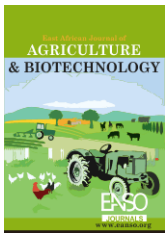

East African Journal of Agriculture and Biotechnology
eajab.eanso.org
Volume 7, Issue 1, 2024
p-ISSN: 2707-4293 | e-ISSN: 2707-4307
Title DOI: https://doi.org/10.37284/2707-4307

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Assessment of Effects of Adopted Sustainable Soil Fertility Management Practices on Arabica Coffee Yields among Smallholder Farmers in Ibanda Municipality

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Article DOI : https://doi.org/10.37284/eajab.7.1.2019

Date Published:

03 July 2024

Keywords:

Sustainable Soil Fertility Management, Agroforestry, Mulching, Composting, Coffee Yields, Coffee Quality.

ABSTRACT

This study aimed at assessing the effects of adopted sustainable soil fertility management practices on Arabica Coffee yields and quality among smallholder farmers in Ibanda Municipality. The guiding objectives of the study were to find out the effect of sustainable soil fertility management practices in Arabica Coffee farming, Arabica coffee yields and quality and the relationship between the sustainable soil fertility management practices and Arabica Coffee yields and quality. Data was collected using a farmer questionnaire and interview guide for extension staff and coffee dealers. It was analysed descriptively using frequency counts and percentages while relationships between sustainable soil fertility management practices and Arabica Coffee yields were analysed using Pearson correlation. The findings show that mulching and composting were the most adopted soil fertility management practices among the Arabica coffee farmers in Kagongo division. The study also found that there was a significant relationship between Arabica coffee yields and farmers' adoption of mulching and composting. The study concluded that the adoption of mulching and compositing improved coffee quality and yields. Therefore, the study recommended up-scaling extension services and giving farmers credit so that they adopt sustainable soil fertility management practices for better Arabica coffee yields and quality.

APA CITATION

Begumisa, S. N., Ssemakula, E. & Tumusiime, B. (2024). Assessment of Effects of Adopted Sustainable Soil Fertility Management Practices on Arabica Coffee Yields among Smallholder Farmers in Ibanda Municipality. *East African Journal of Agriculture and Biotechnology*, *7*(1), 299-311. https://doi.org/10.37284/eajab.7.1.2019

CHICAGO CITATION

Begumisa, Silver Nkwasibwe, Edward Ssemakula and Bernard Tumusiime. 2024. "Assessment of Effects of Adopted Sustainable Soil Fertility Management Practices on Arabica Coffee Yields among Smallholder Farmers in Ibanda Municipality.". *East African Journal of Agriculture and Biotechnology* 7 (1), 299-311. https://doi.org/10.37284/eajab.7.1.2019

HARVARD CITATION

Begumisa, S. N., Ssemakula, E. & Tumusiime, B. (2024) "Assessment of Effects of Adopted Sustainable Soil Fertility Management Practices on Arabica Coffee Yields among Smallholder Farmers in Ibanda Municipality.", *East African Journal of Agriculture and Biotechnology*, 7(1), pp. 299-311. doi: 10.37284/eajab.7.1.2019.

IEEE CITATION

S. N. Begumisa, E., Ssemakula & B. Tumusiime "Assessment of Effects of Adopted Sustainable Soil Fertility Management Practices on Arabica Coffee Yields among Smallholder Farmers in Ibanda Municipality", *EAJAB*, vol. 7, no. 1, pp. 299-311, Jul. 2024.

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

MLA CITATION

Begumisa, Silver Nkwasibwe, Edward Ssemakula & Bernard Tumusiime. "Assessment of Effects of Adopted Sustainable Soil Fertility Management Practices on Arabica Coffee Yields among Smallholder Farmers in Ibanda Municipality". *East African Journal of Agriculture and Biotechnology*, Vol. 7, no. 1, Jul. 2024, pp. 299-311, doi:10.37284/eajab.6.1.2019.

INTRODUCTION

Arabica Coffee is a major source of livelihood for smallholder coffee farmers worldwide. Furthermore, it is a major foreign exchange-earner for the coffee-growing countries in Asia, Latin America and Africa. However, declining yields and cup quality have become a cause for concern among stakeholders along the Arabica Coffee value chain. In most smallholder settings, coffee farmers are failing to recover the inputs in their coffee enterprises.

BACKGROUND TO THE STUDY

According to the International Coffee Organization (ICO, 2023), various countries have experienced a decline in Arabica Coffee volumes because of nutrient loss and inadequate soil fertility management. Globally, Arabica coffee production has fallen from 99.5 million bags in 2018/19 to 94.0 million bags in 2022/2023. Corresponding production figures for Africa are 18.5 to 17.9 million bags, Caribbean, Central America and Mexico (21.3 to 19.2 million bags), South America (61.8 to 81.3) while Asia and Oceania are the only regions that registered an increase from 48.1 to 49.8 million bags. These differences in Arabica coffee volumes have been attributed to inadequate soil fertility management and climate change.

Coffee yields and quality is significantly related to soil fertility and moisture. According to Yadessa. *et al.,* (2019), coffee yields, cup quality and sensory attributes vary with coffee variety, growing environment and agronomic practices. However, the soil quality has been a major factor in the quality and yield of Arabica coffee. Nutrient loss after harvest without replenishment has been found to reduce the soil quality in Arabica Coffee farming systems. Furthermore, lack of shade for coffee trees has been found to affect not only the coffee yields but also the cup quality of Arabica Coffee. This calls for sustainable soil fertility management in order to improve bean size and cup quality parameters (Byrareddy, *et al.,* 2019).

Various soil fertility management practices have been adopted by Arabica coffee farmers in order to improve coffee yields and quality. In large-scale enterprises in Brazil, the use of inorganic fertilizers has improved soil fertility, bean size and quality for Arabica Coffee. However, chemical fertilizer use has been found unsustainable for smallholder farmers. Teixeiraet, et *al.,* (2020) found that the integration of poultry manure, rice straw and coffee husks improved Arabica coffee productivity by 13% in Brazil. Also, the study by Ashabur, *et al.,* (2021) in Indonesia revealed that smallholders use agro-forestry to replenish soil fertility through decomposing leaves. Integration of these practices with some chemical fertilizers has made these countries world leaders in coffee production.

In Sub-Saharan Africa, farmers use a variety of soil fertility management practices in an integrated manner. The commonly used soil fertility management practices include using animal manure, mulching, minimum tillage, and multi-layered agro-forestry. In Arabica Coffee farming, some farmers have started composting coffee husks to address nutrient mining resulting from harvesting without replenishing lost nutrients (Gemechuet et al., 2021). However, the association between organic inputs on Arabica coffee yields is yet to be established.

In Uganda, declining soil fertility is a major constraint in Arabica coffee farming. While fertiliser use is being promoted to address the effect of adopted sustainable soil fertility management practices, cost and sustainability issues have hindered farmer uptake of chemical fertiliser use in Arabica coffee farming. Farmers have been using mulches and animal manure to address soil fertility but the non-availability of mulch and manure transport to fields remains an issue. Others have taken up the use of green

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

manure, crop residues and organic foliar fertilisers to improve Arabica coffee yields. However, not much is known about the variability of coffee yields with the application of organic fertilizer inputs.

While coffee remains a main source of livelihood for small-scale farmers, yields remain sub-optimum. Average yields for Arabica coffee are 600kgs per acre compared to the national target of 1800 per acre (Ibanda Municipality Production Department, 2023; UCDA, 2023). This has negatively affected the earnings of the smallholder farmers who use the income from coffee to pay school fees for their children, pay medical bills and acquire assets like land and livestock. Various measures have been put in place to improve Arabica coffee yields in Kagongo Division. Farmers have been advised to cut old coffee trees so that they can regenerate and produce better yields (UCDA, 2023). The government has also provided fertilizers to the farmers to improve soil fertility but this has proved unsustainable because the farmers do not have funds to buy more fertilizers to improve soil fertility (Ibanda District, 2023).

Scholars like Wulandari et al. (2022) have suggested that the adoption of mulching, agro-forestry and composting would be a sustainable strategy to improve Arabica coffee yields among smallholder farmers in Kagongo Division. However, knowledge about farmers' adoption of mulching, agro-forestry and composting in Arabica coffee farming in Kagongo Division is scanty. Therefore, the current study will assess the effect of farmers' adoption of the three practices on Arabica coffee yields and quality as a stepping stone to improving coffee yields and quality for improving the standard of living of the smallholder farmers in Kagongo Division.

MATERIALS AND METHODS

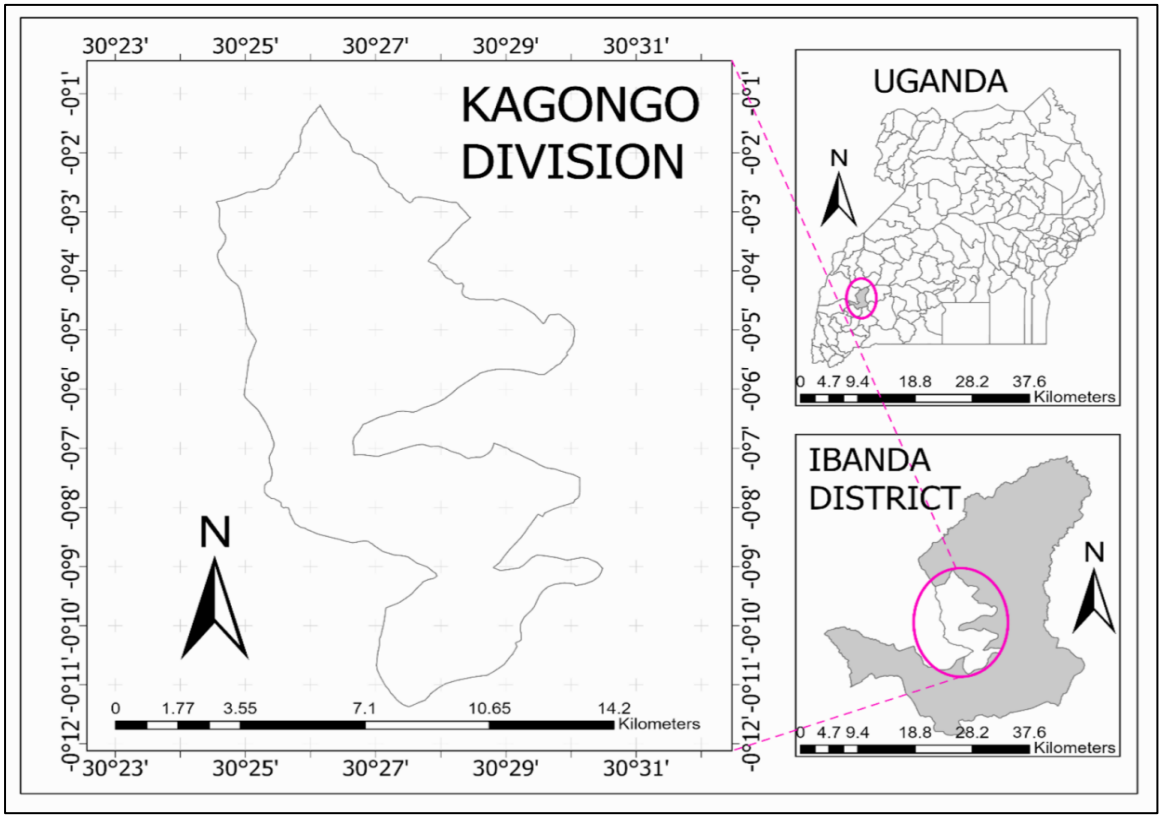
Area of Study

This study was conducted in the Kagongo division of Ibanda municipality in Ibanda district. The district lies at an altitude of 1296.43 meters above sea level. It is bordered by Kitagwenda District to the west, Kiruhura District to the east, Mbarara and Buhweju District to the south and Kamwenge District to the north. The average annual rainfall of the area ranges from 1400 mm to 1800 mm and has an annual daily average temperature ranging between 11 °C and 25 °C.

The population of the study area is 249,625 people (UBOS, 2016), with 57947 households, of which 33,532 (57.8%) earn their livelihoods from farming. The study area experiences bimodal rainfall from mid-November to mid-May, with the annual rainfall ranging between 100 - 1300 mm. The maximum temperature is 24 ^{o}C to 27 ^{o}C and the minimum is 13 ^{o}C to 16 ^{o}C. The study area is among the major food crops and cash crops producing districts in the country. Arabica coffee is the major cash crop in the area. Other crops include – potatoes, sorghum, beans, sweet potatoes, onions, and maize.

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

Figure 1: Map showing the location of Kagongo Division, Ibanda Municipality



Data Collection

A descriptive cross-sectional research design using both quantitative and qualitative approaches for data collection was adopted for the study. The study population comprised of smallholder Arabica coffee farmers in Ibanda Municipality, the extension officer and Arabica coffee dealers. Purposive sampling was used to select Kagongo Division because it is the major Arabica coffee-producing division In Ibanda Municipality. Simple random sampling was used to select the wards where to conduct the study while area sampling was used to select the cells from which to draw a purposive sample of the Arabica coffee farming households.

Questionnaire administration was used to collect data from the Arabica coffee farmers while interviews were conducted with the extension officer and coffee dealers. In addition to these data collection methods, the researcher used own observation to see the sustainable soil fertility management practices and the appearance of the coffee trees. The validity of the study instruments was established through content validity analysis while reliability was tested through piloting the tools and Cronbach Alpha analysis.

Data Analysis

Both descriptive and inferential analysis were used to analyse data for the study. Descriptive analysis using frequency counts and percentages was conducted to identify the different SSFM practices adopted by Arabica coffee farmers and Arabica coffee yields. Inferential statistical analysis involved using Pearson correlation to establish the relationship between adopted soil fertility management practices and Arabica Coffee yields and quality.

RESULTS

Demographic Characteristics of the Respondents

The socio-demographic characteristics of the smallholder Arabica coffee farmers are likely to affect farmers' adoption of integrated soil fertility management practices. Therefore, the farmers' demographics were first analysed as shown in *Table 1*

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

Table 1: Arabica farmer demographics characteristics

	Category	Frequency	Percentage
Age	25 and below	29	10.1
	26 - 50	95	32.9
	51 +	164	56.9
Gender	Male	240	83.3
	Female	48	16.7
Education	No formal education	18	6.2
	Primary	137	47.6
	Secondary	98	34
	Tertiary	35	12.2
Marital Status	Single	17	5.9
	Married	267	92.7
	Widowed	4	1.4
Household size	1 - 3 members	53	18.4
	4 - 6 members	165	57.3
	7+	70	24.3

The results revealed that the majority of the Arabica Coffee farmers were aged 51 years and above (56.9%) followed by those who were aged 26-50(32.9%) and those aged 25 years and below (10.1%). The findings also show that the majority of the respondents were male (83.3%), with primary education (47.6%), married (92.7%) and with 4-to 6 family members (57.3%).

The farm size, farming experience, access to extension services and credit are important issues to consider when examining farmers' adoption of sustainable soil fertility management. Farm size determines the effort the farmers will use in mulching, agroforestry and composting in order to sustain soil fertility. Farming experience determines the farmers' capacity to apply sustainable soil fertility management practices while access to credit and extension services empowers the farmer with knowledge and funds to manage soil fertility. Therefore, the farm size, farming experience, access to credit and extension services were analysed as shown below:

Table 2: Farm characteristics of Arabica Coffee farming in Kagongo Division

	Category	Frequency	Percentage
Farm size	less than 1 acre	58	20.1
	1 - 2 acres	176	61.1
	3 – 4 acres	32	11.1
	5 +	22	7.7
Farming experience	4 years and below	34	11.8
	5 - 8 years	68	23.6
	9 - 11 years	74	25.7
	12+ years	112	38.9
Access to extension	YES	80	27.8
	NO	208	72.2
Access to credit	YES	88	30.6
	NO	200	69.4

The results revealed that the majority of the Arabica Coffee farmers had 1-2 acres of land, followed by those with less than an acre of land (20.1%), those with 3-4 acres of land and those with 5 acres or more. The results also show that the majority of the farmers had 12 years or more experience in farming (38.9%) followed by 9-11 years (25.7%), 5-8 years experience (23.6%) and those with 4 years experience or less (11.8%). Furthermore, the study shows that the majority of the farmers did not have access to extension services (72.2%) and agricultural credit (69.4%).

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

Adopted Sustainable Soil Fertility Management Practices

Adoption of mulching is an important practice that does not only conserve water in the soil but adds nutrients to the soil which nutrients can improve coffee yields and quality. Farmers' responses on the adoption of mulching are summarized in *Table 3.*

Table 3: Arabica coffee farmers' adoption of mulching

Variable	M	SD	Implication
Farmer mulches coffee only when mulch is available	4.69	.566	Very High
Farmer uses semi-dried grass to mulch my coffee	4.55	.862	Very High
Farmer uses bean husks to mulch my coffee	3.65	.889	High
Farmer uses mulch on their coffee farms every season	2.56	684	Moderate
Farmer uses dry grass to mulch my coffee	2.73	.986	Moderate
Scale: Very High=4.21-5.00; High=3.41-4.20; Moderate=2.61-3.40; Low=1.81-2.60; Very Low=1-1.80			

Table 3 shows that there was very high use of mulching only when mulch is available (M = 4.69, SD = .566), very high use of semi-dry grass (M = 4.55, SD = .862), high use of bean husks for mulching (M = 3.65, SD = .889), moderate mulching every season (M = 2.56, SD = .684) and moderate usage of dry grass (M = 2.73, SD = .986).

These results indicate that the majority of the Arabica Coffee farmers had poor mulching practices because they mulch only when mulch is available, indicating that they do not take time to look for mulch when it is not locally available. Furthermore, the farmers use semi-dried mulch yet it produces heat which affects soil temperatures, in addition to using bean husks which do not favour microbial activity in the soils. However, there was moderate adoption of good practices like mulching every season and using dry grass. Therefore, poor mulching practices are likely to predict poor Arabica coffee yields and quality.

Arabica Coffee Farmers' Adoption of Agroforestry in Kagongo Division

Agroforestry has been introduced in Arabica coffee farming because it reduces moisture loss, acts as windbreakers and decomposed leaves produce humus that helps in improving soil fertility. Therefore, farmers' adoption of agroforestry in Arabica coffee farming was observed and the findings are summarized below:

Table 4: Arabica coffee farmers' agroforestry practices in Kagongo Division

Variable	M	SD	Implication
Farmers have planted trees whose leaves take long to decompose like jackfruit	4.76	.326	Very high
Farmers planted trees that are alternate hosts to Arabica Coffee pests	4.12	584	High
Farmer uses recommended trees like Gravellia, *Ficus natalensis, Ficus mucuso*	3.25	.612	Moderate
Farmer uses recommended spacing in agroforestry	2.52	.689	Low
Scale: Very High=4.21-5.00; High=3.41-4.20; Moderate=2.61-3.40; Low=1.81-2.60; Very Low=1-1.80			

Table 4 shows that there was very high use of trees with leaves which take long to decompose (M = 4.76, SD = .326), high use of trees that are alternate host to Arabica Coffee pests (M = 4.12, SD = .584), moderate use of recommended trees (M = 3.25, SD = .612) and low use of recommended spacing for agroforestry (M = 2.52, SD = .689). This is still an indication that the Arabica coffee farmers' use of best practices for agroforestry was low because they used trees whose leaves take long to decompose such as Avocado, Guavas, and those that are alternate host to Arabica coffee pests such as Jatropha yet this can compromise yields and quality. However, some farmers were using recommended trees such as Calliandra at a spacing of at least 10 feet from

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

other trees and Moringa at a spacing of 20 feet. This indicated that the poor agroforestry practices could be compromising the yields and quality of Arabica coffee yields.

Arabica Coffee Farmers Adoption of Composting in Kagongo Division

Composting is an important agricultural practice that coffee farmers can use to sustainably improve soil fertility in their farms. Through composting, Arabica coffee farmers can improve soil fertility, yields and quality using locally available biomass instead of buying organic fertilizers. Therefore, the composting practices of the Arabica coffee farmers were analysed as shown below:

Table 5: Arabica Coffee farmers' adoption of composting

Variable	M	SD	Implication
Farmer recycles crop residue to improve soil fertility on my coffee farm	4.56	.326	Very High
Farmer uses compost manure to improve soil fertility on my coffee farm	3.56	1.684	High
Farmer uses farmyard manure to improve soil fertility	3.36	.886	Moderate
Farmer uses green manure to improve soil fertility on my coffee farm	3.23	.689	Moderate
Farmer uses liquid manure to improve soil fertility on my coffee farm	1.89	.987	Low

Scale: Very High=4.21-5.00; High=3.41-4.20; Moderate=2.61-3.40; Low=1.81-2.60; Very Low=1-1.80

Table 5 shows that farmer's adoption level of compositing was moderate. There was a very high adoption of crop residue recycling (*M* = 4.56, *SD* = .326) and a high adoption of compositing (*M* = 3.56, *SD* = 1.684). The adoption rate was moderate in use of farmyard manure (*M* = 3.36, *SD* = .886) and green manuring (*M* = 3.23, *SD* = .689). However, there was low adoption of liquid manure (*M* = 1.89; *SD* = .987).

These findings were supported by the agricultural extension officer who said that there was moderate adoption of sustainable soil fertility management practices. He said,

> *'There is generally low adoption of soil fertility management in Kagongo Division. This is because they have got used to the soils being fertile. However, the soils have got exhausted, and they need more soil nutrients"*

The Status of Arabica Coffee Yields in Kagongo Division

The Arabica coffee yield among the smallholder coffee farmers in Kagongo Division was also analysed. This is because these yields determine what the farmers will get out of coffee farming for livelihood improvement. The findings on the farmers' yields are summarized below:

Table 6: Table showing Arabica Coffee Yields among the farmers studied

	N	Minimum	Maximum	Mean	Std. Deviation
Green beans in bags	288	10	80	45.6	1.831
Kiboko (kgs)	288	240	2450	1320	1.564
FAQ in Kgs	288	50	520	220.5	1.492
Valid N (listwise)	288				

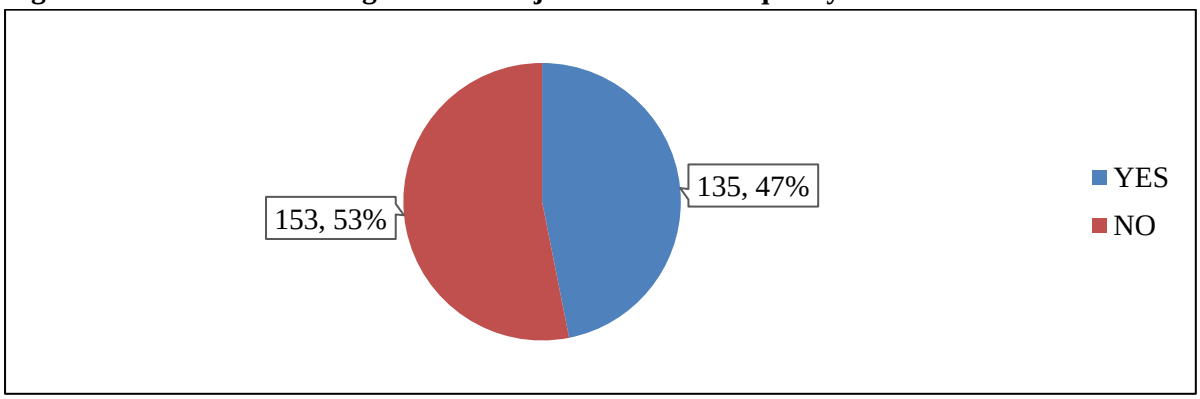
Table 6 shows that the minimum green bean yield for the farmers was 10 bags while the maximum was 80 bags (*M* = .456, *SD* = 1.831). The minimum yield in terms of Kiboko in kilograms was 240kgs while the maximum was 2450 kilos (*M* = 1320, *SD* = 1.564). The minimum yield in FAQ kilograms was 50kgs while the maximum was 520 kilos (*M* = 220.5 *SD* = 1.492).

These findings were supported by the observations of the researcher. Most of the coffee plants where there was mulching and composting had bigger stem girths, had dark green leaves and the appearance of the trees was better than where there was no mulching or manuring.

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

Farmers were also asked to state whether they had ever had their coffee rejected because of quality. The findings are illustrated in Figure 2

Figure 2: Farmer ever having his coffee rejected because of quality



According to *Figure 2*, 47% of the farmers had ever had their coffee rejected because of quality while 53% had never. This indicated that the majority of the farmers had good-quality coffee.

The reasons for the rejection of farmers' coffee were analysed and the findings are summarized in *Table 7*.

Table 7: Farmers' reason for rejection of Arabica Coffee

Reason	Frequency(N=288)	Percentage
Discoloured beans	150	52.1
Inadequately dried coffee	110	38.2
Coffee mixed with animal dung	50	17.4

Table 7 shows that 52.1% of the Arabica Coffee farmers said that their coffee had once been rejected for discoloured beans, 38.2% cited inadequately dried coffee while 17.4% had coffee mixed with cow dung. Therefore, the main reason for the rejection of coffee was discoloured beans.

The findings were corroborated by the coffee dealers who said that coffee quality issues were mainly discoloured beans and improperly dried beans. He said,

> *"Coffee farmers do not have good post-harvest handling practices. Some of the farmers first keep the green beans so that they turn black before being dried. At the same time, they dry the coffee halfway in order to get better yield".*

Sustainable Soil Fertility Management and Arabica Coffee yields

The main focus of the study was to establish the relationship between sustainable soil fertility management and Arabica Coffee yields in Kagongo Division.

Table 8: Perception of the effect of sustainable soil management on coffee yields

Variable	M	SD	Implication
I can now get better yields because of mulching	4.52	.356	High
I can now get better yields because of planting shade trees	3.24	.897	Moderate
I can now get better yields because of compositing	4.35	.658	High

Table 8 shows that there was a high perceived impact of mulching (M = 4.52, SD = .356) and compositing (M = 4.35, SD = .658) on Arabica Coffee yields in Kagongo Division. However, the effect of agroforestry on Arabica Coffee yields was moderate (M = 3.24, SD = .897). This

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

indicated that according to the farmers, mulching and compositing were the most effective sustainable soil fertility management practices that improved Arabica Coffee yields in Kagongo Division.

The relationship between mulching and coffee yields was first analysed and the findings are summarized in the table below:

Table 9: Relationship between mulching and Arabica Coffee yields

		Mulching	Coffee yields
Mulching	Pearson Correlation	1	0.593**
	Sig. (2-tailed)		0.023
	N	288	212
Coffee yields	Pearson Correlation	0.593**	1
	Sig. (2-tailed)	0.023	
	N	288	288

***. Correlation is significant at the 0.01 level (2-tailed).*

A Pearson correlation was conducted to establish if a significant relationship existed between mulching and Arabica Coffee yields among smallholder farmers in Kagongo Division. A significant relationship was found between mulching and Arabica Coffee yield among smallholder farmers in Kagongo Division.

The relationship between mulching and coffee yields was first analysed and the findings are summarized in the table below:

Table 10: Relationship between agroforestry and Arabica Coffee yields

		Agroforestry	Coffee yields
Agro-forestry	Pearson Correlation	1	0.894
	Sig. (2-tailed)		0.078
	N	288	212
Coffee yields	Pearson Correlation	0.894	1
	Sig. (2-tailed)	0.078	
	N	288	288

A Pearson correlation was conducted to establish if a significant relationship existed between agroforestry and Arabica Coffee yields among smallholder farmers in Kagongo Division. A significant relationship was found between agroforestry and Arabica Coffee yield among smallholder farmers in Kagongo Division.

The relationship between composting and coffee yields was first analysed and the findings are summarized in the table below:

Table 11: Relationship between compositing and Arabica Coffee yields

		Compositing	Coffee yields
Compositing	Pearson Correlation	1	0.693**
	Sig. (2-tailed)		0.049
	N	288	288
Coffee yields	Pearson Correlation	0.693**	1
	Sig. (2-tailed)	0.049	
	N	288	288

***. Correlation is significant at the 0.01 level (2-tailed).*

A Pearson correlation was conducted to establish if a significant relationship existed between compositing and Arabica Coffee yields among smallholder farmers in Kagongo Division. A significant relationship was found between

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

composting and Arabica Coffee yield among smallholder farmers in Kagongo Division.

The findings supported the coffee dealers who said that coffee from farms that had mulching and composting yielded better beans and quality:

> *I normally ask about the farmers' practices before I advance them money. This is because coffee from mulched plantations where the farmers put manure in the shambas produce better quality coffee with good outturn.*

The farmers were also asked to show how the adoption of the different soil management practices affected their coffee yields and productivity. The findings are summarized in *Table 11*.

DISCUSSION OF FINDINGS

Adopted Sustainable Soil Fertility Management Practices

One of the main objectives of the study was to establish the adopted sustainable soil fertility management practices among the Arabica coffee farmers in Kagongo Division. The study found that there was high adoption of crop residue recycling and composting. Recycling of crop residues and composting is a sustainable way of soil fertility management because the crop residues and the materials for composting are readily available and might not involve a high cost. The findings are in line with Kwadzo and Quayson (2021) who found high adoption of residue recycling and composting in Ghana because of the relative availability of materials and low costs involved.

The study found moderate adoption of farmyard manure and green manure. Farmyard manure is sustainable only when the household can generate it from the animals available. Bearing in mind that the farmers have small pieces of land, they might find it hard to integrate manure into their coffee farms because of the lack of animals. Furthermore, the low use of green manure could be because of a lack of guidance bearing in mind that farmers' access to extension services was low. The findings agreed with those of Mairura, et al., (2022), who found that the lack of domestic animals hindered farmers' use of farmyard manure in coffee farming in the Upper Eastern Region of Kenya.

There was low adoption of legumes and liquid manure in Arabica Coffee farming in Kagongo Division. This also could be because of the lack of extension services and lack of acess to agricultural credit. When the farmers do not have information on the use of green manure, they will not use it. At the same time, lack of funds might limit the farmers' ability to buy liquid manure to apply in their coffee shambas. The findings concurred with Kwabena, et al., (2019) who found that lack of cheap agricultural credit was one of the constraining factors in improving soil fertility among smallholder farmers in Malawi.

That notwithstanding, Arabica coffee farmers in Kagongo Division have tried sustainable soil fertility management for some time. The study found that the sustainable soil fertility management practice in which the farmers had more experience was composting which the majority of the farmers had practised for five seasons followed by agroforestry and mulching. A possible explanation for this could be because of the lack of biomass for mulching because of the small land sizes. Similarly, farmers' knowledge about agro-forestry could be very low because of poor extension services. The findings agreed with Hasibuan, (2022) who found that the lack of biomass was responsible for low adoption of mulching among the farmers in Kuala Lumpur.

Arabica Coffee Yields among Smallholder Farmers in Kagongo Division

The study found that there were wide variations in Arabica Coffee yields between farmers. The minimum green bean yield was 10- 80 bags, 240 – 2450 kgs for Kiboko while FAQ yields ranged from 50 -520 kilos. This indicated that while the yields were comparable to those obtained elsewhere, there were wide variations among the Arabica coffee farmers. These findings indicated that yield varied by the practices of the Arabica Coffee farmers.

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

The study also found that the rejection rate for the Arabica coffee at the factories was 47%. This indicated that nearly half of the farmers' coffee had been rejected as of poor quality. This level of rejection shows that the farmers' practices could have been proven and resulted in rejected coffee at the factory. The rejection levels did not tally with those of Akenroye et al (2021) who found that the level of rejection of Arabica coffee in Ethiopia was less than 2%. Therefore, there was a problem with Arabica coffee quality in Kagongo Division.

The study found that the major reasons for the rejection of the coffee were discoloured beans and high moisture content. This indicated that the post-harvest handling practices of the farmers were responsible for poor-quality coffee that was rejected by the traders. While soil management practices could affect quality, the reasons for the rejection of the farmers' coffee appear to have been less concerned with soil fertility. This implied that soil fertility management practices did not appreciably affect the quality of the Arabica coffee in Kagongo Division. This was in disagreement with previous scholars like Jabbar et al (2022) who found a close association between coffee quality and soil fertility management practices.

Sustainable Soil Fertility Management and Arabica Coffee Yields

The study found significant relationships between sustainable soil fertility management practices and Arabica coffee yields. A Pearson correlation revealed that a significant relationship existed between mulching and Arabica Coffee yields among smallholder farmers in Kagongo Division. This indicated that farmers' adoption of mulching improved Arabica coffee yields among those who practised mulching. However, its efficacy depends on the availability of biomass for mulching. The findings agreed with those of Netsere and Takala (2021) who found that mulching was one of the sustainable soil fertility management practices that improved coffee yields in Ethiopia.

The study also found a statistically significant relationship between composting and Arabica Coffee yield among smallholder farmers in Kagongo Division. This indicated that farmers who practised composting had better coffee yields than those who did not. This is an implication that composting is a sustainable soil fertility management technique among Arabica Coffee farmers in Kagongo Division. However, this requires effective extension which was found lacking in Kagongo Division. The findings agreed with Gemechuet et al., (2021) who found that composting was an effective strategy to address nutrient mining resulting from harvesting without replenishing lost nutrients.

However, the study did not find any significant relationship between agroforestry and Arabica Coffee yields among smallholder farmers in Kagongo Division. This implied that farmers who had adopted agroforestry had not gained more yields because of the adoption of the practice. This could possibly be because of neglect of other soil fertility management thinking that agroforestry was enough. Alternatively, it could be because of the use of trees that might not be shading leaves that added humus to the soil. According to Yadessa et al, (2019), the mere adoption of agroforestry without supplementary soil management practices might not produce good coffee yields.

Analysis of the Arabica farmers' perception on the impact of sustainable soil fertility management practices was high for mulching and composting. This implied that the farmers who practised mulching and composting were satisfied with the yields they got. The findings concurred with Nzeyimana et al, (2020), who found that composting and mulching were sustainable methods of improving soil fertility and coffee yields in Rwanda.

However, the farmers had low opinion on the effect of agroforestry on Arabica Coffee yields in Kagongo Division. This could possibly be due to the lack of information about the trees to use and how to space the trees so that the coffee trees could get enough light. However, Mwaura, et al,

Article DOI : https://doi.org/10.37284/eajab.7.1.2019

(2021) found that proper agro-forestry practices retained soil moisture in the coffee plantations and hence improved bean quality and yields.

CONCLUSIONS

Objective one established that the main sustainable soil fertility management practices were crop residue recycling and composting. This could possibly be because the crop residues are readily available after harvest, and it does not cost a lot to recycle them into the fields. Furthermore, composting using the available materials does not cost a lot of money and it provides quick sources of organic manure to apply to the fields of coffee. The study concluded that upscaling these forms of soil fertility management practices could be sustainable for improving Arabica coffee yields.

Objective two established that the Arabica coffee yields in Kagongo Division were comparable to the rest of the Arabica coffee yields. However, the yields varied across different farmers. Therefore, varying levels of adoption of sustainable soil fertility management practices resulted in yield variations among the farmers.

Objective three established a significant relationship between Arabica coffee yields, mulching, and composting. However, the relationship with agroforestry was not significant. The study concluded that mulching and composting were the more sustainable soil fertility management practices for the Arabica coffee farmers in Kagongo division.

Recommendations

Based on the study findings, the researcher recommends that extension services be upscaled so that farmers are trained on the implementation of sustainable soil fertility management practices in Arabica coffee farming. This is because the farmers appear to be experimenting on their own without expert guidance. The study also recommends that farmers should be provided with affordable agricultural credit. This is because soil fertility management requires funds for buying manure, employing labour and procurement of agro-forestry trees. When the farmers have access to credit, they can easily apply practices that are beyond their means. The study also recommends strengthening of farmers' groups in the area. In these groups, the farmers can visit each other so that they benchmark the best practices they observe among other farmers.

Areas for Further Study

The study recommends further research on the reasons why farmers might not adopt certain soil fertility management practices by identifying factors affecting adoption, extension staff can devise ways of improving adoption rates.

The study further recommends further study on the impact of different agroforestry trees on soil fertility in Arabica coffee farming. The findings can provide innovative ways of using agroforestry to improve soil fertility and coffee yields.

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