Nyeri County about the effect of household income on coffee yield.

2.3.5 Farming Experience

The farmers experience from previous engagement in coffee production was likely to increase their production over the years. It has been reported that the more experienced a farmer is, the more likely it is that their output will increase because they understand how to manage farm inputs, hence reducing production losses (Kamau, 2019). Awe *et al.* (2021) noted that agricultural experience significantly influenced farmers' adoption of agroforestry technology. This means that farmers with more farming experience

often have more information and knowledge, resulting in better decision-making. Marinus *et al.* (2023) reported that increase in farming experience among the maize farmers in Vihiga County resulted in a decrease in the yield gap resulting to sustainable incomes for the smallholder farmers. This shows that higher experience translated to better management which results in reduced yield gap among the farmers.

Jyothirmai *et al.* (2023) noted that increase in the farming experience decreased the groundnut yield gap. This infer that farmers who had more experience were better decision makers in terms of input use, labour use and investment of income. However, Abubakar and Sule (2019) found that maize farmers' technical efficiency was not affected by their farming experience. Given the foregoing literature, it is impossible to make a judgment on the influence of farming experience on crop production; so, it is crucial to access the effect of farming experience on coffee production and resulting yield gap.

2.3.6 Land Size

A direct effect between owned land size and land dedicated for coffee cultivation has been reported. Wambua *et al.* (2019) reported that the larger the size of land the higher the rate of operations which may pushes farmers to adopt new technology, resulting in increased coffee yield. Furthermore, larger land sizes may allow for some testing of new technology without compromising the scale of the main crop, potentially encouraging its acceptance. Rizzo *et al.* (2023) reported that land size determined the potential income earned by farmers practising intensive cropping system. This was due to the small parcels of land owned which was projected to continue decreasing due to high population.

Gebeyehu (2016) and Ng'ombe (2017) found a positive effect between sizes of land and coffee as well as maize productivity, respectively. This shows that size of land is an important factor in agricultural production and its size would determine the level of output. However, Munialo (2020) noted that larger land sizes reduced maize output disparities, demonstrating the importance of land in agricultural productivity. However, due to increased scale of operation and expenditures, especially for commodities that

require significant management and labour, such as coffee, there may be an inverse relationship between land area and production.

2.4 Effect of Agronomic Practices on Coffee Yield Gap

Plant productivity in most agricultural production systems is determined by the type and intensity of management, notably cultivation practices (Kansiime *et al.*, 2019). Coffee farming procedures include, among other things, site selection and management, field layout and design, continual land improvement, record keeping, and tenure structure (Ndirangu, 2020). These procedures may have a substantial consequence on volumes and quality of coffee produced, affecting yield gaps and farmer income. The study concentrated on specific agronomic procedures like pruning, weed control, pest and disease control, nutrition management, variety type, and integrated cropping systems.

2.4.1 Pruning

Pruning is done after the main harvest in order to increase output and reduce insect and disease incidence. Pruning coffee trees promotes the establishment of new plant tissues, provides good harvests, extends the productive life of coffee, allows spray penetration, and increases Coffee Leaf Rust (CLR) and Coffee Berry Disease (CBD) resistance (Musa *et al.*, 2020). Belyi (2012) reported that farmers were afraid of pruning because they felt it may destroy their coffee trees and diminish their harvests. Farmers, on the other hand, used selective pruning to ensure that the tree continue to produce and that they have a crop for that season. Monzon *et al.* (2023) observed that some practices such as regular pruning, fertiliser application and proper weed management resulted to higher profits among the smallholder oil palm farmers. This shows that among other practices, pruning is significant as it results to regeneration of healthy and better yielding shoots that increase production.

Sarirahayu and Aprianingsih (2018) noted that many coffee farmers do not prune their coffee trees, or if they do, they do it insufficiently due to a lack of information on how to boost regrowth. Furthermore, for pruning to be effective, it must be done in conjunction with other agronomic measures. Karim *et al.* (2021) observed that trimming affected the amount of red cherry per tree and green bean production. These

findings are also in line with those of Dufour (2019) who found that pruning had an effect on coffee yield. Tosto *et al.* (2023) reported that pruning increased the probability of branch emergence which had an impact on cocoa growth and productivity. This shows that pruning is an important management practice to most perennial crops as it boosts their productivity when done in the recommended way. However, more information is required to determine the influence of coffee pruning on coffee yield gap in Nyeri County.

2.4.2 Fertilizer Application

Soil fertility enhancement includes both organic and inorganic fertilizer application. In the near term, applying fertilizer could be one of the more effective approaches to addressing nutritional deficits. However, in Kenya most smallholders cannot access huge quantities of mineral fertilizers. Constant macro and micronutrient fertilization of coffee crops helps to maintain adequate soil nutrient levels (Villaseor *et al.*, 2020). The proper source of fertilizer, the right time for application, the right amount to apply, and the right technique of application of fertilizer are all important factors in achieving optimal production (Williams, 2021). Furthermore, proper fertilizer types and rates are dependent on the soil fertility state, which can be assessed through soil analysis (Marinus *et al.*, 2023; Suchithra & Pai, 2020).

A study on coffee fertilization was undertaken, and the results reveal that fertilizers, along with other factors like coffee age and density, have an impact on volumes and yield quality (Breitler *et al.*, 2022). Andrade *et al.* (2020) observed intensive use of fertilizer resulted in higher yields on estate farms compared to smallholder farms that do not normally follow the suggested application parameters. Niewiadomska *et al.* (2020) found that applying foliar fertilizers to coffee crops had a considerable favorable effect on nitrogen fixation and thus plant yields. Kiwelu *et al.* (2021) noted that the large yield gap estimate was greatly contributed by the quantity of fertilizer used. The data indicated that many smallholder farmers did not apply the required rates or did not apply it at all, which may be the cause of the increased production disparity.

Assefa (2023) noted that reduced fertiliser application resulted to the low yield response of maize which showed a potential for increased production with increase in fertiliser application. Therefore, increase in right fertiliser, with the recommended quantities at the right time would increase production with countercheck of mineral accumulation of the soil through testing and analysis. However, due to expense, the majority of smallholder farmers may not source their fertilizer from reputable distributors and may be unaware of the rates, time, and location of application. This may have an impact on their productivity, resulting in less income and investment in coffee production.

2.4.3 Weed Control

Weed management is done to avoid competition for growth inputs such as light and nutrients, which can lead to low yields and low-quality coffee grades (Asfaw- Tessema, 2021). Weeds in coffee plantations diminish crop vigor and yields, serve as alternate hosts for diseases such as CLR and insect-pests, disrupt field activities, and eventually raise production costs due to weeding labor requirements (Berquer *et al.*, 2023). Weeds are classified into two types: annual and perennial weeds where mechanical, cultural, chemical, and integrated weed management techniques are used to manage them (Khan *et al.*, 2019). Further, Dash *et al.* (2023) recorded that a considerable percentage of the farmers (35%) had low adoption of weed management practices. This showed that the low maize production and the large yield gap experienced by farmers may have been contributed by the weeds that pose harm to the maize. This is due to competition of nutrients and others acting as alternative hosts for pests and diseases.

Kufa (2014) found that a combination of enhanced methods, including on-time weeding, increased the farmer's variety and cultivar output. Asteneh *et al.* (2015) noted that despite the availability of better weeding technology, farmers lacked proper information, which prevented them from employing it. This imply that better weed management practices would ultimately result in increased production and improved quality of output. This indicates that farmers' capacity to identify and control weeds may be determined by their understanding of available control strategies and technologies.

2.4.4 Disease Control

Disease control is an essential activity in coffee farming. In Kenya CLR and CBD affect mostly the traditional coffee varieties, necessitating the use of fungicides (Alwora & Gichuru, 2014). Other diseases, such as bacterial blight of coffee, fusarium bark, fusarium rot, and brown eye spot, are known to have a substantial impact on the quality and quantity of coffee, resulting in reduced yields (KARLO, 2019). Approximately 30% of coffee growers have little or no knowledge of better technologies and appropriate fungicides for disease control (Buyinza, 2019). This has impacted quality control in coffee, resulting in low, poor-quality yields and, as a result, big yield disparities. Madias *et al.* (2023) reported that fungicides application reduced yield gap among the smallholder maize farmers. This may have been contributed by the knowledge that farmers had on the appropriate fungicide to use, rite time of application and right spraying technique.

Kiwelu *et al.* (2021) discovered that infestations of coffee disease caused by poor control of CLR and CBD had a substantial impact on productivity. This could be due to insufficient fungicide spraying, application at the wrong time, or the high cost of fungicides used to control severe coffee diseases. As a result, farmers failed to buy and use the correct fungicide at the appropriate rate and time. Furthermore, Monyo *et al.* (2020) indicated that if these diseases are not controlled, crop output will be reduced by 50 to 0%, resulting in significant crop loss and, in certain cases, tree death. Also, Winck *et al.* (2023) noted that among other management practices in Soy bean production disease management was significant and contributed to reduced yield gap among the farmers. This implied that proper disease management would result in output increase and most likely quality improvement with reduced yield gap. Therefore, increased occurrence of diseases may be caused by climate change, however, the appropriate use of fungicides might be encouraged as an integral aspect of coffee production.

2.4.5 Insect-pest Control

Around 1000 insect species affect coffee worldwide, with 35 known to attack coffee in Kenya (Agegnehu & Dawa, 2015). The insect attacks coffee flowers, berries, leaves, branches, stems, and roots, causing yield and quality to suffer. Antestia bugs, coffee

berry borer, thrips, coffee scales, stem borers, berry moths, and leaf miners are among the major insect pests (Shimales-Biru, 2019). It is advised to practice pest scouting and pest management. Furthermore, an integrated Pest Management approach should be used, which includes the combination of chemical, biological and cultural pest control strategies (Flint & Van den Bosch, 2012). It is critical to examine the economic threshold level (ETL) where the pest population is likely to produce crop losses if not controlled, which extends to the expense of management employing insecticides (Rwomushana *et al.*, 2019).

Leharwan *et al.* (2023) noted that use of insecticides for plant protection was important in production of chick peas and resulted increased production due to increased training on chemical use. Wang *et al.* (2015) observed that the main hinderance to Robusta production within the Central growing zone in Uganda was coffee twig borer (*X. compactus*) damage. Furthermore, the study discovered that predicting pest influence is difficult due to pest prevalence and intensity of temporal and spatial fluctuations. This suggests that some pests and diseases may be linked to other biophysical parameters like temperature and precipitation. As a result, pest treatment may have a significant impact on production costs in order to increase yields.

2.4.6 Coffee Varieties

KARLO-CRI has advised the implementation of better crop technology in response to low coffee production and big coffee yield gaps reported by smallholder farmers (Wambua *et al.*, 2019). Because of their distinctive traits of great beverage quality, higher yields, and disease resistance, enhanced coffee types provide new prospects for smallholder farmers (Breitler *et al.*, 2022). Batian and Ruiru 11 are enhanced coffee varieties that are resistant to CLR and CBD while traditional cultivars include K7, SL28, and SL34. High yields of improved coffee types have encouraged farmers to embrace upgraded varieties. This has been promoted by the progressive rehabilitation of existing coffee farms by replacing traditional coffee types with improved kinds or by grafting scions of new varieties onto old, healthy root stocks (Kiwelu *et al.*, 2021). However, the rate of adoption of enhanced coffee types is uncertain.

Cheruiyot and Sang (2023) indicated that majority of farmers (73%) in the Western Rift of Kenya preferred the improved varieties due to their disease resistance attribute that aided to reduced costs in production up to 30%. This imply that farmers may be willing to plant the improved varieties however some may be reluctant to uproot and prefer grafting their traditional varieties. Kamau *et al.* (2017) noted that higher adoption of better varieties and enhanced farm management practices ha the potential to increase coffee yield. This could be due to the increased volume of coffee produced by improved varieties, allowing growers to have more quantities for grinding. As a result, it is necessary to determine the extent to which enhanced coffee varieties have been adopted and how this acceptance has aided smallholder farmers in improving their livelihoods. Chemedda *et al.* (2023) revealed that coffee productivity was greatly contributed by the enhanced seed in Ethiopia because it was complementary to agro-inputs such as fertilizers and production chemicals. Furthermore, due to CLR and CBD resistance, improved coffee cultivars reduced chemical consumption.

2.4.7 Integrated Cropping System

The amount and quality of coffee harvests are affected by cropping systems. Guo *et al.* (2016) observed that majority of estate farms practiced monocropping, which means that the field is only used for the production of coffee only. Coffee monocropping is appealing to smallholder farmers because of the initial high yield per hectare and high plant densities (Lacombe *et al.*, 2016). However, more inputs are required in the long run due to a lack of organic matter from leaf litter, increased nitrate and phosphate leaching, and increased weeds due to sunlight availability (Jezeer *et al.*, 2018). Monocropping in coffee may also result in poor growth, low yields, and major soilborne infections in coffee plants, resulting in economic losses and impeding the coffee industry's long-term development.

However, Kenya's long-term goal of food self-sufficiency encourages smallholder coffee producers to intercrop food crops (KARLO, 2019). This is done to increase their protein, vitamin, and mineral intake. Such crops should be non-climbing, mature early, and not serve as alternate hosts for coffee pests and disease. Legumes, onions, and Irish potatoes may be included (Ocimati *et al.*, 2019). However, Andrew and Philip (2014) reported that cooperative administrators discourage farmers from intercropping, which

has been shown to improve crop diversification. This occurrence was due to the , increased nutrient uptake, gradual soil warming and high disease incidence. For example, bananas are thought to be a major host for the coffee worm (*Pratylenchus coffeae*), which considerably decreases coffee yields if not controlled. Intercropping in coffee, on the other hand, may help provide shade to the coffee bushes while also maximizing land utilization.

The cropping system was shown to be unimportant in the production of coffee by Ngango *et al.* (2019). This means that farmers who produce coffee in a monocrop system have better levels of technical efficiency than those who produce coffee in an intercropped system. Ebbisa (2023) observed that multi-cropping systems increased efficiency in resource use hence lowering input wastage and cost of production. This implied that to create sustainable and resilient households to food security, intercropping system can be enhanced. The impact of farmers' integrated cropping systems on coffee production and the ensuing yield gap cannot be clearly concluded from the literature reviewed above, highlighting the necessity to investigate the impact of farmers' integrated cropping systems on coffee production and the resultant yield gap.

2.5 Effect of Cooperative Diversity on Coffee Yield Gap

Cooperatives pool the market and bargaining power of people to increase their scale of achievement in business. They do so by presenting alternatives to poverty and powerlessness (Abera *et al.*, 2021). The Government recognizes cooperatives for making substantial contribution to state development as they operate in virtually every sector of the economy (Prieto *et al.*, 2020). Building and construction, agriculture, banking juakali, transportation, handicraft, housing development, customer service and insurance are all areas where cooperatives are involved (Kiswili *et al.*, 2019).

Cooperative societies are in charge of milling, auctioning, and marketing in the coffee industry. The Kenya Planters Cooperative Union (KPCU) is linked with majority of producers' primary cooperative groups. Previously, KPCU experienced leadership disputes and a management crisis inside its leadership structure, which impacted its operations and delivery to farmers (Wanyama, 2009). Due to the same issues, KPCU has been unable to pay farmers for their produce on time. These difficulties have

prompted several cooperatives to begin milling and marketing their own coffee without going through KPCU (Ndirangu, 2020). The cooperative provides crucial services to farmers, like inputs, training and extension services, credit, and marketing information, among other things that are important in determining yield per unit area.

2.5.1 Input Provision

Cooperatives have evolved over time to provide input services to their members, including herbicides, pesticides, fungicides, and fertilizers. Nkhoma (2011) found that high fertilizer and pesticide prices and late deliveries have led farmers to reduce their use of these inputs. As a result, low-quality cherries are delivered, and significant losses of small cherries occur during the pulping step of processing. Sebhatu *et al.* (2020) found that delays in input supply are caused by inadequate governance and inefficiencies in cooperatives. This shows the significant purpose of agro-inputs in agricultural production.

Nwafor *et al.* (2020) observed that there was a strict regulation in the Kenyan coffee business today that required all smallholders to produce their coffee through a cooperative. The findings of this study demonstrated the value of cooperative input buying and supply to farmers. This could be attributed to lower transaction costs for various inputs, making them more affordable to smallholder farmers. Schmitt (2021) discovered that poor resource management was related to high transaction costs. Paudel *et al.* (2023) observed that resource scarcity reduced sustainable intensification of adoption of hybrid maize resulting to severe consequences on the economic output. This imply that inputs recommended for production determine the extent of management and final product obtained by farmers. This implies that farmers may not need to obtain input from other sources if inputs are available at the cooperative at the appropriate time, amount and the recommended quality.

2.5.2 Extension Services

Coffee cooperatives provide numerous services, including extension services. Extension can provide farmers with information on their productivity (Abegunde *et al.*, 2019). Despite belonging to a cooperative, smallholders have reduced contact with extension activities such as training due to a shortage of agricultural extension and

knowledge (Krell *et al.*, 2021). Karfakis *et al.* (2015) noted smallholder farmers have less access to extension services than larger farms. Only 41% of agricultural households in Tanzania's Mbeya Region receive extension assistance (Otieno *et al.*, 2019). The rest of the population is left to fend for itself, utilizing ineffective measures that may harm coffee output. Also, many of the extension agents providing services were not educated in coffee and its activities, however, some were qualified to provide livestock assistance.

The inadequate extension visits for smallholder farmers contributed to widening of coffee production gap. (Van Dijk *et al.*, 2020). Farmer gain from extension services aids to improving field management techniques and increasing likelihood of closing the production gap. Rizzo *et al.* (2023) indicated that extension services contributed to decreased yield gaps due to increased knowledge among farmers. This showed that knowledgeable farmers were likely to take better decisions hence increasing productivity and reducing yield gaps. As a result, transferring suggested agricultural practices through extension officers may assist farmers in closing productivity gaps.

2.5.3 Training

Coffee cooperative societies are putting efforts to increase farmers production. The technique employed over the last decade is intensive training to demonstrated different practices to be adopted. Petcho *et al.* (2019) found that, despite the fact that cooperative organizations are supposed to help their members improve their productivity, agricultural cooperatives have little effect on paddy yields. This was attributed to agricultural cooperatives failing to give adequate training to their members and members failing to fully participate in the training provided. However, when agricultural cooperatives gave training to their members, there was a significant rise in livestock and farm output and revenues.

It was also worth noting that the majority of coffee cooperatives have not engaged in farmer training, resulting in poor uptake of enhanced agronomic techniques and low production (Dietz *et al.*, 2020). Leharwan *et al.* (2023) noted that demonstration of improved technologies to chick pea farmers enhanced their adoption of the technologies. This shows that training is an integral part of creating awareness among farmers and hence increase their productivity, lowering yield gaps. As a result, considerable yield

gaps have been identified, which might be decreased with sufficient training in coffee management and manufacturing.

2.5.4 Credit Accessibility

Credit availability enhances farmer liquidity by increasing access to new technologies and inputs in particular (Nkegbe, 2018). It also allows timely acquisition of production inputs inaccessible with their own resources. Isaga (2018) noted that most farmers obtain bank credit to run their coffee operations. However, due to the hazards connected with farming, most financial institutions avoid lending to smallholder farmers, and those that do usually need company documents and security, which such farmers lack. Access to credit helps smallholders overcome cash restrictions, which might impair their capacity for inputs use and timely implementation of agricultural decisions.

Islam *et al.* (2023) reported that credit access facilitated financial capability, bringing women-headed families towards a balance in the usage of inputs such as fertilizer. This implies that financial constraints limit production activities, and hence credits bridge the gap, causing farmers to expand their investment in production. Munialo (2020) discovered that credit access facilities significantly reduced maize yield variation, indicating the relevance of credit facilities in providing adequate supply of farm inputs. Numerous studies have highlighted the significance of credit in expanding access to agro-inputs such as chemicals and seeds, which helps growers narrow large productivity differences. It also aids in the management of inevitable shocks in farming (Owusu, 2017; Akwaa-Sekyi, 2013). Farmers are likely to purchase superior seed, fertilizers, and other critical inputs if they have access to financing.

2.6. Theoretical Framework

Jean-Baptiste Say, a French economist, proposed the production theory in 1803 for which this study is inclined to with several modifications. According to the theory, smallholder farmers must decide what, how to and how much to produce (Guido, 2020) and determine the best input mix for producing desired result. A production function is a mathematical statement of technology that produces the most output from a given set of inputs or specifies how inputs collaborate to generate a specific level of output

(Sickles & Zelenyuk, 2019). The relationship between inputs and outputs is represented as follows:

$$Q = f(X_i) \dots\dots\dots(1)$$

where;

Q = Output

X_i = Various inputs

In comparison to other types of analysis, production function analysis is used to describe the utilisation and creation process. In the study, the Cobb-Douglas production function will be applied. The Cobb-Douglas production function indicates a specific level of technology, where changes in the levels of technology contributed to a change in the production function (Mohajan, 2021). Thus, the Cobb-Douglas production function can be used to describe combinations of multiple input and output as follows:

$$Q = AL^\beta K^\alpha \dots\dots\dots(2)$$

where;

Q - Output obtained

L - Labour input

K - Capital input

β - Output elasticity of labour

A - Total factor productivity.

α - Capital output elasticity.

The degree of homogeneity is determined by the sum of α and β where diminishing returns to scale ($0 \leq \alpha + \beta \leq 1$), constant returns to scale ($\alpha + \beta = 1$), or increasing returns to scale ($\alpha + \beta \geq 1$) are used (Doll & Orazem, 1984).

Although the initial function was limited to two variables, it can be expanded to any number of variables. As a result, the production function allowed coffee production (Q) to be stated as a function of inputs such as land, fertilizer, fungicide, herbicide and

pesticide in this study. As a result, the study's production function for smallholder coffee producers will be expressed as:

$$Q = F(X_1, X_2, X_3, X_4, X_5, X_6) \dots \dots \dots (3)$$

where;

- Q - Coffee production
- X_1 - Foliar fertilisers
- X_2 - Herbicide
- X_3 - Inorganic Fertilisers
- X_4 -Organic fertilisers
- X_5 -Fungicide
- X_6 - Pesticide

As more inputs are used, output is expected to increase up to a particular point where more input will have negative effect on production due to overutilization.

2.7 Conceptual Framework

The conceptual framework proposed was used to assess how three separate aspects of coffee production, namely socio-economic characteristics, agronomic practices, and cooperative diversity, would result in optimal levels of coffee yields for smallholder farmers. The effect of the different variables on the coffee yield gap was either direct or indirect. The existing coffee yield gap (dependent variable) was estimated to determine the current level in effort of narrowing the gap and was expressed as an index. Further, various socio-economic characteristics were identified to determine their effect on coffee yield gap including the age, education level, farming experience, gender, household income and land size. The agronomic practices adopted for the study included pruning, fertiliser application, weed control, disease control, insect-pest control, integrated cropping system and coffee varieties whose effect on the yield and the resultant yield gap as observed. The cooperative diversity: input provision, extension services, training and credit accessibility determined the effect of services offered by the cooperatives on farmers' yields. Some of the external factors that influenced coffee yields and yield gap are the intervening variables including climate change, and government policies. The study was conceptualised as in Figure 2 below.

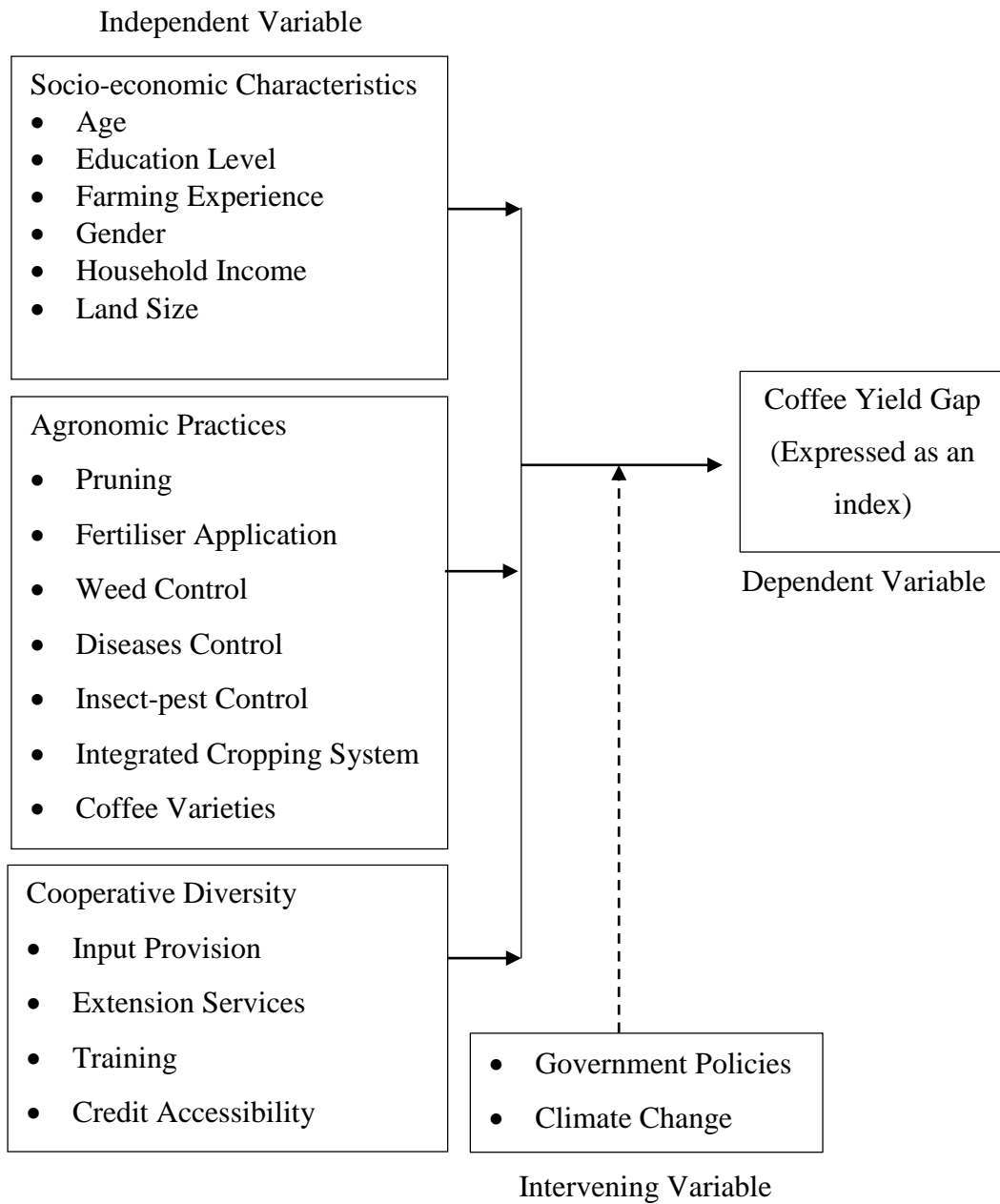


Figure 2: Conceptual Framework

Source: Author's Conceptualization

CHAPTER THREE

METHODOLOGY

3.1 The Study Area

This study was carried out in Nyeri Central sub-county, Nyeri County (Figure 3). Nyeri County lies between Aberdare ranges and Mt Kenya within the central region of Kenya (Nathan *et al.*, 2020). It between longitudes 36° 38' east and 37° 20' east and between the Equator 0° and latitude 0° 38' south covers and covers an area of 3,352 km² with a population of 759,164 (KNBS, 2019). Nyeri County is bordered by Nyandarua County to the west, Laikipia County to the north, Meru County to the north east, Kirinyaga County to the east and Murang'a County to the south (Ajak *et al.*, 2020). Nyeri County service delivery as well as management is divided into administrative units including: Kieni East, Mukuruweni, Tetu, Mathira East Kieni West, Nyeri Central, Mathira West, and Nyeri South sub-counties (Department of finance and economic planning, 2018). The County experiences long rains that run from March-May (1200-1600 mm) and short rains experienced in October-December (500-1500 mm). The County is endowed with lightly acidic soils and temperatures between 12.8 °C to 20.8 °C within an altitude 3,076 m–5,199 m above sea level (MoALF, 2016). Nyeri County is the second coffee producing County in Kenya and hence considered as a suitable area for this study (AFA, 2021). This study selected Nyeri Central sub-county due to the identification of challenges faced by farmers that majority have turned away from coffee production to other agricultural activities which lowered the coffee output of the sub-county.

3.2 Research Design

This study used the cross-sectional research design which measured the coffee yield gap against the socio-economic characteristics, agronomic practices and cooperative diversity. The design was useful in identifying the relationship of the explanatory and the explained variable which is the outcome of interest (Sedgwick, 2015). The research design assisted in answering the questions of what, when, where and how the primary data would be obtained (Wainaina, 2022).

3.3 Target Population

The study focus was on smallholder coffee farmers in Nyeri County. In Nyeri Central sub-county there were about 7,000 small-scale coffee farmers (AFA, 2021). Majority

of the farmers were registered in different cooperative societies found within Nyeri Central sub-county.

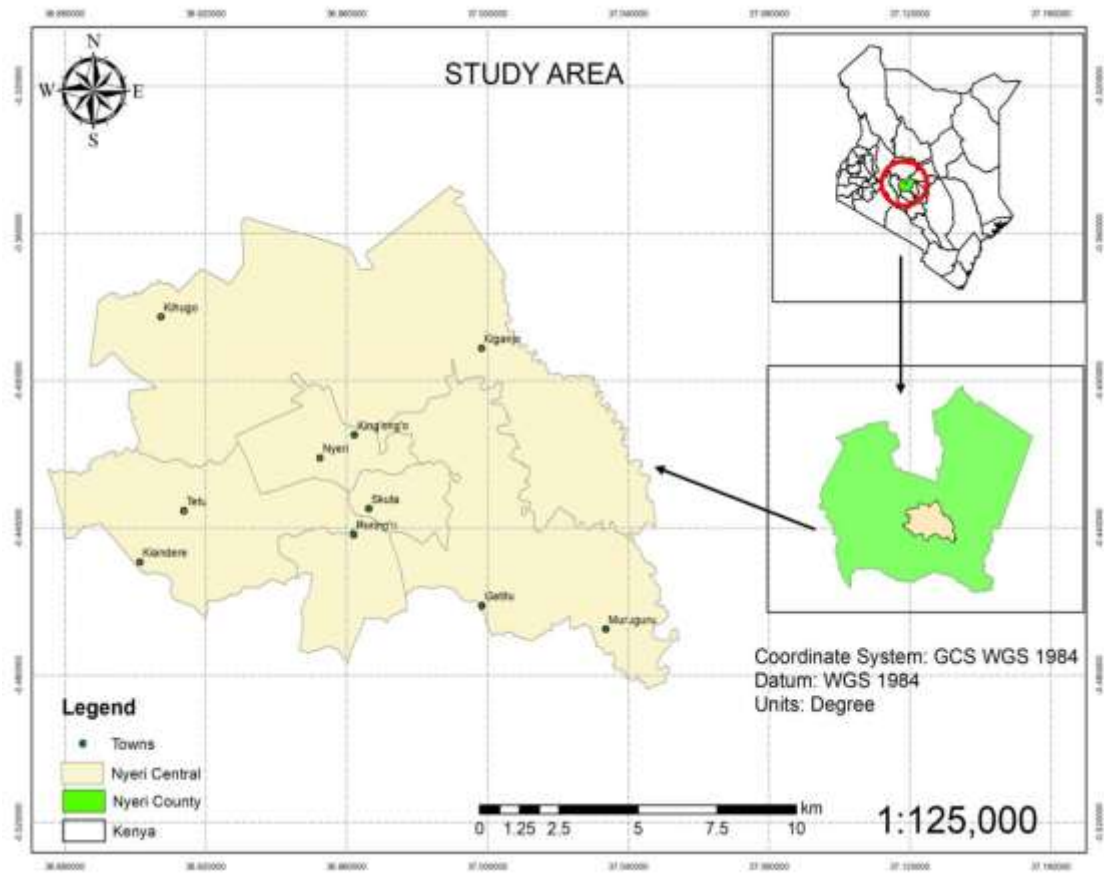


Figure 3: Map of Kenya showing Nyeri County and Nyeri Central sub-county
Source: Geocurrent (2019)

3.4 Sample Size and Sampling Procedure

3.4.1 Sample Size

A sample of smallholder coffee farmers was determined using a proportionate to size sampling method (Kothari, 2004) with a few modifications:

$$n = \frac{N}{1+N(e^2)} \dots\dots\dots(4)$$

where:

n- Sample of smallholder coffee farmers.

N- Population of smallholder coffee farmers in Nyeri Central sub-county.

e- Allowable total error (0.075).

Therefore, sample size was:

$$n = \frac{7000}{1 + 7000(0.075^2)}$$

$$n = 175$$

Table 1: Smallholder Coffee Farmers Sample Size in Nyeri Central sub-county

| Cooperative Society | Number of Farmers | Proportion | Sample |
|---------------------|-------------------|------------|--------|
| Mutheka | 6000 | 0.86 | 149 |
| Njuriga | 160 | 0.02 | 5 |
| Githiru | 840 | 0.12 | 21 |
| Total | 7000 | 1 | 175 |

3.4.2 Sampling Procedure

A systematic random sampling procedure was used where smallholder farmers' list was obtained from the different cooperative societies and through random selection the first respondent was chosen. The subsequent units were selected after k^{th} interval until the total sample was achieved. The sampling interval (k) was determined by:

$$k = \frac{\text{Population}}{\text{sample size}} \dots \dots \dots (5)$$

The interval was:

Mutheka Cooperative Society:

$$k = \frac{6000}{149}$$

k^{th} interval = 40

Njuriga Cooperative Society:

$$k = \frac{160}{5}$$

k^{th} interval = 32

Githiru Cooperative Society:

$$k = \frac{840}{21}$$

k^{th} interval = 40

3.5 Research Instrument

A semi-structured questionnaire that included open-ended and closed questions was used for primary data collection (Appendix I). The questionnaires containing open-ended and closed questions aided in obtaining both quantitative and qualitative information from the participants (Braun *et al.*, 2021). The questionnaire was divided into parts: part A was specific on farmer characteristics including education level, age, gender, household size and number of dependents. Part B sought information on farm characteristics of household including land size, land under coffee, farming experience, record keeping and household income. The part C covered the agronomic practices including fertiliser application, pruning, weeding, insect-pest control, integrated cropping system and disease control. Part D included questions on the farmers' coffee yields for the different varieties for a period of 3 years. Finally, part E covered the cooperative diversity including questions on credit provision, input provision, training and extension support.

3.6 Pilot Study

A pilot study was conducted in Gatundu sub-county, Gatundu North Constituency a month prior to the actual study. The area was chosen for it had similar climatic conditions as those of Nyeri Central sub-county that are favourable for coffee farming. The objective of the pilot survey was to test whether the questions were easily understood and logical. It aided in determining the difficulties that the study would encounter. It also helped to identify the ambiguity of the questions, phrasing, sequence and interview period so as to adjust them appropriately (Bui *et al.* 2023). The pilot survey also aided in identifying the range of answers indicated by farmers as well as understanding respondents' reactions. The pilot study participants were 10 % of the total sample, 18 smallholder coffee farmers, which was the minimum number of respondents required for carrying out a statistical analysis (Castillo *et al.*, 2020).

3.6.1 Reliability

The research instrument used in the preliminary study was subjected to a split half method. The split half technique was used because the instrument had many similar questions or statements to which a participant was to respond (Revelle & Condon, 2019). The questions from the research instrument used during the pilot study were

randomly separated into half where a correlation between both parts was determined using Spearman Brown Correlation Coefficient. The result of the correlation was 0.694 (Table 2) which translated that the instrument reliability was acceptable at 0.7 (Cooper & Schindler, 2003).

Table 2: Spearman Brown Correlation for Split Half Reliability Test

| | | | |
|--------------------------------|-----------------------|-----------------|-----------------|
| Cronbach's Alpha | Part 1 | Value | 0.274 |
| | | Number of Items | 10 ^a |
| | Part 2 | Value | 0.896 |
| | | Number of Items | 10 ^b |
| | Total Number of Items | | 20 |
| Correlation Between Forms | | | 0.532 |
| Spearman-Brown Coefficient | Equal Length | | 0.694 |
| | Unequal Length | | 0.694 |
| Guttman Split-Half Coefficient | | | 0.654 |

3.6.2 Validity

The research employed a systematic approach to content validity, which entailed a thorough literature review to determine important items for inclusion in the research tool. The research tool was then presented to experts in coffee sector from the County Department of Agriculture and supervisors from the Faculty of Agriculture to validate the survey tool used for the study.

3.7 Data Collection

The semi-structured questionnaire used in this study enabled the collection of both quantitative and qualitative data. The survey was conducted in April 2023 among randomly selected smallholder coffee farmers' households (Appendix II) and data developed on questionnaires captured the required information in line with the research objectives. Through the help of extension officers in the cooperative societies, the identified coffee farmers were contacted a week prior to the survey and informed of the date for data collection. The study involved administration of a semi-structured questionnaire to farmers in a face-to-face interview. Data collected was on socio-economic characteristics of household, agronomic practices and cooperative diversity as described in Appendix I.

3.8 Data Analysis

Data cleaning and descriptive statistics were performed using SPSS version 29 where the smallholder coffee farmers information was summarised and presented as tables. Frequencies, means and standard deviation were used as the descriptive indicators which were valuable in examining demographic characteristics as well as determining the relationship between variables. The data collected included; socio-economic characteristics, agronomic practices, cooperative diversity that affected coffee yield gap were also subjected to a fractional logit regression using STATA version 17 for the basis of description, analysis and inference of conclusions.

3.8.1 Estimation of Coffee Yield Gap

During the determination of the yield gap, the difference between the experimental yields obtained at KARLO-CRI and actual yields realised by farmers mainly attributed to agronomic practices was computed. The KARLO-CRI station trials were used as a benchmark to provide a comprehensive indication of potential yields. The variation between the benchmark and average farmer yields (absolute yield gap) provided important information on the scope to increase productivity (Asante *et al.*, 2022). The extent of yield gap depended on the yield potential used that was the benchmark. Yield gap was estimated as:

$$\text{Yield Gap (Yg)} = \text{Potential research yield}(P_{(ry)}) - \text{Average farmer yields}(A_{(fy)}) \dots\dots (6)$$

The yield gap was also expressed as yield gap index using equation 5 below:

$$I_{(yg)} = \left[\frac{P_{(ry)} - A_{(fy)}}{P_{(ry)}} \times 100\% \right] \dots\dots\dots (7)$$

where;

- I_(yg)- Yield gap index.
- P_(ry)- Potential research yields
- A_(fy)- Actual farmers' yields

The coffee yield gap index per farmer ranged from 84.99% to 96.90%. The yield gap index for Ruiru 11, Batian and SL 28 coffee varieties was 88.54%, 93.78% and 95.68% respectively.

3.8.2 Effect of Socio-economic Characteristics, Agronomic Practices and Cooperative Diversity on Coffee Yield Gap

To determine the socio-economic characteristic, agronomic practices and cooperative diversity on coffee yield gap a fractional logit regression was performed. The fractional logit regression is a generalised method for fractional outcome variables. It was used due to the limited value of the coffee yield gap index that ranged between 0 to 1. Anteneh and Endalew (2023) and Gallani *et al.*, (2015) reported that any response variable inform of an index, ratio, rates or quotas are best explained using the fractional outcome regression models. The model has also been used in various studies to examine the relationship between a fractional outcome and exogenous variables (Anteneh & Endalew, 2023). The regression model takes the form shown in equation (8) as generated by Papke and Wooldridge (1996).

$$E(y_i/x_i) = g(x_i\beta) \dots\dots\dots(8)$$

where;

y_i - Dependent variable (coffee yield gap index).

X_i - Explanatory variables of observation i .

β - Regression coefficient.

$g(\cdot)$ - Distribution function.

$0 \leq y_i \leq 1$ - Denotes range of the dependent variable.

To estimate the model parameters, the fractional regression model log likelihood was maximised using the form:

$$\ln L(\beta) = \sum_{i=1}^N w_i y_i \ln[g(x_i\beta)] + w_i(1 - y_i) \ln[1 - g(x_i\beta)] \dots\dots\dots(9)$$

where;

y_i - Dependent variable (coffee yield gap index).

N - Sample size.

x_i - Explanatory variables of observation i .

w_i - Optional weight.

The function $g(\cdot)$ is a logit distribution expressed as:

$$g(x_i\beta) = \frac{e^{x_i\beta}}{1+e^{x_i\beta}} \dots \dots \dots (10)$$

The result of the empirical specification of the fractional regression model is:

$$E(y_i/x_i) = g(u_i) = \beta_0 + \sum_{k=1}^N \beta_k x_{ik} + e_i \dots \dots \dots (11)$$

where;

$E(\cdot)$ - Denotes the variance operator.

Y_i - Dependent variable.

X_i - Explanatory variables of observation i .

N - Sample size.

U_i - Represents variables included in equation

β_k - The unknown parameter to be computed.

X_{ik} - The independent variables.

e_i - Represents the error term.

Thereafter, a post estimation analysis for the tests of the marginal effects was performed so as to determine the level of change caused by the independent variables on the dependent variable. The hypothesised variables of the coffee yield gap functions were provided in table 3. The rational of considering the identified factors was based on previous yield gap and coffee production literature. The expected positive or a negative sign of the model coefficients signified the change of the explanatory variable on the explained variable.

3.9 Ethical Consideration

This study ensured confidentiality, high integrity and privacy of the smallholder coffee farmers' information. A research introductory letter (Appendix III) from the Chuka University informed the farmers the nature and use of the information that was provided. The study sought for informed consent and ensured privacy to the information

from the farmers. The study also complied with Chuka University Institutional Ethical requirements and approval (Appendix IV). The National Commission for Science, Technology and Innovation (NACOSTI) research permit obtained allowed for effective collection of data for the study (Appendix V). A written letter was presented to the Ministry of Agriculture, Livestock and Fisheries in Nyeri County seeking permission and informing them of the nature and reason for collecting data in Nyeri Central sub-county. Using the Turnitin software the similarity index was checked to ensure the thesis was at the minimum acceptable level.

Table 3: Expected Signs for Socio-economic Characteristics, Agronomic Practices and Cooperative Diversity Variables

| Variable | Description | Measurement | Expected Sign |
|---------------------------------------|------------------------------|---|---------------|
| Socio-economic Characteristics | | | |
| Age | Respondent's age | Years | +/- |
| Gender of Household Head | Male or female | Dummy (1= male, 0= otherwise) | +/- |
| Education | Education level | Years | +/- |
| Land Size | Size of land owned | Ha | +/- |
| Farming Experience | Years in farming | Years | +/- |
| Household Income | Coffee income | KES | +/- |
| Agronomic Practices | | | |
| Pruning | Adopter or non-adopter | Dummy (1= adopter, 0= otherwise) | +/- |
| Weed Control | Weed control method | Man days | +/- |
| Disease Control | Disease control method | Man days | +/- |
| Insect-pest Control | Pest control method | Man days | +/- |
| Fertiliser Application | Type of fertiliser used | Kg/ Ha | +/- |
| Cropping System | Type of cropping system | Dummy (1= monocrop, 0= otherwise) | +/- |
| Coffee Variety | Type of coffee variety grown | Categorical (1= SL 28, 2= Ruiru 11 and 3= Batian) | +/- |
| Cooperative Diversity | | | |
| Input Provision | Farm input provision | Dummy (1= fertiliser, 0= otherwise) | +/- |
| Extension Services | Extension services received | Dummy (1= received services, 0= otherwise) | +/- |
| Credit Access | Credit received | Dummy (1= received credit, 0= otherwise) | +/- |
| Training | Training received | Dummy (1= received training, 0= otherwise) | +/- |

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Response Rate

This study had a sample of 175 respondents for which questionnaires were administered. Out of the 175 questionnaires only 156 were completed and received hence used as the sample of respondents for analysis (Table 4). This represented 89% response rate which was achieved through direct administration of questionnaires. The questionnaire return rate in this study was considered sufficient according to Vergani *et al.* (2022) and Brtnicova *et al.* (2018) that stated over 80% response rate was adequate for data analysis, discussion and drawing of conclusions and recommendations.

Table 4: Smallholder Coffee Farmers Questionnaire Response Rate

| Cooperative Society | Sample Size | Achieved Sample Size | Percentage |
|---------------------|-------------|----------------------|------------|
| Mutheka | 149 | 130 | 83.33 |
| Githiru | 21 | 21 | 13.46 |
| Njuriga | 5 | 5 | 3.21 |
| Total | 175 | 156 | 100 |

4.2 Descriptive Statistics of the Smallholder Coffee Farmers Socio-economic Characteristics

This study determined the socio-economic characteristics among the smallholder coffee farmers including; gender of the respondent, education level, age, gender of household head, coffee farming experience, household size, sector of employment, income from coffee, land size, land under coffee, rent in land, type of labour and record keeping. These study findings are as detailed below:

4.2.1 Gender of the Respondent

Nyeri Central sub-county coffee farming was found to be dominated by men as it was observed that the male smallholder coffee farmers were the majority (57.69%) compared to females at 42.31% (Table 5). This male active involvement in coffee production could be as a result of their access to resources and the African background of the roles of different members of the household. Tadesse *et al.* (2020) observed similar findings that majority of the smallholder coffee farmers (95%) in Southern Ethiopia were males.

Table 5: Gender of Smallholder Coffee Farmers

| Gender of Respondent | Frequency | Percent |
|----------------------|-----------|---------|
| Male | 90 | 57.69 |
| Female | 66 | 42.31 |
| Total | 156 | 100 |

4.2.2 Smallholder Coffee Farmers' Characteristics

This study sought to determine the average age, education level, household size, and farming experience of the smallholder coffee farmers. The mean age of smallholder coffee farmers was noted to be 60.19 years, with the youngest farmer being 31 years and the oldest farmer being 80 years (Table 6). This implies that the smallholder coffee farming cluster was skewed towards the ageing who were likely to be inefficient and less healthy which may have lowered their production considering the labour-intensive coffee activities. Further, the high elderly involvement in coffee farming was most likely due to access and control of household resources including; land, capital, equipment and collaterals to obtain loans. Also, it can be attributed to rural-urban migration of the young people and engagement of youths in competing enterprises such as horticulture, dairy, business activities and formal employment. Similar findings were observed by the Kenya coffee platform (2018) which noted that many of the smallholder coffee farmers in Kenya (49%) were aged from 60 years and above and was attributed as the “old man’s crop”.

Table 6: A Summary of Smallholder Coffee Farmers' Characteristics

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|-----------------------------|--------|--------------------|---------|---------|
| Age (years) | 60.192 | 13.039 | 31 | 80 |
| Schooling Years | 12.801 | 4.421 | 0 | 20 |
| Household Size | 4 | 1.659 | 2 | 10 |
| Years of Farming Experience | 26.071 | 14.042 | 7 | 60 |

This study determined the level of education in terms of schooling years which revealed an average of 13 years which translated to attainment of secondary level of education among the smallholder coffee farmers (Table 6). This revealed that the smallholder farmers were able to profitably run their coffee farming enterprise as they received some formal education. This may be due to their ability to assimilate information and influence decisions in terms of income investment, management practices, land use and

input use. Moreover, Wambua (2020) reported similar findings that 65.2% of the smallholder coffee farmers in Embu County attained secondary education. Also, Danquah *et al.* (2019) noted that 28.6% of smallholder maize farmers had attained secondary level of education in Ghana.

Further, the average number of members living in each household was 4 with the smallest household having 2 members and the largest having 10 (Table 6). Therefore, household size most probably influenced coffee production levels through approximation of available family labour supply for coffee activities. However, during the study, it was observed that not all the available family labour was used in coffee production most likely due to involvement in other major activities such as food crop production, dairy farming and business engagements. Mwaniki (2022) observed similar findings that smallholder tomato farmer's household had an average of 4 members in Kirinyaga County.

Further, the smallholder coffee farmers' average farming experience was 26.07 years within a range of 7 to a maximum of 60 years (Table 6). This implies that the smallholder coffee farmers had high experience and most probably had better decision making, reduced production losses as well as better management of inputs. Similar findings were reported by Keru (2021) who indicated that 60% of the smallholder farmers in Murang'a County had over 21 years of experience in coffee production and marketing.

4.2.3 Gender of Household Head Among the Smallholder Coffee Farmers

During the study, household heads were found to be the decision makers on behalf of the household. The male headed smallholder farmers' households were 70.51% while only 29.49% were female headed (Table 7). This reveals that the male dominance was due to their control of household resources including; land, capital and assets and also the fact that males provided more labour input in coffee activities than their female counterparts. Hence, males were able to complete tasks within a given amount of time where the females would take more. Similarly, Degefa *et al.* (2023) noted that many of the smallholder sorghum households (78.86%) in Western Ethiopia were male headed.

Table 7: Gender of Household Head Among Smallholder Coffee Farmers

| Gender of Household Head | Frequency | Percent |
|--------------------------|-----------|---------|
| Male | 110 | 70.51 |
| Female | 46 | 29.49 |
| Total | 156 | 100 |

4.2.4 Sector of Employment

During the study, the sector of employment revealed the main income source for the smallholder coffee farmer. The study noted that farmers belonged to different sectors of employment including: full-time farming (86.54%), businesses and farming (12.82%) and formal employment (0.64%) [Table 8]. This revealed that majority of the households depended on farming as the major source of their livelihood hence there is need for government and cooperatives societies to look into the coffee prices to sustainably reduce poverty among the coffee farmers. The findings are in agreement with those of Ronalds *et al.* (2023) who reported that majority of the coffee farmers (53.5%) in Rubirizi District in Uganda were full-time involved in coffee farming activities which was their main source of income.

Table 8: Sector of Employment Among the Smallholder Coffee Farmers

| Sector of Employment | Frequency | Percent |
|----------------------|-----------|---------|
| Farming | 135 | 86.54 |
| Farming and Business | 20 | 12.82 |
| Formal Employment | 1 | 0.64 |
| Total | 156 | 100 |

4.2.5 Income Received and Rating of the Income from Coffee Farming

During the study, farmers' sources of income were found to be diverse where income from coffee farming was approximated to be KES 37,063.82 per acre with the lowest income being KES 10,000 and the highest being KES 92,000 (Table 9). The amount of income from coffee was as a result of fluctuation of prices offered each year by the cooperative societies, agronomic practices, access to production information and old age which may have resulted in variation in yields that translated to differences in income. Moreover, the amount received was likely to affect farmers' investment in good agricultural practices that would improve the coffee quantity and quality produced. In contrast, Wairegi *et al.* (2018) estimated that the average income per acre for smallholder coffee farmers in Kenya to be KES 62,800.

Table 9: Income Received from Coffee Farming

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|-------------------------------|----------|--------------------|---------|---------|
| Income from Coffee (KES/Acre) | 37063.82 | 22381.3 | 10000 | 92000 |

Further, 73.72% of the smallholder coffee farmers rated the coffee income as low while 25% and 1.28% of the respondents rated it as moderate and high incomes, respectively (Table 10). The low-income rating observed could be attributed to fluctuation of prices in the global market and the poor cooperative management. This is likely to result in farmers' difficulties in meeting the household needs (paying school fee, running household errands and meeting basic needs) as well as reinvesting in coffee production considering that the income is paid once a year. These findings are in line with those of Ndirangu (2020) who noted that majority of the smallholder coffee farmers (90.1%) agreed that income from coffee was low which led to their poor management practices.

Table 10: Rating of Income from Coffee Farming

| Rating of Income from Coffee | Frequency | Percent |
|------------------------------|-----------|---------|
| Low | 115 | 73.72 |
| Moderate | 39 | 25 |
| High | 2 | 1.28 |
| Total | 156 | 100 |

4.2.6 Smallholder Farmers Farm Characteristics

This study sought to determine the land size owned by the smallholder farmers, the size of land dedicated to coffee production, rent in land and type of labour employed. The mean land size was noted to be 0.779 ha with the minimum land size being 0.202 ha and a maximum of 2.226 ha. Also, an average of 0.260 ha was used for coffee cultivation with the smallest portion being 0.130 ha and the largest being 0.809 ha (Table 11). These findings show a direct relationship between land owned and the land under coffee as farmers allocated smaller proportions of land to coffee due to small land sizes owned. Also, land fit for agricultural production was limited which most probably was due to land fragmentation resulting to uneconomical lands for coffee production. Similar findings were observed by Debela *et al.* (2020) who noted that land size for most smallholder farmers in Ethiopia ranged between 0.25 ha to 6 ha and. Nginyangi

(2011) who reported that the land size under coffee cultivation among smallholder farmers in Mathira District ranged within 0.1 ha to 0.26 ha.

Further, the average land size rent by smallholder farmers was 0.775 ha with the smallest land size being 0.101 ha and the largest being 2.833 ha (Table 11). This implies that farmers took additional parcels of land for agricultural production however, it was not necessarily for coffee production. In contrast, Munezero *et al.* (2023) noted that an average of 0.368 ha was rent by smallholder onion farmers in Uganda.

Table 11: A Summary of Land Size, Land Under Coffee, Rent in Land and Type of Labour

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|-------------------------|-------|--------------------|---------|---------|
| Size of Land Owned (ha) | 0.779 | 0.486 | 0.202 | 2.226 |
| Land Under Coffee (ha) | 0.260 | 0.150 | 0.130 | 0.809 |
| Rent in Land (ha) | 0.775 | 0.455 | 0.101 | 2.833 |
| Casual Labour | 4 | 2.359 | 0 | 12 |
| Family Labour | 3 | 1.829 | 0 | 9 |
| Permanent Labour | 1 | 0.393 | 0 | 2 |

Further, the labour distribution was observed to be either casual, family or permanent labour with an average of 4 casual labourers, 3 family labourers and 1 permanent labourer. The labourers were involved in coffee farm operations including: pruning, removal of suckers, weeding management, application of organic and inorganic fertilisers, disease control, insect-pest control and harvesting (Table 11). This suggests that most coffee operations are carried out by casual labourers which is attributed to the seasonal nature of coffee agronomic activities such as pruning, weeding, spraying against pest and diseases and application of organic and inorganic fertilizers that require casuals rather than the permanent labourers. In contrast, Munialo *et al.* (2019) reported that majority of smallholder maize farmers (53.3%) preferred family labour with an average of 4 members per household due to its low monitoring and compensations costs as compared to the hired labour in Western Kenya.

4.2.7 Record Keeping Among Smallholder Coffee Farmers

This study sought to determine whether farmers kept records or not and it was noted that 83.97% of the smallholder farmers did not keep farm records and only 16.03% of the farmers kept the farm records (Table 12). This was probably attributed to illiterate

farm workers employed, procrastination, and forgetfulness. This imply that majority of the farmers could not accurately estimate the costs incurred, type of inputs used and activities carried out in the farm over the years. The study findings are in agreement with that of Fani *et al.* (2023) who noted 54.2% of smallholder maize farmers in Western Cameroon did not keep farm records while 45.8% kept records.

Table 12: A Summary of Record Keeping Among the Smallholder Coffee Farmers

| Record Keeping | Frequency | Percent |
|-----------------|-----------|---------|
| No Records Kept | 131 | 83.97 |
| Kept Records | 25 | 16.03 |
| Total | 156 | 100 |

4.3 Descriptive Statistics of Smallholder Coffee Farmer Agronomic Practices

4.3.1 Preferred Coffee Varieties Among the Smallholder Coffee Farmers

This study sought to determine the type of variety that the smallholder coffee farmer grow whether the improved varieties (Ruiru 11 and Batian) or traditional varieties (SL 28, SL34 or K7). The study revealed that the smallholder coffee farmers grow different coffee varieties including SL 28 (80.13%), Ruiru 11 (8.97%), Batian (1.92%) with some farmers growing a combination of the different varieties (Table 13). The high preference for SL 28 variety in Nyeri Central sub-county was probably due to its excellent quality and heavy cherry as reported by majority of the farmers. The findings are in agreement with that of Gichigi (2015) who observed that majority of the smallholder coffee farmers (77%) grew SL28 variety in Nyeri County.

However, during the study it was observed that some farmers were improving their traditional varieties through grafting especially using Ruiru 11. This aided to minimize costs of management and increase yields as Ruiru 11 was reported to be high yielding and disease resistant. Kiwelu *et al.* (2021) reported similar findings that farmers were gradually rehabilitating their traditional coffee varieties by replacing the bushes through grafting scions of improved varieties onto the traditional variety healthy root stock in Tanzania.

Table 13: Coffee Varieties Grown by Smallholder Coffee Farmers

| Variety | Frequency | Percent |
|---|-----------|---------|
| SL 28 | 125 | 80.13 |
| Ruiru 11 | 14 | 8.97 |
| Combination of Ruiru 11 and SL28 | 8 | 5.13 |
| Batian | 3 | 1.92 |
| Combination of SL 28, Batian and Ruiru 11 | 3 | 1.92 |
| Combination of Batian and SL28 | 2 | 1.28 |
| Combination of Ruiru 11 and Batian | 1 | 0.64 |
| Total | 156 | 100 |

4.3.2 Agronomic Practices Applied by Smallholder Coffee Farmers

This study intended to determine the agronomic practices the smallholder coffee farmers carried out in the last cropping year. During the study, it was found that majority of the smallholder coffee farmers carried out different agronomic practices ranging from: weed management (90.38%), bush management (80.13%), insect-pest control (71.15%) and disease management (70.51%) with few farmers carrying out coffee tree training (5.13%) and soil testing and analysis (3.21%) [Table 14].

Further, the study sought to determine the frequency of agronomic practices used by the farmers where 42.73% carried out disease management practices at least three times per cropping year (Table 14). This was because majority of the coffee farmers grew SL 28 which has been reported to be susceptible to diseases especially the CLR and CBD hence required proper control. Buyinza (2019) also reported similar findings that majority of coffee growers (56.2%) in Uganda frequently sprayed their coffee against diseases. During the study, disease control was done using fungicides following the coffee spraying schedule on the frequency of disease spraying, using the right fungicides, recommended application rates and right application time for effective disease control.

Moreover, some of the agronomic practices such as application of inorganic fertilisers (52.08%) and management of coffee bushes (49.6%) were carried out at least twice within a cropping year (Table 14). Ndirangu (2020) made similar observations that majority of the smallholder coffee farmers (44.3%) carry out pruning and 43.8% practised fertiliser application at least two times within a cropping year. Moreover, farmers with higher frequency of fertiliser application as recommended by extension

officers had higher average yields. The findings are in agreement with those of ICO (2019) which indicated that poor on-farm management such as fertiliser and manure application resulted in low average yields among smallholder farmers. During the study, farmers preferred using selective method of coffee pruning where they chose one stem to prune in a specific period so that they can remain in production throughout the cropping cycle.

Table 14: A Summary of Agronomic Practices Among Smallholder Coffee Farmers

| Agronomic Practices | Frequency | Percent | Very Often (thrice per cropping year) | Often (twice per cropping year) | Less Often (once per cropping year) | Not at All (zero times) |
|---|-----------|---------|---------------------------------------|---------------------------------|-------------------------------------|-------------------------|
| Weed Management | 141 | 90.38 | 2.13 | 21.99 | 75.89 | 0 |
| Bush Management (Pruning & Desuckering) | 125 | 80.13 | 0.8 | 49.6 | 49.6 | 0 |
| Insect-pest Management | 111 | 71.15 | 4.34 | 23.42 | 33.33 | 0.9 |
| Disease Management | 110 | 70.51 | 42.73 | 27.27 | 29.09 | 0.91 |
| Application of Organic Fertilisers | 104 | 66.67 | 10.58 | 43.27 | 42.31 | 3.85 |
| Change of Cycle | 100 | 64.1 | 0 | 27 | 73 | 0 |
| Application of Inorganic Fertilisers | 48 | 30.77 | 4.17 | 52.08 | 43.75 | 0 |
| Intercropping | 41 | 26.28 | 12.2 | 34.15 | 53.66 | 0 |
| Grafting | 21 | 13.46 | 0 | 4.76 | 90.48 | 4.76 |
| Soil Testing and Analysis | 5 | 3.21 | 0 | 0 | 97.58 | 0 |

The weed management (75.89%), grafting (90.48%) and soil testing and analysis (97.58%) were agronomic practices carried out once per cropping year (Table 14). This was attributed to the nature of the agronomic practices which determined their low frequency of implementation. Moreover, it was likely that grafting was hindered by the skill required and costs associated with the practice. Similarly, Torrez *et al.* (2023) reported that recommended management practices such as weed management, soil

testing, fertiliser application and harvesting techniques were applied on one occasion in a cropping year.

However, some coffee farmers did not carry out some management practices including: grafting (4.76%) and application of organic fertilisers (3.85%) [Table 14]. This was most likely due to some farmers having coffee bushes that are yet to come into production, lack of information and skill regarding coffee grafting and low labour availability for application of the organic fertilisers. Solidaridad (2022) reported similar findings that high cost of labour in coffee production poses a huge threat to sustainability of coffee productivity and value chain.

4.3.3 Input Used by Smallholder Coffee Farmers

This study intended to determine the inputs used by farmers in coffee production where five farm inputs namely; manure, inorganic fertilisers, pesticide, herbicide, foliar and fungicide are being used. The average quantity of fertiliser used in coffee production was observed to be 320 kgs/ha (Table 15). This implies that some farmers met the nutrient requirement of the coffee bushes because the inorganic fertilisers provided them and it is likely that some farmers used the recommended rates, applied using the right methods, and at the right time which most probably influenced their yields. Similarly, Wambua (2020) reported that 73.4% of the smallholder coffee farmers in Embu County applied recommended rates of fertilisers with an average range of 266 kg/ha to 400 kg/ha.

Table 15: A Summary of Farm Inputs Used in Coffee Production

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|-------------------------------|---------|--------------------|---------|---------|
| Inorganic Fertiliser (kg/ha) | 320 | 66.658 | 250 | 410 |
| Organic Manure (kg/ha) | 2158.94 | 1298.591 | 1000 | 5000 |
| Foliar Fertiliser (litres/ha) | 1.622 | 0.505 | 1 | 3 |
| Pesticide (litres/ha) | 1.196 | 0.472 | 0.5 | 2 |
| Fungicide (litres/ha) | 2.025 | 0.848 | 1 | 4 |
| Herbicide (litres/ha) | 2.192 | 0.546 | 1 | 3 |

Also, an average of 2,158.94 kgs/ha of organic manure were used for coffee production (Table 15). This resulted from the fact that majority of smallholder farmers reared chicken, dairy cows and goats which was their main source of farmyard manure hence no costs to purchase it was incurred. This finding is in line with that of Agri Farming

(2022) which reported that an average of 2,500 kgs of manures are used in coffee production per year. The findings of this study imply that the use of organic manure is likely improve the soil physical properties that probably influenced farmers' yields.

Further, it was noted that coffee farmers use additional input in their coffee production with an average of herbicides (2.192 l/ha), fungicide (2.025 l/ha), foliar fertilisers (1.622 l/ha) and pesticide (1.196 l/ha) [Table 15]. This showed that farmers used less pesticide compared to both herbicide and fungicide. This may be due to farmers awareness of disease susceptibility of the coffee varieties they grow and hence require appropriate control measure. Also, lack of information on the best insect-pest control measures and lack of a defined pesticide control schedule influenced pesticide use. Similar findings were reported by Wambua (2020) who noted that the average quantity of fungicide and herbicide used in coffee production was 2.5 litres per hectare in Embu County. Considering pesticide use, the findings contrast those of Agri Farming (2022) which noted that the quantity of pesticide used among small-scale farmers was approximately 2 litres per ha while farmers in Nyeri Central sub-county used an average of 1.196 litres per ha.

4.3.4 Integrated Cropping System Practised by the Smallholder Coffee Farmers

This study sought to determine the type of cropping system used by the smallholder coffee farmers where 62.18% of the smallholder coffee farmers were found to practise monocropping system while 37.82% practised intercropping (Table 16). This showed that farmers preferred monocropping system probably due to the high plant densities. Moreover, the different cropping system used by farmers was, probably, due to the inherent heterogeneity of socio-economic characteristics that influenced farmers decision on coffee management. Ronalds *et al.* (2023) reported that 75.8% of farmers intercrop their coffee while 24.2% practised monocropping system which was a contrast to this study.

Further, intercropping was observed to be carried out using different type of crops ranging from beans (83.33%), bananas (62.18%), avocado (18.52%) and macadamia (17.34%) [Table 16]. This showed that majority of farmers preferred food crops as intercrop most probably due to food security concerns and also fruit trees probably to

provide income which resulted to maximum utilisation of land. The findings are in agreement with those of Blomme *et al.* (2023) who indicated that intercropping among smallholder farmers in Ethiopia increased food availability and security.

Table 16: A Summary of the Integrated Cropping Systems Among Smallholder Coffee Farmers

| Characteristic | Description | Frequency | Percent |
|--------------------------------------|---------------|-----------|---------|
| Cropping System | Monocropping | 97 | 62.18 |
| | Intercropping | 59 | 37.82 |
| | Total | 156 | 100 |
| Type of Crop in Intercropping System | Beans | 37 | 83.33 |
| | Bananas | 11 | 62.18 |
| | Avocado | 8 | 18.52 |
| | Macadamia | 3 | 17.54 |

4.4 Descriptive Statistics of Cooperative Diversity Among Smallholder Coffee Farmers

4.4.1 Access to Credit

This study sought to determine the credit accessibility of the smallholder coffee farmers from the cooperative societies. It was found that 92.95% of the farmers did not have access to loans or credit while only 7.05% accessed credit (Table 17). Similarly, Mwaniki (2022) indicated that in Kirinyaga County, 77.03% of tomato farmers had no access to loans and 22.97% accessed loans. This was attributed to various reasons given by the farmers during this study including: 84.14% had no need to secure loan facilities, 13.79% did not have adequate collateral to secure a loan facility, 13.1% attributed the high interest rates for the credit ,4.14% the lack of awareness of availability of agricultural credits and the long credit application procedure was indicated by 2.17% of the farmers (Table 17).This revealed that most of the farmers had little financial resources which most probably would have affected timely acquisition of farm inputs resulting to inefficiency in their coffee production.

However, Mulume *et al.* (2022) noted that the major reasons for shortage of credit among smallholder farmers in Democratic Republic of Congo (DRC) was reduced household income and low farmers' participation in groups and cooperatives. Also, Kamau (2019) reported that the main reason why smallholder potato farmers did not acquire credit was due to the insufficient collaterals to secure loan facilities. This

showed that majority of the farmers (84.14%) had no interest in taking loan for coffee farming which could be attributed to the low returns from coffee resulting to reluctance in taking credit to expand the coffee enterprise. Also, some farmers lack security such as title deeds and assets that would enable them to acquire credits.

Table 17: Access to Credit Among Smallholder Coffee Farmers

| Characteristic | Description | Frequency | Percent |
|------------------------------------|---|-----------|---------|
| Access to Credit | No credit | 145 | 92.95 |
| | Acquired credit | 11 | 7.05 |
| Reasons for Not Applying for Loans | No need | 122 | 84.14 |
| | Inadequate collaterals to secure a facility | 20 | 13.79 |
| | High interests on loans | 19 | 13.1 |
| | Not aware of the availability of agricultural credits | 6 | 4.14 |
| Use of Credit | Long credit application procedure | 3 | 2.07 |
| | Farm inputs | 9 | 80 |
| | Expand business | 2 | 20 |

Further, it was observed 80% of the coffee farmers who received credit used it to acquire farm inputs such as fertilisers, herbicide, pesticide and fungicide while 20% of the farmers used the credit to expand their other business enterprises (Table 17). Similar findings were reported by Mwaniki (2022), Kamau (2019) and Mohammed *et al.* (2019) who observed that many of small-scale farmers utilised their credits to purchase farm inputs to enhance production. This implies that most of the smallholder coffee farmers acquire credit to boost their agricultural activities.

4.4.2 Access to Extension Services

This study sought to determine whether farmers are receiving extension services from the cooperative societies. This study observed that majority of smallholder coffee farmers (53.85%) did not access extension services and only a few (46.15%) had received the services from the cooperative societies (Table 18). This showed that the effect of extension services especially by the cooperative societies and County officers are not far-reaching as majority of farmers had no contact with the agents which may have resulted in poor implementation of trainings and information received. Similar observations were made by Otieno *et al.* (2019) who noted that majority of the farm families in Mbeya region, Tanzania had no contact with the extension officers and

where extension was received majority of the officers were not trained in coffee production.

Table 18: Access to Extension Services Among Smallholder Coffee Farmers

| Characteristics | Description | Frequency | Percent |
|-----------------------------|---------------------------------|-----------|---------|
| Extension Services Received | No extension received | 84 | 53.85 |
| | Received extension | 72 | 46.15 |
| Source of Information | Farmer to farmer | 79 | 94.05 |
| | Agricultural training centres | 27 | 32.14 |
| | Agro-chemical companies | 22 | 26.19 |
| | Agricultural shows | 17 | 20.24 |
| | Lead farmers | 6 | 7.14 |
| | Agricultural extension services | 5 | 5.95 |
| | Internet | 5 | 5.95 |
| | NGOs | 3 | 3.57 |
| | Religious group | 1 | 1.19 |
| | Researcher | 1 | 1.19 |
| Number of Visits | Once | 49 | 68.06 |
| | Twice | 15 | 20.83 |
| | Thrice | 6 | 8.33 |
| | More than four times | 2 | 2.78 |

Further, the smallholder coffee farmers obtained production information from different sources including: information from other farmers (94.05%), agricultural training centres (34.14%), agro-chemical companies (26.19%) and agricultural shows (20.24%) [Table 18]. This showed that farmers relied on information shared by other farmers especially from the experienced and trained farmers and also farmer to farmer may be a key information dissemination channel in effort to reach a wide proportion of farmers. Mathinya *et al.* (2022) made similar observations in South Africa that majority of smallholder crop farmers acquired information from their fellow farmers.

Moreover, the frequency of visits by the extension officer in a cropping year among the farmers was as follows; 68.06% of farmers received only one visit, 20.83% received two visits, 8.33% received three visits while 2.78% received more than four visits (Table 18). The low frequency of extension officers' visits indicates low contact between the farmers and the officers which could be as a result of the low ratio of the extension agent to the farmers in Kenya. It has been reported that one extension officer serves approximately 2000 farmers in Kenya against the global recommended ratio by

FAO of 1:400 (Chimbi, 2023). Obare *et al.* (2010) noted similar findings that the smallholder Irish potato farmers' average number of extension officer s' visits in Nyandarua County was 1.09.

4.4.3 Access to Training

This study sought to determine whether coffee farmers access trainings from cooperative societies. During the 2022 cropping year, it was noted that 80% of the smallholder coffee farmers received training related to coffee production while 20% did not receive any training from the cooperative societies (Table 19). This study findings imply that majority of farmers are knowledgeable on matters related to coffee production which led to increased efficiency in coffee farming. Similar observations were made by Prasad *et al.* (2019) that 78.80% of Nepal's coffee farmers had received training on coffee production which increased the volumes of their output.

Table 19: Access to Training Among Smallholder Coffee Farmers

| Characteristic | Description | Frequency | Percent |
|---------------------------------------|----------------------------|-----------|---------|
| Training in Coffee Production | Trained | 125 | 80 |
| | Not trained | 31 | 20 |
| Source of Training | Total | 156 | 100 |
| | Cooperative society | 60 | 48 |
| | County Government of Nyeri | 37 | 29.6 |
| | Chemical company | 24 | 19.2 |
| | Field day | 4 | 3.2 |
| | Total | 125 | 100 |
| Other Training in Agricultural Sector | Not trained | 96 | 61.54 |
| | Trained | 60 | 38.46 |
| | Total | 156 | 100 |

Moreover, it was noted that coffee farmers obtained training from various sources including: cooperative societies (48%), County Government of Nyeri (30.89%), chemical companies (19.94%) and from field day (2.17%) [Table 19]. This study findings, shows that cooperative societies in Nyeri Central sub-county have played major role in farmers training through the extension officer in effort to improve cooperative performance by enhancing understanding and demonstration of agronomic practices. In contrast, Dietz *et al.* (2020) reported that majority of coffee cooperatives did not invest in farmers' training which resulted to low production in Colombia.

Further, 38.46% of the smallholder coffee farmers in Nyeri Central sub-county received training in other agricultural sectors such as livestock, food security among others while 61.54% of the farmers did not receive such training (Table 19). This infers that training is probably an important aspect in all sectors of agriculture to enhance understanding and dissemination of ideas as well as technologies to the farmers in agriculture. Petcho *et al.* (2019) made comparable findings in Thailand that some farmers (34%) had received training on livestock production offered by agricultural cooperatives which increased farmers' productivity and revenue in addition to general farm training received.

4.5 Determination of Yield Gap Experienced by the Smallholder Coffee Farmers

In this study, the yield gap experienced by the smallholder coffee farmers was estimated by comparing actual yields obtained by the farmers with yield data from research by KARLO-CRI. Further, it was noted the farmers' average number of coffee trees per acre was 527 with some farmers having as low as 500 and others with as many as 875 trees per acre. The average cherry produced per tree was 3.548 kgs with a maximum of 10.630 kgs. The findings contrast with those of Wambua (2020) who noted that the average cherry output per tree among smallholder coffee farmers in Embu County was 4.6 kg/tree.

The average total output per acre of land was observed to be 1,869.81 kgs with a maximum of 6,615 kgs (Table 20). Kiwelu *et al.* (2021) reported different findings in Tanzania with smallholder coffee farmers having an average cherry output per acre of 1141 kg/acre. However, the findings showed that smallholder farmers in Nyeri Central sub-county have the potential for more production as farmers can produce a maximum of 10.630 kg/tree and the difference in production was most probably due to the different integrated cropping system and agronomic practices among the smallholder coffee farmers.

The research data from KARLO-CRI showed that arabica coffee potential yields are 30 kilogrammes per tree. The average number of trees recommended per hectare for the SL 28, K7 and SL 34 (traditional varieties) is 1,330 as well as 2,500 for Ruiru 11 and 1,950 for Batian (improved varieties) [KARLO, 2019]. The average farmer yield for

the 3 years was used as a reference for farmers' attainable yield. During the study, the yield variation per variety was determined as the difference between experimental yields from KARLO-CRI stations trials and actual farmer yields obtained for each variety in Nyeri Central sub-county.

Table 20: A Summary for Coffee Production in the Study Area

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|------------------------------------|----------|--------------------|---------|---------|
| Average Trees Owned per Acre | 527.034 | 51.851 | 500 | 875 |
| Average Total Cherry per Tree (kg) | 3.548 | 2.411 | 0 | 10.630 |
| Average Total Output per Acre (kg) | 1869.917 | 1301.544 | 0 | 6615 |

The actual farmers' yield was an average of 8,593.920 kg/ha, 3,545.277 kg/ha and 1,722.423 kg/ha for Ruiru 11, Batian and SL 28, respectively and the yield gap was 66,406.080 kgs, 53,454.722 kgs and 38,177.577 kgs for Ruiru 11, Batian and SL 28, respectively. Further, the average yield gap index for Ruiru 11, Batian and SL 28 was 88.54%, 93.78% and 95.68% respectively (Table 21). These study findings revealed a significantly large yield gap where farmers with traditional coffee varieties had a wider yield gap compared to those farmers with improved varieties.

The study findings also noted that growing of improved variety-Ruiru 11 is better compared to improved variety-Batian in effort to minimizing the yield gap as Ruiru 11 had higher yields and lower yield gap compared to Batian. This large coffee yield gap estimate may have been influenced by varieties of coffee grown, low contact with extension officers which result poor implementation of recommended agronomic practices, and lack of credit access to boost production. Moreover, there is a large exploitable gap as revealed by the yield gap index that may be crucial in increasing coffee productivity hence reducing yield gap.

Table 21: A Summary of Yields, Yield Gap and Yield Gap Index

| Variety | Improved Varieties | | Traditional Variety |
|-------------------------|--------------------|-----------|---------------------|
| | Ruiru 11 | Batian | SL 28 |
| Research Yields (kg/ha) | 75000 | 57000 | 39900 |
| Farmers Yield (kg/ha) | 8593.920 | 3545.277 | 1722.423 |
| Yield Gap | 66406.080 | 53454.722 | 38177.577 |
| Yield Gap Index | 88.54% | 93.78% | 95.68% |

Yield gap studies conducted revealed different magnitudes of yield gap in different crops for example: Wang *et al.* (2015) noted that the estimated coffee yield gap among smallholder farmers in Uganda was between 45%-57% that was contributed mainly by the biotic, abiotic and management factors. Assefa (2023) reported 18% efficiency gap index, 20% resource gap index and 63% technology gap index among smallholder maize farmers in Ethiopia which was contributed by the slow adoption of technologies and poor management practices.

Singh *et al.* (2023) reported that the overall yield gap index for cotton in Bhadradi Kothagudem district of Telangana was 21.69% that was attributed to size of land such that if the size of land was increased, there was likelihood that the yield gap would reduce. In Kenya, Munialo *et al.* (2020) reported 35% and 54% yield gap index in maize in high and low agro-ecological zones, respectively which was contributed by the soil management factors. Therefore, smallholder farmers are yet to unleash their full potential in agricultural production and hence experience yield gaps that need appropriate strategies to address them.

4.6 Fractional Logit Model on the Effect of Socio-economic Characteristic on Coffee Yield Gap Among Smallholder Farmers in Nyeri County

This study hypothesised that socio-economic characteristics would affect coffee yield gap in Nyeri Central sub-county. The fractional logit regression model used contained one dependent variable (coffee yield gap index) which was a fractional outcome (between 0 to 1) and five explanatory variables including: gender of household head, age, schooling years, household size and labour after dropping the household income, land size and farming experience that were highly skewed and insignificant to the study. The model showed that the log pseudo likelihood was -103.552 where $p=0.0015<0.05$ implied that the independent variables strongly influenced the coffee yield gap. The coefficients also had negative signs which implied that a unit increase in the independent variable decreased the coffee yield gap by a certain level.

Table 22: Fractional Logit Regression Output and Marginal Effect of Socio-economic Characteristics

| Yield Gap Index | Coefficient | Standard Error | P>z | Marginal Effect |
|--------------------------|-------------|----------------|-------|-----------------|
| Gender of Household Head | -0.0083 | 0.0027 | 0.002 | -0.0019** |
| Age | 0.0001 | 0.0001 | 0.108 | 0.0000 |
| Schooling Years | -0.0018 | 0.0008 | 0.024 | -0.0004** |
| Household Size | -0.0018 | 0.0008 | 0.027 | -0.0004** |
| Labour | -0.0017 | 0.0007 | 0.035 | -0.0003** |

Key: ** denoted p-value significant at 5% significance level.

The model results revealed a negative but significant effect of the gender of the household head on coffee yield gap. The model's marginal effect indicated a 0.0019 unit decrease in coffee yield gap as a result of increased male household heads (Table 22). This infers that male household heads took investment decisions with regards to coffee production including; dedicating portions of land to coffee and using credits acquired to purchase farm inputs which most likely contributed to the improved implementation of recommended agronomic practices resulting to increased coffee production among the farmers. Similar findings were noted by Ronalds *et al.* (2023), Guadie (2020) and Gishu *et al.* (2018) that male household heads had a negative and significant effect on production. Hence increasing male household heads increased chances of increasing yields significantly contributing to reduced yield gap. Therefore, it is likely that the male household heads contributed immensely to reduced yield gap among smallholder farmers in Nyeri Central sub-county.

Also, a negative and significant effect between schooling years and coffee yield gap was observed. The marginal effect showed that as the number of schooling years increased, the coffee yield gap decreased by 0.0004 units (Table 22). This implies that increased level of education among the farmers increased farmers' coffee production efficiency which was likely to minimize yield gap. It also implies that education most probably enhanced farmers with skills that increased their implementation of agronomic practices, use of improved technologies and application of recommended inputs, thus attaining high productivity. Similar observations were made by Osinowo and Tolorunju (2019) who reported that poultry farmers' schooling years negatively and significantly influenced the technical inefficiency in Nigeria. This implied that the more the years of schooling of the poultry farmer the higher the production resulting to

reduced technical inefficiency. Therefore, the more literate a coffee farmer was the higher the chance that their yield gap would be low.

Further, the household size portrayed, a negative and significant effect on coffee yield gap. The marginal effect implied that an additional member to the household size would decrease coffee yield gap by 0.0004 units (Table 22). Based on the study findings, the reduced coffee yield gap was probably due to the increase in farmers' investment in coffee production especially by the male household heads, and increased labour availability that improved production significantly. Adane and Bewket (2021) reported similar findings that household size in Southern Ethiopia negatively and significantly affected the coffee quality and climate change adaptations. This was due to increase in labour availability for coffee maintenance and harvesting that enabled farmers to adjust and protect their coffee against climate change. Hence a large household size guaranteed the availability of family labour because most probably the individuals would participate in coffee activities.

The findings also indicated a negative and significant effect between labour and the coffee yield gap. The model's marginal effect revealed that an addition to the family labour would decrease coffee yield gap by 0.0003 units (Table 22). This implies that family labour was probably more reliable and efficient than the hired labour due to its readily availability and that it's an asset and source of wealth for the household. The findings are in agreement with those of Pereira *et al.* (2022) who observed that family labour was significant and negatively contributed to coffee production in Brazil thereby increasing yields achieved.

4.7 Fractional Logit Model on the Effect of Agronomic Practices on Coffee Yield Gap Among Smallholder Farmers in Nyeri County

The effect of agronomic practices on coffee yield gap was determined using the fractional logit regression analysis which used eight independent variables: weed management, insect-pest management, disease management, intercropping, use of organic fertiliser, bush management, grafting and coffee tree training and one dependent variable: coffee yield gap index (between 0 and 1). The model's log pseudo likelihood was -103.552 where $p=0.0000<0.05$ which implied that the interactions of the variables were significant at 5% significance level. The findings show that weed

and disease management significantly affected coffee yield gap negatively contributing to decreased yield gap while insect-pest management positively influenced the coffee yield gap. However, intercropping, use of organic fertiliser, bush management, grafting and coffee tree training variables were found to be insignificant and did not influence the outcome of this study.

In addition, a negative and significant effect between weed management and coffee yield gap was noted. The model's marginal effect showed that a unit increase in weed management practices would translate to a decrease in coffee yield gap by 0.0014 units (Table 23). This infers that weeds pose a hinderance to achievement of high coffee yields most probably due to competition for the limited plant development resources such as space, light, water and nutrients. However, it was discovered that farmers applied herbicides especially during the first weeding were likely to increase yields due to increased weed control efficiency. Similar findings were noted by Monzon *et al.* (2023) who reported a negative and significant effect between weed control and oil palm yield gap. Therefore, increased weed management would result in increased actual yields obtained by the farmer hence reduced yield gap.

Table 23: Fractional Logit Regression Output and Marginal Effect of Agronomic Practices

| Yield Gap Index | Coefficient | Standard Error | P>z | Marginal Effect |
|----------------------------|-------------|----------------|-------|-----------------|
| Weed Management | -0.0059 | 0.0029 | 0.04 | -0.0014** |
| Insect-pest Management | 0.0135 | 0.0026 | 0.000 | 0.0032** |
| Disease Management | -0.0145 | 0.0029 | 0.000 | -0.0034** |
| Intercropping | 0.0034 | 0.0019 | 0.082 | 0.0008 |
| Use of Organic Fertilisers | 0.0014 | 0.0020 | 0.496 | 0.0003 |
| Bush Management | -0.0015 | 0.0026 | 0.564 | -0.0004 |
| Coffee Tree Training | -0.0022 | 0.0027 | 0.421 | -0.0005 |
| Grafting | -0.0011 | 0.0020 | 0.601 | -0.0003 |

Key: ** denoted p-value significant at 5% significance level

The model findings revealed a negative but significant effect between disease management practices and the resulting coffee yield gap. This model's marginal effect imply that a unit increase in disease management practices decreased coffee yield gap by 0.0034 units (Table 23). During the study, it was noted that farmers were aware that the coffee variety that majority grew was susceptible to CBD and CLR and that

inappropriate control would result to fatal losses. Hence farmers invested in purchasing fungicides to control the diseases and also followed the recommendations in disease spraying schedule that showed the right time for application of the fungicides. The study also noted that farmers sprayed their coffee against diseases at least three times in a cropping year (Table 14). Moreover, through experience farmers have resulted to appropriate use of the fungicides achieving better management of diseases as compared to insect-pest management lowering yield losses and reducing coffee yield gap. Singh *et al.* (2023) reported similar findings that among other management practices, disease management negatively and significantly affected Indian mustard production which contributed to increased crop production and narrowed the yield gap. Therefore, disease management is important in enhancing production which would results in reduced yield gaps.

However, the insect-pest management practices positively influenced the coffee yield gap. The marginal effect showed that an increase in insect pest management practices increased coffee yield gap by 0.0032 units (Table 23). This showed that farmers sacrificed for insect-pest control however, the inappropriate and indiscriminate use of the pesticides in regards to the type, rate, method and time of application were experienced. This resulted to insect-pest resistance that probably made it harder to eliminate the pest which prompted for increased control measures. However, due to lack of information the farmers as reflected by the low pesticide quantities used (Table 15) and low frequency of insect-pest management (Table 14) resulted to low yields that increased the coffee yield gap. Moreover, it was also noted that coffee farmers had no insect-pest spray guides or well-defined spraying schedules and their frequency of scouting the coffee farm was low. The findings are counterintuitive however, they concur with those of Chepchirchir *et al.* (2021) who noted that the insect-pest control practices on tomato production was positive and contributed significantly to the attainable tomato yields. This was due to insect-pest resistance and high spread rate in open field tomato production.

4.8 Fractional Logit Model on the Effect of Cooperative Diversity on Coffee Yield Gap Among Smallholder Farmers in Nyeri County

The effect of the cooperative diversity on coffee yield gap was also determined using the fractional logit regression performed using six explanatory variables: value addition

of coffee, extension, production and market information, credit, training and input services, and one dependent variable: coffee yield gap index (between 0 and 1). The model's log pseudo likelihood was -102.228 where p value=0.0000<0.05 which showed significance at 5%. This study findings, showed that processing and marketing information, extension and training revealed a negative but significant effect on coffee yield gap while value addition of coffee, credit and input services were insignificant to the study.

Table 24: Fractional Logit Regression Output and Marginal Effect of Cooperative Diversity

| Yield Gap Index | Coefficient | Standard Error | P>z | Marginal Effect |
|-----------------------------------|-------------|----------------|-------|-----------------|
| Value Addition of Coffee | -0.0022 | 0.0019 | 0.261 | -0.0005 |
| Extension | -0.0048 | 0.0021 | 0.021 | -0.0011** |
| Production and Market Information | -0.0069 | 0.0031 | 0.027 | -0.0016** |
| Credit | 0.0024 | 0.0019 | 0.214 | 0.0006 |
| Training | -0.0049 | 0.0019 | 0.013 | -0.0012** |
| Input Services | 0.0047 | 0.0024 | 0.051 | 0.0011 |

Key: ** denoted p-value significant at 5% significance level

The model showed that influence of extension services on coffee yield gap was negative but significant. The marginal effect revealed that an additional visit by the extension officer would result in a decrease in the coffee yield gap by 0.0011 units (Table 24). The study findings revealed that farmers who were able to access more extension officer's visits were likely to reduce their yield gap probably due to the exchange of production information and knowledge on recommended agronomic practices. It was also likely that the extension officers addressed specific challenges faced by farmers and monitored the implementation of agronomic practices which resulted to improved management of the coffee enterprise significantly minimizing the yield gap. Ghimire *et al.* (2015) reported similar findings to this study that extension services negatively and significantly contributed to the rice yield gaps. Therefore, extension services play a role in disseminating information and recommended agronomic practices minimizing yield gaps.

This study observed a negative but significant effect between the production and marketing information on coffee yield gap. The model's marginal effect indicated a 0.0016 unit decrease in coffee yield gap as the farmers received more production and marketing information. (Table 24). This implies that providing production and marketing information to farmers was likely to encourage them resulting to increased productivity and reduced yield gap. This was probably due to the transparency in cooperative management operations, recommendation of strategies to boost the volumes and quality of farmers' yield to enhance cooperative performance, provision of inputs at subsidized price and reviewing of coffee prices contributing to farmers income. These findings are in agreement with those of Otieno *et al.* (2019) who noted that production was negatively and significantly influenced by the production, processing and marketing information that farmers acquired. Therefore, production and marketing information provides direction to farmers and cooperative societies which encourages improved production translating to increased coffee yields and reduced yield gap.

Further, a negative but significant effect between training and coffee yield gap was observed. The marginal effect revealed that the more trainings a farmer received would result in a decrease in coffee yield gap by 0.0012 units (Table 24). This implies that training equipped farmers with skills and abilities that contributed to improved coffee production and resulted to reduced yield gap. It was likely that trainings enhanced understanding among farmers through practical demonstration of different agronomic practices. Therefore, farmers who attended more trainings were likely to reduce their yield gap significantly. Similar findings were observed by Salam and Sakar (2023) who indicated a negative but significant effect between training and adoption of hybrid rice varieties there by significantly increasing productivity and technical efficiency of the smallholder farmers.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the Findings

This study aimed to assess the influence of socio-economic characteristics, agronomic practices and cooperative diversity on coffee yield gap among smallholder farmers in Nyeri Central sub-county, Nyeri County. This study applied a cross-sectional research design that aided in obtaining information from 156 smallholder coffee farmers. The respondents to the study were identified through a systematic random sampling procedure where a semi-structured questionnaire was administered. Descriptive statistics and the fractional logit regression model were used to describe the data using SPSS version 29 and STATA version 17.

During the estimation of the coffee yield gap among the smallholder farmers in Nyeri Central sub-county showed that the average actual farmers yield was 8,593.920 kg/ha, 3,545.277 kg/ha and 1,722.423 kg/ha for Ruiru 11, Batian and SL 28, respectively. The study findings also showed that yield gap which was the variation between the KARLO-CRI station yields and farmers' actual yields was 66,406.080 kgs, 53,454.722 kgs and 38,177.577 kgs for Ruiru 11, Batian and SL 28, respectively. Further, the study revealed that the yield gap index per farmer ranged between 84.99% to 96.90%. The yield gap index for Ruiru 11, Batian and SL 28 was 88.54%, 93.78% and 95.68%, respectively.

The study also sought to determine the effect of socio-economic characteristics on coffee yield gap among the smallholder farmers. Five socio-economic characteristics were considered in the fractional logit regression model and the model results showed the following: gender of the household head (p-value= 0.02<0.05), schooling years (p-value= 0.024<0.05), household size (p-value= 0.027<0.05) and labour (p-value= 0.035<0.05) were significant socio-economic characteristics on coffee yield gap. This study findings also implied that an increase in the male household heads decreased the coffee yield gap by 0.0019 units while an increase in schooling years decreased the coffee yield gap by 0.0004 units. Further, the study findings indicated that an increase in the household size by an individual decreased the coffee yield gap by 0.0004 units while an inclusion of one more person into the family labour decreased the coffee yield gap by 0.0003 units. Moreover, the omitted household income, land size and farming

experience socio-economic variables were found to be insignificant to the study. Therefore, household heads, schooling years, household size and labour are important socio-economic characteristics that contributed to reduced coffee yield gap.

This study also determined the effect of agronomic practices on coffee yield gap among the smallholder farmers. Eight dependent variables: weed management, insect-pest management, disease management, intercropping, use of organic fertiliser and bush management, grafting and coffee tree training and on independent variable: coffee yield gap index were included in the regression model. The model findings indicated that weed management, insect-pest management and disease management where $p < 0.05$ were significant on coffee yield gap. The results further showed that an increase in weed management practices decreased the yield gap by 0.0014 units. An increased in insect-pest management practices increased coffee yield gap by 0.0032 units while an increase in disease management practices decreased coffee yield gap by 0.0034 units. However, intercropping, use of organic fertiliser, bush management, grafting and coffee tree training variables were found to be insignificant in this study. Hence, weed management and disease management are key agronomic practices that contribute to decreased coffee yield gap.

The effect of cooperative diversity on coffee yield gap was determined and the findings revealed that extension, production and marketing information as well as training were significant on coffee yield gap. The findings of the model revealed that extension services processing and marketing information and training were significant at 5% significance level. The model outcomes also showed that increasing extension services by one visit decreased coffee yield gap by 0.0011 units. It also showed that an increase in processing and marketing information resulted to a decrease in the coffee yield gap by 0.0016 units while an increase in trainings decreased the coffee yield gap by 0.0012 units. However, value addition of coffee, credit and input services were insignificant cooperative diversity variables to the study. Therefore, extension services and trainings are essential cooperative diversity aspects that reduced coffee yield gap.

5.2 Conclusion

This study concluded that the actual farmers yields were far below their potential productivity which resulted to large yield gap for the improved and traditional varieties. The estimated large yield gap requires that feasible actions to be undertaken to narrow the gap to a sizeable level so that farmers can benefit from coffee production. The influence of socio-economic characteristics on the coffee yield gap was concluded that gender of the house hold head, schooling years, household size and labour had a negative but significant effect on the coffee yield gap. Also, it was noted that majority of farmers who participated in coffee production were the elderly who were considered frail and reluctant to implement the production information received contributing to increased yield gap.

Further, weed and disease management positively and significantly influenced the coffee yield gap. However, insect-pest management had significant but negative outcome on the coffee yield gap. It was also concluded that the frequency of operation for different agronomic practices should be increased and applied in the recommended way to considerably influence the coffee yields. Moreover, the extension support, access to production and marketing information as well as training were negative but significant cooperative diversity characteristics on coffee yield gap. However, each of the independent variables resulted to different levels of change on the dependent variable.

5.3 Recommendation

Based on the finding of this study, it is recommended that:

- i. Enhancement of awareness for continued uptake of improved coffee varieties such as Ruiru 11 and Batian because of their lower yield gap experienced compared to the traditional varieties. Therefore, adoption of the improved varieties would considerably reduce coffee yield gap.
- ii. The cooperatives societies and County stakeholders need to come up with strategies for increasing education level to farmers to facilitate better understanding of technologies and practices through trainings, demonstrations, field visits among others.

- iii. Empowerment of farmers in application of the recommended agronomic practices that would contribute to increased production.
- iv. Strengthening of extension services by the cooperatives societies and County stakeholders to help disseminate technologies and information to farmers as well as monitoring of farm activities.

5.4 Suggestions for Further Research

- i. Establish the effect of integrated cropping systems on coffee production and income among the smallholder farmers.
- ii. Determine the effect of uptake of improved varieties on coffee yield gap among smallholder farmers.

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APPENDICES

Appendix I: Survey Questionnaire for Smallholder Farmer

I kindly request that you answer the following questions as honestly as possible. I shall treat all the responses with the highest degree of confidentiality and the information will be used to meet the objectives of this study. Please read the guides indicated within the questions.

Ward

Village

Date of interview

Name of Cooperative Society

Factory

Coffee Variety

Part A: Demographic Data of Respondent

1. Kindly specify your gender /___/ (male = 1, female = 0).
2. Specify the Gender of the household head: /_____/ (male = 1, female = 0).
3. Kindly specify your age? _____ Years
4. Please specify your education level? /___/ (1= No formal education [0 schooling years], 2= Primary [1-8 schooling years], 3= Secondary [9-15 schooling years] and 4= Tertiary [above 15 schooling years]).
5. What is your household size? _____
6. Indicate the number of dependents? _____
7. What is your sector of employment? /___/ (1= Farming, 2= Business, 3= Farming and Business, 4= Employed)

Part B: Farm Characteristics

8. Indicate your coffee farming years _____ Years
9. How much is your land size? _____ acres.
10. Do you rent land? / ___/ (1= Yes, 0= No)
11. If yes in 10,
 - a) How much land do you rent? _____ Acres.
 - b) How much rent do you pay? _____ KES per year.
12. Do you rent out portions of your land? /_____/ (1= Yes, 0= No)

13. If yes in 12, How much land do you rent out? _____ Acres.
14. How much rent is paid? _____ KES per year.
15. How much land is under coffee? _____ Acres.
16. Kindly indicate your average annual income per acre of coffee in the last 3 years.
- _____
- _____

17. How would you rate your income from the coffee enterprise?

High [], Moderate [], Low []

18 a) Do you keep records of the activities you perform in the coffee farm? /_____/

(No= 0, yes= 1).

b) Where did you learn about record keeping? _____

c)What are the benefits of keeping records? _____

Part C: Agronomic Practices

19. How often do you carry out coffee agronomic practice? Kindly fill in the table for the practices you carry out and the frequency with which you carry out the practices.

| Agronomic practices | Choice of Practice | How often do you do the practice | | | |
|---|--------------------|----------------------------------|-----------|----------------|----------------|
| | | Very often (4) | Often (3) | Less often (2) | Not at all (1) |
| Weed management | | | | | |
| Pest management | | | | | |
| Disease management | | | | | |
| Intercropping | | | | | |
| Application of inorganic fertilisers | | | | | |
| Application of organic fertilisers | | | | | |
| Soil testing and analysis | | | | | |
| Bush management (Pruning & Desuckering) | | | | | |
| Coffee tree training system | | | | | |
| Grafting | | | | | |

| | | | | | |
|--------------------|--|--|--|--|--|
| Change of cycle | | | | | |
| Picking/Harvesting | | | | | |

Key: 1= no practice carried out, 2= once per cropping year, 3= twice per cropping year, 4= thrice per cropping year

20. a) How many casual workers do you employ throughout the year for the coffee activities? _____

b) For which activities are they employed?

Planting

Pruning

Weeding

Spraying

Fertilizing

Picking

Sorting and grading

Change of cycle

Other(specify) _____

c) How much is the casual worker paid per day? _____ KES.

21. Do you have permanent workers employed throughout the year for the coffee activities? / _____ / (1= Yes, 0= No)

22. If yes in 21,

How much is the permanent worker paid? _____ KES.

For what activities are they employed? _____

23. a) Kindly consider the following with regards to labour availability in the last cropping year.

| Activity | Number of Labourers | | | Number of days taken |
|---------------------------|---------------------|---------------|------------------|----------------------|
| | Family | Casual labour | Permanent labour | |
| Bush management | | | | |
| Fertiliser application | | | | |
| Weeding | | | | |
| Spraying against pest | | | | |
| Spraying against diseases | | | | |
| Ploughing | | | | |

| | | | | |
|----------------------|--|--|--|--|
| Coffee tree training | | | | |
| Harvesting | | | | |

24. How many kilograms of fertilisers, fungicide, pesticide and herbicide were used on coffee production in the last cropping season?

| Input | Quantity in kg used | Price per kg |
|-----------------------|---------------------|--------------|
| Inorganic fertilisers | | |
| Manure | | |
| Foliar fertilisers | | |
| Pesticides | | |
| Fungicides | | |
| Herbicides | | |

25. What type of integrated cropping system do you carry out? / _____/ (1= Monocropping, 2= Intercropping)

26. If (1in 25), What are the benefits/ challenges of monocropping?

| Benefits of Monocropping | Challenges of Monocropping |
|--------------------------|----------------------------|
| | |
| | |

27. If (2in 25), What are the benefits/ challenges of Intercropping?

| Benefits of Intercropping | Challenges of Intercropping |
|---------------------------|-----------------------------|
| | |
| | |

Part D: Coffee Yields

28. What is your coffee production per crop year?

| Crop year | Crop season | Number of mature coffee trees | Total quantity of cherry produced (Kgs) | Quantity of cherry produced per acre | Production per tree (kgs) |
|-----------|-------------|-------------------------------|---|--------------------------------------|---------------------------|
| 2022/2023 | May July | | | | |
| | Oct-Jan | | | | |
| 2021/2022 | May July | | | | |
| | Oct-Jan | | | | |
| 2019/2021 | May July | | | | |

| | | | | | |
|--|-------------|--|--|--|--|
| | Oct- Jan | | | | |
|--|-------------|--|--|--|--|

b) Which is the most productive season?

May- July season

October-January Season

29. Are you aware of the improved Coffee varieties? /___/ (1=Yes, 0= No).

30. If yes in 29, a) Which year did you learn about Ruiru 11 and Batian varieties _____ Year.

b) From what source? _____

31. Have you taken up any of the improved coffee varieties? /___/ (1=Yes, 0= No).

32. If yes in 31, please fill the table below.

| Variety | Number of Trees |
|----------|-----------------|
| Batian | |
| Ruiru 11 | |

33. What is your improved coffee production per crop year?

| Crop year | Number of mature coffee trees | Total quantity of cherry produced (Kgs) | Quantity of cherry produced per acre | Production per tree (kgs) |
|------------|-------------------------------|---|--------------------------------------|---------------------------|
| 2022/ 2023 | | | | |
| 2021/2022 | | | | |
| 2019/2021 | | | | |

34. What is the production per season?

| Crop year | May-July Season | October- January Season |
|------------|-----------------|-------------------------|
| 2022/ 2023 | | |
| 2021/2022 | | |
| 2019/2021 | | |

35. Are the Improved coffee varieties helpful in controlling pests and diseases in your farm? /___/ yes = 1, no = 0

36. Have you been able to increase your production using the improved coffee varieties? /___/ (1=Yes, 0= No).

37. Have the improved coffee variety production affected your income? /___/(1= yes, 0=no)

38. Explain your response in question (37). _____

39. What was the output price for the year 2022? _____

40. What is the total income generated from coffee in 2022? _____

Part E: Cooperative Diversity

41. What type of services are offered by the cooperative?

- Inputs provision
- Credit facilities
- Training
- Extension services
- Nursey establishment
- Field Days
- Other(specify)_____

42. a) Have you receive any extension visits from the cooperative in the last cropping year? /_____ / [1= yes, 0= no]

b) If no (42 a), what was the sources of your farming information?

- Researcher
- NGOs
- Agricultural extension services
- Agricultural training centres
- Agricultural shows
- Lead farmers
- Internet
- Farmer to farmer
- Agro-chemical companies
- Online groups (Facebook& WhatsApp)
- Religious group
- other(specify)_____

c) If yes (42 a), a) Indicate the number of extension visits in the last cropping year?

- Once
- Twice
- Thrice
- More than four times

b) Specify the terms of engagement with the extension services?

Free

Paid

Other terms (specify) _____

c) Did you receive the information at the right time through the extension services? / _____ / (1= yes, 0= no).

d) Did you apply this information? / _ / (1= yes, 0= no).

e) If yes in (d), was the information beneficial in your production? (Specify in what way) _____

43. a) Do you take credits to increase you farming/ coffee activities? / ____ / (1= Yes, 0= No)

b) If no (43 a), why did you not take the credits/ loans?

(specify) _____

c) If yes (43 a) Did you acquire the loan/ credit from the cooperative during the last 12 months? / _____ / (1= yes, 0= no).

44. If yes (43c), what was the major use of the received credit? (Tick where appropriate)

Farm inputs

School fees

Food

Land

Expand business

Farm implements/ equipment

Other (specify) _____

45. What amount of loan was received? _____

46. Does the cooperative offer trainings to farmers on coffee farming? / ____ / (1= Yes, 0= No).

47. If yes (46)

a) How often are the trainings organized in one cropping year?

Once

Twice

Thrice

Four times and above

b) In which field(s)? (Tick the appropriate answer)

- Pest management
- Production
- Marketing
- Cycle change
- Grafting
- Fertilizer application
- Picking and harvesting
- Record keeping

Others (specify) _____

c) Are the trainings beneficial? (Specify in what way) _____

47. If no (46), Have you received any other training in agricultural production? / ___ /
 (1= yes, 0= no)

48. If yes (47), Who organized the training?

49. a) Do you apply the techniques you have learnt from the agricultural training in your farm? / ___ / (No = 0, yes = 1)

b) Was the training beneficial? / ___ / (No = 0, yes = 1)

c) If yes (49 b), In what way? _____

50. Does the cooperative provide inputs (Fertiliser and agrochemicals) for coffee production? / _____ / (1=yes,0= no)

51. If yes in 50 a) Are the inputs readily available?

Fertiliser/ _____ / (1= yes, 0= no), agro-chemicals/ _____ / (1= yes, 0= no)

b) Are the inputs in enough quantities? / _____ / (1= yes, 0= no)

c) Are the inputs available at the right time/ stage of production? / _____ /

(1= yes, 0= no)

Your participation is appreciated.

Appendix II: Pictorial Representation of Data Collection



A)



B)



C)



D)

A-Coffee bush inspection

B-Inspection of harvested cherry

C-Harvesting coffee cherries

D-Demonstration of coffee pruning.

Appendix III: Introductory Letter

Florence Wairimu Ndung'u,
P.O Box, 4869,
Thika.

Dear sir/ madam,

I am Florence Wairimu Ndung'u, a student in Chuka University pursuing MSc. Agricultural Economics. One of the requirements for my studies is a research project entitled "**Analysis of Socio-economic Characteristics, Agronomic Practices and Cooperative Diversity on Coffee Yield Gap Among Smallholder Farmers in Nyeri Central sub-county, Nyeri County**". Kindly spare a few minutes and give your honest response to the attached questions. Your information shall not only be used for this study and will be handled with integrity Thank you.



Yours faithfully,
Florence Wairimu Ndung'u.

Appendix IV: Chuka University Institutional Ethics Review Committee Letter



CHUKA UNIVERSITY INSTITUTIONAL ETHICS REVIEW COMMITTEE

Telephones: 020-2310512/18

P. O. Box 109-60400, Chuka

Direct Line: 0772894438

Email: info@chuka.ac.ke,

Website: www.chuka.ac.ke

21st March, 2023

REF: CUIERC/ NACOSTI/348

TO: Florence Wairimu Ndung'u

RE: Analysis of Socio-Economic Characteristics, Agronomic Practices and Cooperative Diversity on Coffee Yield Gap Among Smallholder Farmers in Nyeri County

This is to inform you that *Chuka University IERC* has reviewed and approved your above research proposal. Your application approval number is *NACOSTI/NBC/AC-0812*. The approval period is 21st March, 2023 – 21st March, 2024.

This approval is subject to compliance with the following requirements;

- i. Only approved documents including (informed consents, study instruments, MTA) will be used
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by *Chuka University IERC*.
- iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to *Chuka University IERC* within 72 hours of notification
- iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to *Chuka University IERC* within 72 hours
- v. Clearance for export of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days upon completion of the study to *Chuka University IERC*.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) <https://oris.nacosti.go.ke> and also obtain other clearances needed.

Yours sincerely


Dr. Benjadrin Kanga
SECRETARY

**Appendix V: National Commission for Science Technology and Innovation
Research Licence**

| | |
|--|--|
|  REPUBLIC OF KENYA |  NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION |
| Ref No: 741547 | Date of Issue: 13/April/2023 |
| RESEARCH LICENSE | |
|  | |
| <p>This is to Certify that Miss. Florence Wairimu Ndungu of Chuka University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nyeri on the topic: ANALYSIS OF SOCIO-ECONOMIC CHARACTERISTICS, AGRONOMIC PRACTICES AND COOPERATIVE DIVERSITY ON COFFEE YIELD GAP AMONG SMALLHOLDER FARMERS IN NYERI COUNTY for the period ending : 13/April/2024.</p> | |
| License No: NACOSTI/P/23/25033 | |
| 741547 |  Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION |
| Applicant Identification Number | |
| Verification QR Code | |
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