Original Research Article

Soil quality indicators under conventional and organic coffee farming systems in Rwanda

ABSTRACT

Aims: The aim of this study was to assess the soil quality under conventional and organic coffee farming Systems

Study design: Two farming systems were selected: Conventional and Organic systems under coffee plantations.

Place and Duration of Study: This study was carried out between May 2021 and March 2022. The soil samples were collected from Karaba coffee growers' cooperative (KOAKAKA) within Karambi coffee washing station zone in Kigoma Sector of Huye District, Southern Province of Rwanda. The soil samples were analyzed in Research and postgraduate laboratory of soil and plant at University of Rwanda Biotechnology Laboratory Complex.

Methodology: The soil samples were collected across three selected plots from each coffee production system under study. Both disturbed and non-disturbed soil samples were collected from each plot at (0–30 cm) depth to assess selected soil quality indicators.

Results: This study found a significant difference in total organic carbon, organic matter and earthworms abundance between two studied systems. The findings also revealed higher aggregate stability, electrical conductivity, moisture content, soil pH water in the organic coffee farming system than conventional coffee farming system with 0.665, 0.051 (dS/m), 23.84 (%), 5.47 respectively.

Conclusion: Organic farming system provided higher soil qualities, it could improve soil conditions and reduce the demand for inorganic fertilizers hence improve people's livelihood.

Keywords: Conventional farming, KOAKAKA; Organic farming, Soil quality

1. INTRODUCTION

Future food security is challenged by matching food supply to the rapidly growing demand of increasing population and ensuring that is done in an environmentally and socially friendly way [1]. The developing countries mostly rely on agriculture for rural livelihoods and development. Nevertheless, agricultural systems are adversely affected by land pressure and climate change, both of which threaten food production [2].

Soil is a fine non renewable resource [3] that provides ecosystem services such as provisioning, regulating, cultural and supporting services [4], [5]. It is reported that soil contributes in the achievement of several of UN-SDGs [6]. In sub-Sahara Africa (SSA), the high population density has led to decline in soil fertility [7]. Eighty three percent (83 %) of rural people in SSA depend on their land for livelihood while forty percent (40 %) of Africa's soils are currently degraded which hamper soils functions and affect food production [3].

In Rwanda, due to the highest population density of 525/km2 [8], there is land shortage hence lands are intensively cultivated [9]. The soils have then become highly degraded with increased erosion, soil nutrient mining, and high soil acidity (Republic of Rwanda, 2020) [10]. Furthermore, the third National Communication report on climate change has revealed that agriculture produces most emissions of greenhouse gases in Rwanda with the sector accounting for 70.4 per cent of the total national emissions [11]). On the other hand the government of Rwanda targets to reduce GHG emission by 16 percent considering Business As Usual scenario for the period 2020-2050 [10].

To meet food security and concurrently reducing soil degradation and GHG emission, there is a need for adopting farming practices which sustain production and environment. The conventional farming has been promoted as option of replacing soil nutrients exported with harvested crop product or lost by degradation. However, smallholder farmers lack the financial resources to purchase sufficient chemical fertilizers [12] [13]. Beside this, conventional farming practices were claimed to promote low fertility and negative nutrient balance, resulting in higher erosion, leaching, and inherent soil infertility [14]. On the other hand, organic agriculture has been claimed to result in better biological, chemical and physical soil property changes [15] .

Despite the potential of organic farming in enhancing soil properties, its adoption in Rwanda is still low. Little has been studied on the effect of organic farming and conventional farming practices on soil quality in Rwanda. Better understanding on how farming practices affect soil quality could increases their adoption. Therefore the aim of this study was to assess the effect of conventional and organic coffee farming systems on soil quality.

2. MATERIAL AND METHODS

2.1 Study design

The design of this study was based on laboratory experiment for physicochemical and biological soil quality indicators analysis. Soil analysis methods manuals and interpretations norms were used as research instruments.

2.2. Study area

This study was carried out at KOAKAKA cooperative within Karambi coffee washing station zone in Kigoma sector, Huye district, and Southern province of Rwanda (Figure 1).

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The cooperative has its own coffee plantations and produces both conventional and organic coffee [16]. The site is characterized by sub equatorial temperate climate with average temperature of 20°C and the average annual rainfall of 1160 mm [17].

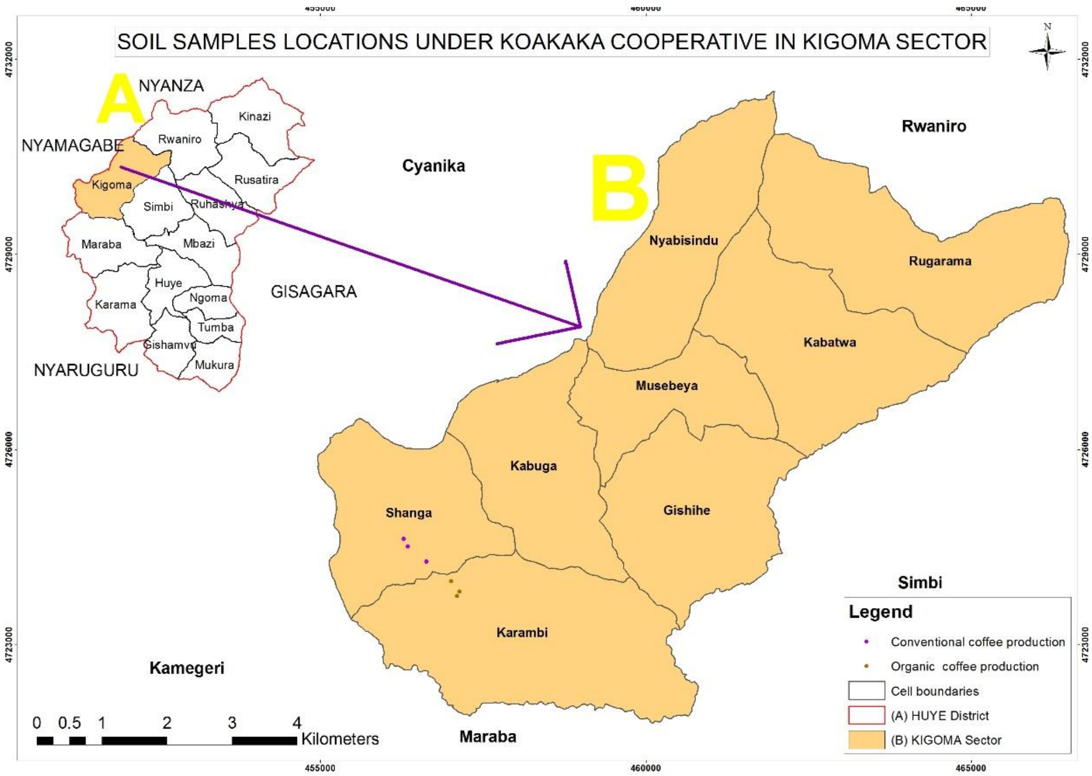

Figure 1: Study area map

2.3. Methodology

Sampling was conducted in May, 2021 from organic and conventional farming system. The coffee plantation under conventional system is managed since the creation of the cooperative in 2002. The management practices of coffee under this system include spraying of pesticides to control pests & diseases and application of chemical fertilizers. Organic farming system were initiated in 2016 and its management includes mixing coffee with agroforestry trees (Markhamia lutea; Grevillea Robusta and Persea Americana among the others); supplying organic manure; using mechanical methods and plant extract to control pest and diseases.

The soil samples were collected across three selected plots from each coffee production system under study. Both disturbed and non-disturbed soil samples were collected from each plot at (0–30 cm). The samples were labeled and transported to the Research and postgraduate laboratory of soil and plant at University of Rwanda Biotechnology Laboratory Complex for analysis. The methodology used for every parameter is summarized in (Table 1). The t-test was performed using the GenStat software 15th edition at 95 % statistical significance level to evaluate whether there was a significant difference among means of soil quality indicators of two coffee production systems under study.

Table 1. The summarized methods for every analyzed parameter

Parameter	Methods
Soil moisture Content	Gravimetric method [18].
Soil Bulk density	Core method [19]
Soil aggregate stability	Wet sieving technique using Yodders apparatus [20], [21].
Soil electrical conductivity	Using the conductivity meter [19] .
Soil pH	Glass Electrode pH Meter [19].
Soil total nitrogen	Colorimetric method with sulfuric acid digestion [19].
Available phosphorous	Bray and Kutz 1method [19].
Exchangeable potassium	Extraction with 1M NH4OAc [22].
Exchangeable acidity	1M KCl extraction solution [19].
Total organic carbon	Walkley and Black wet oxidation method [19].
Organic matter	Multiplying organic carbon with Van Bemmelen factor [23].
Earthworms' abundance	Hand Counting [24].

3. RESULTS AND DISCUSSION

3.1. Effect of coffee production system on soil biological quality indicators

There was a significant difference in total organic carbon, organic matter and earthworms' abundance between two assessed systems (Table 2). The high organic carbon found in organic farming could be linked to the decomposition of agroforestry tree biomass and other organic debris. The similar findings were previously reported by [25], [26] who reported the higher total organic carbon in farms under organic management practices.

The higher organic matter content was also found in organic managed farms compared to conventional managed farms. This could be due to the regular organic manure supply, mulching and litter fallen from associated agroforestry tree species. Previous researchers ([27] also reported the higher organic matter content under organic managed farms

The present study findings have shown the higher earthworm's number under organically managed farms compared to conventional farms. This could be due to the higher organic matter content and soil moisture reported under organically managed farms in the study area which are known to facilitate the microbial activity. It have been reported that once the ground has more organic fertilizers, agroforestry species and mulching really generate soil organic carbon and influencing biological activity [28]. Previous researchers have reported the same case [27].

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Table 2. Results of biological quality indicators under conventional and organic coffee production systems

Parameter	Conventional farming system	Organic farming System	p-value
Organic carbon (%)	1.41	2.9	0.001
Organic matter (%)	2.43	5	0.001
Earthworms' abundance (per square meter)	109.3	149.7	0.03

3.2. EFFECT OF COFFEE PRODUCTION SYSTEM ON SOIL PHYSICOCHEMICAL QUALITY INDICATORS

There was a significant difference in soil moisture content; organic coffee production system exhibited the higher moisture content compared to the conventional system (Table 3). This suggest that the application of organic matter; mulching and fallen litter from agroforestry trees shaded the soil hence reduced amount of water that evaporates from soil. Similar results were reported by[27], which observed increase in soil moisture content in organic cropping system.

The conventional coffee production system scored higher bulk density than the organic system (Table 3). However, the obtained bulk density were not above the critical value of 1.63 g/cm3 at which root penetration and seed emergency are hindered [29]. The high bulk density obtained in conventional farming could be due to exposure of the soil to agents of erosion that removed the less dense fine particles leaving behind coarse particles made up of heavier sand minerals. The findings of this study collaborate the findings of [29], [30] Organic matter is recognized to rise the soil organic matter and thus reduces its bulk density. The similar findings were reported by [31] [29].

The aggregate stability under organically managed farms was higher than the conventional managed ones (Table 3). This could be due to minimal disturbance and higher soil organic carbon. It agrees [32] who found less disturbed soils to be of better aggregation than highly disturbed soils the findings are not far from what reported [33]. The organic production system scored higher concentration of ions compared to the conventionally managed farms. The findings of this research have shown that the organically managed farms scored higher pH values than the conventionally managed farms. This could be due to application of organic matter that added basic cations hence favoured the increase in soil pH. The similar results were reported by [34] ,who observed increase in soil pH due to incorporation of organic compost.

The organically managed farms scored higher total nitrogen than conventionally managed farms. This high rate could be due to nitrogen-fixing trees intercropped in the farm and decomposition of pruned materials from agroforestry trees biomass. The findings confirms the reports of [35] who reported higher nitrogen content for soil under organic farming system.

The higher concentration of available phosphorus was noticed in organically managed farms compared to conventionally managed farms. Previous researchers have reported that the higher organic matter content contribute in soil microbial activity and thus availability of phosphorus [36].Therefore, the higher organic matter content and earthworms population

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abundance recorded in organically managed plots could have contributed to the phosphorus level under farms.

Table 3. The results of physicochemical quality indicators under conventional and organic coffee production systems

Parameter	Conventional farming system	Organic farming System	p-value
Moisture content (%)	20.62	23.84	0.01
Bulk density (g/cm3)	1.235	1.164	0.09
Aggregate stability	0.601	0.665	0.04
Electrical conductivity (dS/m)	0.039	0.051	0.001
pH water	5.18	5.47	0.04
Total Nitrogen (%)	0.136	0.139	0.96
Available phosphorous (ppm)	7.267	14.267	0.08
Exchangeable potassium cmol (+)/kg	0.0055	0.0063	0.08
Total Exchangeable acidity cmol (+)/kg)	0.689	0.503	0.27

4. CONCLUSION

In light of the research findings for the assessment of soil quality indicators under organically and conventionally managed coffee, the assessment show a clear trend in higher soil qualities for the organic farms' physicochemical and biological characteristics. The statistically significant higher levels of aggregate stability, electrical conductivity, moisture content, organic carbon, organic matter and earthworms' abundance show a greater soil quality level in organic coffee farms in relation to their conventional counterparts. Generally, more was learnt from both coffee production systems. Therefore, proper crop production practices and sustainable land use and management systems are key strategies to maintain soil ecosystem for today and future generations.

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