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Soil quality Change Following Compost and Farmyard Manure Application in Maize and Cassava based Agro-ecosystems of Mvomero and Masasi -Tanzania

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Abstract

Soil quality is a major driver for improved crop production and sustainable food security. While crop response to soil applied organic amendments is widely studied, little has been done to establish the effect of such amendments on soil quality. Field experiments were conducted for two seasons (2019/20 and 2020/21) in Mvomero and Masasi districts to study the effects of compost (CP) and Farmyard manure (FYM) application on selected soil quality attributes. Both CP and FYM were applied on maize, and cassava plots at 0.0 t ha^{-1} (Control), 2.5 t ha^{-1}, 5 t ha^{-1} and 7.5 t ha^{-1}. Maize variety TMV-1 and Kiroba cassava variety were used as test crops in a Randomized Complete Block Design (RCBD) with three replications. Representative soil samples were collected before applying soil amendments and at the end of each season and analyzed for soil pH, Organic carbon (OC) and Extractable phosphorus (P). Assays of activities of ß-glucosidase and Phosphatase were performed on the samples as indicators of soil quality change. Results indicated that soil OC and soil extractable P increased with CP and FYM application rates at both sites. Activities of ß-glucosidase and Phosphatase increased in line with OC and extractable P, respectively. Application of CP or FYM at 5 t ha^{-1} and 7.5 t ha^{-1} resulted into statistically similar effects on soil OC, extractable P and activities of ß-glucosidase and Phosphatase. It was concluded that application of either CP or FYM at 5 t ha^{-1} can improve soil OC and P availability in degraded soils of Masasi and Mvomero, while activities of ß-glucosidase and phosphatase can serve to indicate such changes in soil quality.

Keywords: Organic amendments; Soil health indicators; ß-glucosidase; Phosphatase; Maize and cassava systems.

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1. Introduction

Increasing human population results into increased demand for food and fiber while total arable land for food and fiber production is decreasing due to land degradation caused by unsustainable land use and allocation of agricultural land into nonagricultural uses. This calls for sustainable farming approaches that can maintain soil healthy status for sustainable agricultural production.

Recycling of organic matter (OM) and nutrients in the soil depends on the availability of mineralisable OM and soil microbial populations responsible for the decomposition and mineralization process (Bunemann *et al*., 2018). Soil microbes act on soil OM through secretion of extracellular enzymes that save as a useful tool for monitoring soil biochemical quality change [1]. Soil enzymes are biological catalysts that alter the rate of biological decomposition and nutrient recycling through increasing the reaction rate at which organic materials decompose to release plant available nutrients [2, 3]. They mediate organic matter decomposition and number of other biochemical processes and reactions in the soil system thereby maintaining soil ecology, physical and chemical properties, hence enhancing soil fertility and health status [4]. Due to quick response to soil amendments, easy of measurements, and their linkage to principal microbial reactions in nutrient cycles, soil enzyme activities save as a sensitive indicator of soil quality change [2].

Soil quality is the measure of the ability of the soil to perform necessary functions such as nutrient cycling, nutrient supply and storage, temperature regulation, and provision of habitat for soil inhabitants [5, 6]. A change in soil quality is determined mainly by most soil sensitive attributes that can be used as indicators for the change [7]. Biological indicators often show quicker results on changes in soil quality than changes in inherent soil properties such as texture and mineralogy [7, 8]. Activities of soil enzymes have gained attention as biochemical indicators for soil quality.Though there are varieties of enzymes in soils, those which are involved in hydrolases and the degradation of main litter components are the most often used for soil quality evaluation [2].

Soil ß-glucosidase and Phosphatases are involved in nutrient recycling through their functions in the carbon and phosphorus cycles, respectively [9, 10]. Beta- Glucosidase belongs to Glycosidases, a group of enzymes that catalyze the hydrolysis of glycosides through breaking down of the glycosidic bonds [2]. Among the Glycosidases, β-glucosidase is the most common and widely used soil quality indicator due to its role in releasing low molecular weight sugars that are vital carbon source for soil microorganisms [11]. Beta- glucosidase thus govern the C-cycle through its role of converting complex sugars into simpler ones through catalysing the cleavage of individual glucosyl residues from various glycol-conjugates including α- or β-linked polymers of glucose, an important C source for the growth and activity of soil microorganisms [12, 13]. On the other hand, phosphatases is a general name for a broad group of enzymes that catalyse the hydrolysis of both esters and anhydrides of H_3PO_4 [14]. The commission on enzymes of the International Union of Biochemistry classified phosphatases into five major groups including that of Phosphomonoesterases [14]. According to Tabatabai [14], phosphomonoesterases are further classified into acid phosphatases (showing optimum activities in acid soils) and alkaline phosphatases which show optimum activities in alkaline soil conditions. Both acid and alkaline phosphatases play important role in soil organic P mineralization hence plant P nutrition [15]. Soil microorganisms including bacteria, fungi, actinomycetes and plant roots produce Phosphatase enzymes playing a key role of cleaving phosphate group from its substrates and transforming plant unavailable organic P into inorganic P that is available for plant uptake [16].

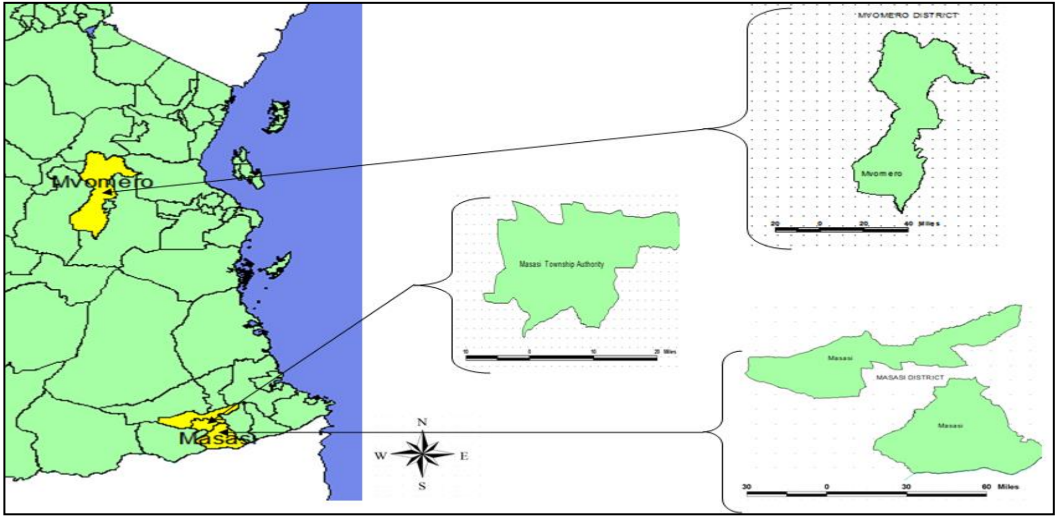
Both farmyard manure (FYM) and compost (CP) are important sources of carbon for soil organisms. Organic forms of nutrients including organic P are transformed into inorganic forms through mineralization processes in the soil hence improving soil organic matter content, microbial activities and nutrient availability for plant uptake. Thus, incorporation of FYM and CP into the soil may change soil organic carbon (organic matter) content, availability of nutrients and the soil pH. Such changes in soil biochemical attributes influences the activities of ß- glucosidase and Phosphatase [4, 17, 18] which can be monitored as indicators for change in soil quality. The quantity and quality (C and N content) of soil incorporated organic material determines the extent of soil microbial activities hence the quality of the soil system [4, 19]. Various research works [20, 21] indicated that, agro-ecological farming approach can help to improve soil health/quality and hence increase crop yields. However, limited studies have been conducted in the low altitude areas of Tanzania especially under cassava and maize systems to monitor the effect of applied FYM and CP on soil quality using soil enzyme activities as biochemical indicators for soil quality change. This study was therefore conducted to determine the effects of different rates of FYM and CP on soil pH, Soil OC and available P in relationship to activity of ß-Glucosidase and Phosphatases as indicators of soil quality changes.

2. Materials and Methods

2.1. Study Sites Description and Duration

This study was conducted in Mvomero and Masasi Districts in Tanzania from December 2019 to September 2021. The first site is located in Vianzi village at 20 km North of Morogoro town. The field lay from latitude 06˚44' 562″ to 06˚44' 582″ S and longitude 037˚22' 951″ to 037˚33' 930″ E at 547 meters above the sea level (m.a.s.l.) in the semi-arid Eastern zone. Long-term average Temperatures ranges between 24°C and 27.5 °C with the lowest temperature recorded in June and highest in December [22]. The area receives a uni-modal and erratic annual precipitation long term averaged at 873 mm(long term average) [23]. However, it fluctuates between 538 mm in dry years and 1550 mm in wet years. The second site was at Mumbaka village located 10 km South of Masasi town laying from latitude 10˚47' 25.1″ to 10 ˚47' 25.9″ S and longitude 038˚53′ 35.4″ to 038˚53′ 36.8″ E and altitude of 293 m.a.s.l. The average annual temperature is 25.0 °C in Masasi while the average annual rainfall is 975 mm [22]. The selection of these districts and sites were based on the representative of low lands of Tanzania where cassava and maize are important crops for food security but the areas faces serious problems of low soil fertility.

Figure-1. Section map of Tanzania showing location of research sites



2.2. Planting Materials

Cassava variety Kiroba and maize variety TMV1 were used as test crops both of which are registered varieties in Tanzania. Kiroba is a high yielding variety but moderately susceptible to Cassava Mosaic Disease (CMD) and Cassava Brown Streak Diseases (CBSD). The two crops are among the priority food crops in the studied sites but with serious limitations of soil fertility.

2.3. Land Preparation and Soil Sampling

At the beginning of 2019/20 cropping season, the field at each experimental site was prepared by clearing and tilling the land using a tractor, followed by leveling the soil using a hand hoe. Experimental plots measuring 4 m × 4 m were established for planting maize or cassava. Individual maize plots were separated by 1m aisles while the blocks were separated by 1.5 m aisles. Cassava plots were separated by1m aisles while the blocks were separated by 2 m aisles. After establishment of the fields, soil samples were collected separately from each experimental plot at 0 -15 cm depth using soil auger before application of treatments to establish baseline soil characteristics. At the beginning of 2020/21 cropping season, experimental plots were cultivated using hand hoe to avoid mixing of treatments and cassava or maize was planted on the same plots as in the previous season. Subsequent soil samples were randomly taken from a net plot (1.5 m × 3 m and 2 m× 2 m for maize and cassava respectively) established in each experimental plot at the end of each cropping season for two consecutive seasons. Composite soil samples from each net plot were shipped to the laboratory at Sokoine University of Agriculture for determination of soil pH, organic carbon, available P and activities of ß-glucosidase and Phosphatase as indicators of soil quality change following the application of different rates of CP and FYM.

2.4. Experimental Design, Treatments and Crop Management

The experiment involved a Randomized Complete Block Design (RCBD) with three replications. The treatments (CP and FYM) were separately applied in maize and cassava plots by broadcasting on entire experimental plots and incorporated at three different rates of 2.5, 5.0 and 7.5 t ha^{-1} including a control (0 t ha^{-1}) before planting. Cassava variety (‘Kiroba) and maize variety (TMV 1) all registered in Tanzania were used as test crops planted at the spacing of 1 m × 1 m and 0.75 m × 0.3 m, respectively. Both cassava and maize crops were not top dressed but all other agronomic practices were performed to keep the crop plants free from weed and insect pest infestation to harvesting time when soil sampling was done for assay of soil enzyme activities.

2.5. Weather Data Collection

Weather data (rainfall and temperature) were collected from the onsite installed weather stations.

2.6. Laboratory Analysis

2.6.1. Determination of Soil pH, Organic Carbon and Available Phosphorous

Soil pH, OC and available P are among the key soil quality attributes influenced by applications of soil organic amendments. The three soil attributes are also known to affect the rates of enzyme mediated soil reactions hence activities of soil enzymes [14]. Before assay of soil enzyme activities, soil samples from each experimental plot were analyzed for pH, organic carbon and available phosphorous for data quality control and inference on their relationship with observed activities of soil enzymes and soil quality change. Soil pH was determined in a 1:2.5 (w/v) soil: water suspension using a pH meter [24] and the Walkley and Black-wet oxidation method as outlined by Nelson and Sommers [25] was used for determination of soil organic carbon. Bray-1 method [26] was used to extract available P from acid soils with pH_{water} less or equal to seven and Olsen method Olsen and Sommers [27] was used to extract P from alkaline soils with pH_{water} above seven. Irrespective of the extraction method used, extractable P in soil extracts was quantified following the phosphomolybdic-ascorbic acid colorimetric method using a UV-VS spectrophotometer [28].

2.6.2. Assay of Activities of Phosphatase and β-glucosidase

Activities of acid phosphatase (ACP), alkaline phosphatase (ALP) and Beta-glucosidase were determined using the methods described by Tabatabai and Bremner [28] with some modifications. In the current modification, toluene was not used because the incubation period was < 2 hours. According to Bandick and Dick [11] and Shange, *et al.* [29], there is no significant sporulation of microbes when incubation of soil samples take less than two hours. Depending on the pre-determined soil pH, assay of acid or alkaline phosphatase was performed on air dry soil samples. A 1 g of air-dry soil passed through < 2 mm sieve was incubated in 50 mL Erlenmeyer glass flasks with 4 mL of modified universal buffer (MUB) of pH 6.5 and pH 11.0 for assay of activities of acid and alkaline phosphatase, respectively. In both cases, 1 mL of 0.05 M p-nitrophynyl phosphate solution was added as a substrate and the contents were incubated for 1 hour at 37 ºC. After the lapse of 1hour, 1 mL of 0.5 M $CaCl_2$ and 4 mL of 0.5 M NaOH were added to prevent further enzyme activity and enhance yellow color development. The mixture was then quantitatively transferred to and filtered through a Whatman® pre-pleated qualitative filter paper, Grade 2V with diameter of 240 mm. The intensity of yellow color of the filtrate so obtained was then measured by UV-VS spectroscopy (Spectronic Helios Alpha, Fisher Scientific) at 420 nm wavelength. Soil and substrate free controls were included for each soil analyzed to take care of the color not derived from p- nitrophenol released by enzyme activity. Absorbance units obtained were translated into *p*-nitrophenol content of the filtrates using a standard/calibration curve plotted from the results obtained with standards containing known concentrations (0, 10, 20, 30 40 and 50 µg of *p*-nitrophenol. Activity of Beta glucosidase was determined in a similar manner at pH 6.0, using 0.05 M *p*-nitrophenyl β-D- glucopyranoside (PNG) solution as a substrate. To stop the enzyme activity after 1 hour of incubation, one mL of 0.5 M $CaCl_2$ and 4 ml of THAM buffer pH 12 were used instead of NaOH used for assay Phosphatase because the substrate β- glucosidase (PNG) is hydrolysed with time in the presence of excess NaOH [14].

3. Results

3.1. Monthly and Annual Rainfall at Masasi and Mvomero Sites in 2019/20 and 2020/21 Cropping Seasons

At Masasi site rainfall ranged from 6.9 to 471.71mm and 13.4 to 296.83mm for 2019/20 and 2020/21 seasons, respectively with the highest rainfall being recorded in 2019/20 (Fig. 2). At Mvomero site, rainfall ranged from 12.64 to 855.04 mm and 8.45 to 521.99 mm for 2019/20 and 2020/21 seasons respectively. In both sites, higher annual rainfall was recorded during the 2019/20 than the 2020/21 cropping season. Generally, comparing the two sites, the highest annual rainfall was recorded in Mvomero site across the two seasons (Table 1).

Figure-2. Monthly rainfall during the 2019/20 and 2020/21 cropping seasons at Masasi and Mvomero experimental sites

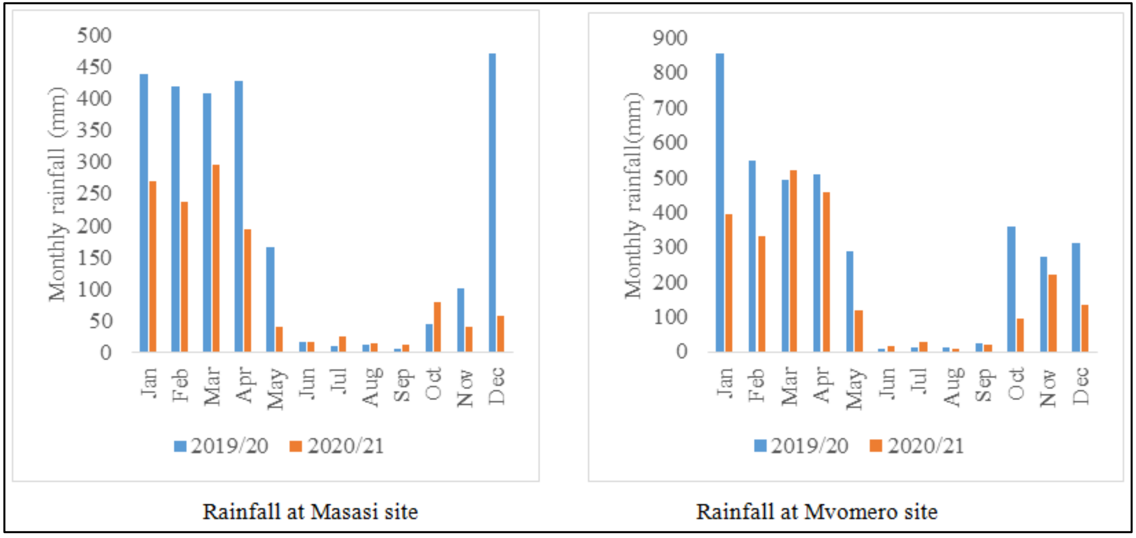


Table-1. Annual rainfall recorded at Masasi and Mvomero sites during the 2019/20 and 2020/21 growing seasons

Experimental site	Total Annual rainfall (mm)	
	2019/20	2020/21
Masasi	2527.1	1291.8
Mvomero	3703.8	2362.4

3.2. Monthly Maximum, Minimum and Average Temperature at Mvomero and Masasi in 2019/20 and 2020/21 Cropping Seasons

The monthly temperature recorded at the two sites were as indicated in Table 2. At Mvomero site, the highest average temperature (28.77 ºC) in 2019/20 was recorded in January while the lowest average temperature (23.81 ºC) was recorded in June. At Masasi site, the highest average temperature (30.02 ºC) was recorded in December in 2019/20 season while the lowest average temperature (26.01 ºC) were recorded between July and in August in 2019/20 and 2020/21 seasons.

Table-2. Monthly temperature (ºC) recorded at Mvomero and Masasi sites in 2019/20 and 2020/21 seasons

			Mvomero							Masasi		
Month		**2019/20**			**2020/21**			**2019/20**			**2020/21**	
	Max	**Av**	**Min**	**Max**	**Av**	**Min**	**Max**	**Av**	**Min**	**Max**	**Av**	**Min**
Jan	33.73	28.77	22.82	32.74	27.78	21.83	32.02	29.01	27.01	30.02	29.01	27.01
Feb	34.73	28.77	21.83	30.76	26.79	21.83	31.02	29.01	27.01	30.02	29.01	27.01
Mar	35.72	28.77	21.83	29.77	25.8	21.83	32.02	29.01	27.01	31.02	28.01	25.01
Apr	31.75	26.79	20.84	29.77	25.8	21.83	31.02	29.01	27.01	31.02	28.01	25.01
May	28.77	24.8	19.84	29.77	25.8	21.83	30.02	27.01	25.01	30.02	27.01	24.01
June	28.77	23.81	17.86	28.77	23.81	17.86	30.02	27.01	23.01	30.02	26.01	24.01
July	29.77	24.8	16.87	28.77	23.81	18.85	29.01	26.01	23.01	29.01	26.01	23.01
Aug	31.75	25.8	18.85	30.76	25.8	18.85	29.01	26.01	23.01	29.01	26.01	22.01
Sept	33.73	27.78	19.84	31.75	26.79	19.84	30.02	27.01	24.01	31.02	27.01	24.01
Oct	32.74	27.78	20.84	33.73	27.78	20.84	30.02	28.01	25.01	31.02	28.01	25.01
Nov	32.74	27.78	21.83	30.76	26.79	20.84	31.02	29.01	26.01	31.02	29.01	26.01
Dec	32.74	27.78	21.83	30.76	26.79	21.83	34.02	30.02	27.01	31.02	29.01	27.01

Key: Jan=January; Feb=February, Mar=March; Apr= April; Aug=August; Sept= September; Oct=October; Nov=November; Dec= December; Max= maximum; Av= average; Min= minimum

3.3. Effects of Varying Application Rates of Farmyard Manure and Compost on the Soil pH

With exception of maize plots receiving CP at 7.5 t ha^{-1} application rate in 2019/20 which recorded the highest and significantly different pH above the controls at Masasi site mean soil pH was not significantly different ($P \geq 0.05$) between FYM and CP application rates in both cassava and maize plots (Table 3). Generally, application of either FYM or CP increased soil pH to some extent across the two seasons but the increase was not statistically significant above the controls., The pH of FYM treated maize plots increased by 2.5 and 5.9 % above the control in 2019/20 and 2020/2021 growing seasons, respectively. Similarly, 8.3 and 4.7% increase in soil pH above the controls was recorded in CP treated maize plots during the 2019/20 and 2020/21 growing seasons, respectively. On the other hand, the pH of FYM treated cassava plots raised by 7.9 and 1.5 % in 2019/20 and 2020/21 respectively.

Table-3. Variations of soil pH in response to FYM and CP application rates at Masasi site

FYM/CP application rates (t ha^{-1})	**Maize**				**Cassava**			
	FYM		**CP**		**FYM**		**CP**	
	2019/20	**2020/21**	**2019/21**	**2020/21**	**2019/20**	**2020/21**	**2019/21**	**2020/21**
0.00	6.99 a	7.28 a	6.48 a	6.58 a	6.85 a	7.04 a	6.71 a	6.91 a
2.50	6.74 a	7.06 a	6.59 ab	6.77 a	7.04 a	6.79 a	6.71 a	7.27 a
5.00	6.92 a	6.83 a	6.90 ab	6.78 a	6.83 a	7.09 a	7.09 a	7.39 a
7.50	7.17 a	6.85 a	7.07 b	6.91 a	7.44 a	7.15 a	7.28 a	7.42 a
CV (%)	2.00	2.40	9.20	0.90	0.90	2.00	5.60	8.80
SE	0.14	0.17	0.62	0.06	0.06	0.14	0.38	0.64
P-Value	0.66	0.48	0.09	0.30	0.40	0.19	0.46	0.21

Means in the same column followed by similar letters are not significantly different at $p \leq 0.05$ according to DNMRT; FYM=Farmyard manure, CP=Compost

The general trend of soil pH after application of FYM or CP at Mvomero site (Table 4) was more or less the same as that of Masasi site. Only FYM treated maize plots had significantly different soil pH from control plots in 2019/2020. On the other hand, in 2020/21, only CP treated maize plots had pH values above the pH recorded in control plots. On average the increase of soil pH in FYM treated maize plots was 2.9 % above the pH recorded in the control plots in 2019/20 while CP treated maize plots had 0.6% increase in soil pH above the control plots in 2020/21cropping season. Generally, there was no significant difference in soil pH of maize and cassava plots receiving the different FMY or CP application rates across the two seasons.

Table-4. Effect of varying FYM and CP application rates on soil pH at Mvomero site

FYM/CP application rate (t ha^{-1})	**Maize**				**Cassava**			
	FYM		**CP**		**FYM**		**CP**	
	2019/20	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
0.00	7.08 a	6.57 a	7.24 a	6.80 b	7.12 a	6.33 a	7.14 a	6.52 a
2.50	7.33 b	6.44 a	7.33 a	6.35 a	7.14 a	6.22 a	7.36 a	6.52 a
5.00	7.26 b	6.55 a	7.14 a	6.74 b	7.16 a	6.52 a	7.51 a	6.49 a
7.50	7.29 b	6.48 a	7.38 a	6.84 b	7.42 a	6.53 a	7.13 a	6.43a
CV (%)	1.10	0.60	1.20	4.90	0.60	2.40	4.60	4.70
SE	0.07	0.04	0.08	0.32	0.04	0.15	0.33	0.30
P -value	**0.03**	**0.96**	**0.06**	**0.04**	**0.23**	**0.34**	**0.35**	0.99

Means in the same column followed by similar letters are not significantly different at $p \leq 0.05$ according to DNMRT; FYM=Farmyard manure, CP=Compost.

3.4. Effects of Varying FYM and CP Application Rates on Soil OC at Masasi Site

Soil OC values measured in maize and cassava plots subjected to different treatments across the two seasons at Masasi and Mvomero sites are summarized in Table 5 and 6 respectively. With exception of FYM treated maize plots which had no significant difference in soil OC across the two seasons, Soil OC increased with FYM and CP application rates at both sites and the highest and significant ($P \leq 0.05$) in soil OC was associated with the highest application rate (7.5 t ha^{-1}) of FYM or CP. At all sites the lowest percentage of soil OC was recorded in the control plots where neither FYM nor CP applied.

Table-5. Effect varying FYM and CP application rates on soil OC at Masasi site

CP/FYM application rate (t ha^{-1})	**Maize**				**Cassava**			
	FYM		**CP**		**FYM**		**CP**	
	2019/20	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
0.00	0.51 a	0.30 a	0.58 a	0.37 a	0.17 a	0.64 a	0.21 a	0.51 a
2.50	0.51 a	0.74 a	0.64 a	0.89 b	0.42 a	0.54 a	0.52 a	0.68 ab
5.00	0.69 a	0.90 a	0.63 a	1.02 b	1.08 b	1.02 a	0.96 ab	1.04 b
7.50	1.09 a	1.23 a	1.13 b	1.16 b	1.41 b	1.89 b	1.19 b	1.35 b
CV (%)	13.20	42.90	8.40	8.40	23.30	49.00	41.30	29.40
SE	0.09	0.32	0.06	0.41	0.18	0.50	0.33	0.23
P -value	0.18	0.20	<.001	0.03	0.005	0.03	0.07	0.008

Means in the same column followed by similar letters are not significantly different at $P \leq 0.05$ according to DNMRT. CP= Compost, FYM = farmyard manure

Table-6. Variations in the soil organic carbon (% OC) with compost and farmyard manure application rates at Mvomero site

CP/FYM application rate (t ha^{-1})	**Maize**				**Cassava**			
	FYM		**CP**		**FYM**		**CP**	
	2019/20	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
0.00	0.81 a	0.79 a	0.47 a	0.48 a	0.77 a	1.19 a	0.93 a	0.66 a
2.50	1.04 a	1.39 ab	0.84 b	0.89 ab	1.41 ab	1.20 a	1.05 a	0.73 a
5.00	1.64 b	1.74 bc	1.07 b	1.09ab	1.68 b	1.61 ab	1.23 a	1.32 b
7.50	1.71 b	2.10 c	1.45 b	1.76 c	1.84 b	2.08 b	1.39 a	1.52 b
CV (%)	23.00	24.10	22.50	26.70	20.80	8.70	31.30	14.20
SE	0.29	0.36	0.23	0.26	0.29	0.13	0.36	0.14
P -value	0.01	0.01	<.001	0.05	0.03	0.01	0.25	0.01

Means in the same column followed by similar letters are not significantly different at $P \leq 0.05$ according to DNMRT; CP=Compost, FYM=Farmyard manure

3.5. Effects of Farmyard Manure and Compost Application Rates on Soil Extractable Phosphorous

Application of FYM and CP 7.5 t ha^{-1} in maize and cassava plots resulted into the highest and significantly different ($p \leq 0.05$) extractable phosphorous both at Masasi and Mvomero sites with exception of compost treated plots in 2019/20 at Mvomero site (Table 7).

Table-7. Variations of soil Extractable phosphorous (mgPkg soil^{-1}) with FYM and compost application rates at Masasi site

	Maize				**Cassava**			
CP/FYM	**FYM**		**CP**		**FYM**		**CP**	
application rate (t ha-1)	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
0.00	3.76 a	5.96 a	6.76 ab	4.86 a	4.34 a	3.73 a	4.59 a	3.92 a
2.50	6.73 b	8.51 a	5.31 a	6.73 a	6.80 a	5.16 a	6.82 a	7.85 ab
5.00	7.87 b	9.06 a	7.59 b	9.08 ab	7.75ab	13.29b	7.23 a	10.14 b
7.50	10.45 c	13.50 b	10.93c	13.40 b	11.34 b	16.51 b	12.21 b	12.85 b
CV (%)	21.50	14.60	28.30	22.5	24.7	11.00	3.80	13.90
SE	1.54	1.35	2.16	1.91	1.86	1.06	0.29	1.21
P -value	<.001	0.02	0.004	0.01	0.02	0.001	0.03	0.03

Means in the same column followed by similar letters are not significantly different at $P \leq 0.05$ according to DNMRT. CP= Compost, FYM = Farmyard manure

At Masasi site, in the FYM treated maize plots, soil P increased by 64.0 and 55.8% above the control for 2019/20 and 2020/21, respectively. In the CP treated maize plots at the rate of 7.5 t ha^{-1}, soil P increased by 38.2 and 63.7% above the control in 2019/20 and 2020/21, respectively. In the FYM (7.5 t ha^{-1}) treated cassava plots, soil P increased by 61.7 and 77.4% above the control for 2019/20 and 2020/21 respectively while in the compost treated cassava plots at the highest rate, soil P increased by 62.4% and 69.5% in 2019/20 and 2020/21 seasons respectively. At Mvomero site, soil P increase by 58.7% and 70% in FYM treated maize plots while in the CP treated plots soil P increased by 43.5% and 66.5% for 2019/20 and 2020/21 seasons respectively. In the FYM cassava treated plots P increased by 68.3% and 81.5% above the control while in the CP treated plots P increased by 61.0 % and 61.7% for 2019/20 and 2020/21 respectively (Table 8).

Table-8. Variations of soil Extractable phosphorous (mgPkg soil^{-1}) with FYM and compost application rates at Mvomero site

CP/FYM Application rate (t ha^{-1})	**Maize**				**Cassava**			
	FYM		**CP**		**FYM**		**CP**	
	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
0.00	4.98 a	5.96 a	4.98 a	3.81 a	4.39a	3.69 a	3.98 a	6.20 a
2.50	6.94 a	8.22 a	6.15 ab	7.73 b	5.42 ab	7.53 a	7.51 b	9.11 ab
5.00	7.72 a	11.22ab	7.87 ab	6.98 b	7.90 b	11.62ab	9.18 b	14.47 bc
7.50	12.06 b	19.93 b	8.81 b	11.37c	13.85 c	19.92 b	10.21 b	16.21 c
CV (%)	19.60	8.60	19.50	26.60	25.60	16.60	21.20	39.80
SE	1.55	0.98	1.35	1.98	2.02	1.77	1.63	4.58
P -value	0.01	0.04	0.10	0.001	0.001	0.01	0.008	0.01

Means in the same column followed by similar letters are not significantly different at $P \leq 0.05$ according to DNMRT
Key: CP= Compost, FYM = Farmyard manure

3.6. Effects of FYM and CP Application Rates on the Activity soil ß- Glucosidase at Masasi and Mvomero Sites

The activity of ß-glucosidase differed significantly ($P \leq 0.05$) following application of different rates of FYM and CP in both crops and at both sites except in FYM treated maize plots at Mvomero in 2020/21 and FYM treated cassava plots in 2019/20 (Table 9). At Masasi site, the highest ß-glucosidase activity (18.03 µgNPg^{-1}dwh^{-1}) was recorded at the highest FYM treated maize plots at application rate of 7.5 t ha^{-1}in 2019/20, which was 41% above the control. At Mvomero site, the highest significant ß-glucosidase activity (15.67 µgNPg^{-1}dwh^{-1}) was recorded in the FYM treated cassava plots at a rate of 7.5 t ha in 2019/20 season, which was 55.8% above the control.

Table-9. Variations of ß-Glucosidase activities (µg pNPg^{-1} dwh^{-1}) to FYM and CP application rates at Masasi and Mvomero sites

	Maize					Cassava			
		FYM		**CP**		FYM		CP	
Site	**Treatment**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	2019/20	2020/21	2019/20	2020/21
Masasi	**0**	7.59 a	10.55 a	7.45 a	8.09 a	7.26 a	9.00 a	7.54 a	7.5 a
	2.5	8.74 ab	11.99 a	8.89 b	9.87 ab	8.75 ab	11.23 ab	8.39a	9.86 a
	5.0	9.26 b	14.87 ab	8.26 ab	14.12 bc	10.63ab	12.79 bc	8.37 a	11.51 ab
	7.5	9.94 b	18.03 b	10.76 c	14.81 c	14.45 b	14.86 c	10.31 b	16.16 b
	CV (%)	11.4	11.7	5	22.3	18.6	14.5	5.6	20.6
	SE	1.016	1.618	0.444	2.61	1.91	1.73	0.48	2.32
	P -value	0.02	0.035	0.003	0.035	0.147	0.01	0.005	0.05
Mvomero	**0**	6.05 a	11.21 a	7.18 a	12.0 a	6.84 a	12.53 a	5.17 a	9.62 a
	2.5	8.88 ab	13.98 ab	7.15 a	13.77 b	10.01 a	13.20 ab	6.22 a	13.13 b
	5.0	12.40 bc	14.04 ab	15.07 b	14.69 bc	15.35 b	14.17 ab	12.03 b	14.42 b
	7.5	15.85 c	15.16 b	15.36 b	14.96 c	15.67 b	14.86 b	13.05 b	15.05 b
	CV (%)	15.2	9.9	3.5	3.9	5.8	12.6	28.9	9.4
	SE	1.638	1.353	0.395	0.537	0.7	1.73	2.63	1.22
	P -value	0.006	0.138	<.001	0.003	0.007	0.05	0.008	0.01

For each site, means in the same column followed by similar letters are not significantly different at $P \leq 0.05$ according to DNMRT

3.7. Effects of FYM and CP Application Rates on Activities of Soil Phosphatase at Masasi and Mvomero Sites

Application of CP and FYM at a rate of 7.5 t ha^{-1} resulted in the highest phosphatase activity at both sites (Table 10). At Masasi site, the highest significant phosphatase activity (40.41 µg pNPg^{-1} dwh^{-1} was recorded in the FYM treated maize plots at a rate of 7.5 t ha^{-1} in 2019/20, which was 85.5% above the control. At Mvomero site, the highest Phosphatase activity (24.27 µg pNPg^{-1} dwh^{-1}) was achieved in the maize plots treated with CP at application rate of 7.5 t ha-1 which was 54.1% above the control.

Table-10. Variations of Phosphatase activities (μg pNPg^{-1} dwh^{-1}) to FYM and CP application rates at Masasi and Mvomero sites

		Maize				**Cassava**			
		FYM		**CP**		**FYM**		**CP**	
Site	Treatment (t ha^{-1})	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
	0	21.37 a	25.87 a	13.87 a	20.63 a	6.62 a	25.91 a	5.97 a	15.91 a
	2.5	27.82ab	33.72 b	28.27 b	38.39 b	9.84 ab	29.62 a	6.91 ab	17.49 a
	5	31.16b	38.81bc	34.57 b	39.68 b	13.6 b	31.58 a	10.67ab	26.67ab
Masasi	7.5	35.38 b	40.41c	36.84 b	41.45 b	14.03 b	32.11 a	14.67 b	33.72 b
	CV (%)	25.2	15.2	8.6	14.1	43.6	4.4	33.8	34.1
	SE	7.29	5.28	2.44	4.94	4.8	1.299	3.23	8
	P -value	**0.032**	**0.003**	**0.0132**	**0.05**	**0.102**	**0.153**	**0.118**	**0.023**
	0.0	7.86 a	12.01 a	7.42 a	11.14 a	7.69 a	12.20 a	5.78 a	12.17 a
	2.5	11.6 a	13.43ab	11.16ab	13.03 a	11.49 b	14.29 b	8.27 a	12.99ab
	5.0	11.68 a	13.93 b	14.53bc	13.8 a	14.79bc	15.02 b	14.01 b	14.24ab
Mvomero	7.5	12.16 a	15.02 b	16.59 c	24.27 a	16.77 c	15.12 b	16.41 b	14.65 b
	CV (%)	10.3	5.7	2.9	25.5	12	13.8	5.4	11.8
	SE	1.11	0.77	0.36	3.397	1.527	1.958	0.605	1.59
	P -value	**0.83**	0.03	**0.017**	**0.253**	**0.003**	**0.004**	**0.001**	**0.083**

For each site, means in the same column followed by similar letters are not significantly different at $P \leq 0.05$ according to DNMRT

4. Discussion

Availability of soil nutrients, soil ion balance and activities of soil microorganisms are greatly influenced by soil pH. At both Masasi and Mvomero sites, there was slight variations in soil pH ranging between 6.35 and 7.29. According to, this pH range is rated as slightly acid to neutral. Since the most important role of soil pH is to control the solubility of nutrients in the soil, this variation could not have affected the performance of the crops negatively as it was still in a good range for availability of most essential nutrient elements and growth of maize and cassava. According to Läuchli and Grattan [30], availability of soil nutrients is optimal within pH range of 6 - 8, a characteristic of most cultivated soils. The observed slight increase of soil pH due to manure application could be attributed to an increase in basic cations released from decomposing FYM and CP. Lack of significant differences in soil pH measured in control and FYM or CP treated plots indicates that FYM and CP used as soil amendments had low soil liming effect and the decomposition process did not release adequate amounts of organic acids and protons to significantly lower the pH below the control plots. This can also be linked to the pH buffering effects of CP and FYM applied to the soils as organic amendments. Onwonga, *et al.* [31] and Otieno and Zingore [32] reported similar findings on increase in soil pH following application of cattle manure. Similarly, Hashemimajd, *et al.* [33] and Latifah, *et al.* [34] reported increase of soil pH following application of CP.

The current study indicated that, soil OC increased with CP or FYM application rates in cassava and maize plots. The observed increase in soil organic carbon following application of either FYM or CP corresponds to increased soil organic matter that increases water holding capacity of the soil and thus increased availability of water for plant use. Tadesse, *et al.* [35], reported similar findings on the increase in soil OM following application of FYM at a rate of 7.5 t ha^{-1}. The data obtained from this study supports also the findings by Angelova, *et al.* [36] who reported an increase in soil organic matter content that corresponded to the applied amount of CP. Hence, the observed increase in soil organic matter corresponded to the rates of FYM and CP applied. This will in turn contribute to improved soil structure for better plant roots penetration, water retention capacity and aeration.

In this study, extractable soil P in the FYM treated maize plots increased by 64% above the control across 2019/20 and 2020/21 at both sites while extractable P in CP treated maize plots increased by 57.25% above the control. The differences in P increase between FYM treated plots and CP treated plots was associated to differences in nutrient content and release patterns of the two soil amendments. These results corroborates with those reported by Jjagwe, *et al.* [37].

Change is soil OC and extractable P following FYM and CP applications indicates that addition of FYM and CP contributes to improved soil organic matter content as well as the availability of P which is among the major essential but often limiting plant nutrients in highly weathered tropical soils. The observed increase in soil extractable P with increasing activity of Phosphatase enzyme is attributed to the hydrolytic effect of the enzyme resulting into solubilization of organic P and its subsequent release in inorganic forms available for plant uptake. Zemichael and Dechassa [38], reported three folds (300%) increase in soil OM and two folds (50%) increase in soil extractable P following application of FYM at a rate of 10 t ha^{-1} and CP at a rate of 7 t ha^{-1}. In this study, soil available P and OC was low in the control plots and in some cases seem to decrease from one season to another. The low levels of available P and OC were attributed to the limited P input from external sources and continuous removal of available P though plant uptake. Apriyani, *et al.* [39], reported similar findings where available soil phosphorous in the control was low and continued to decrease throughout the study.

The application of either FYM or CP resulted into enhanced activity of ß-glucosidase and phosphatase enzymes indicating improvement in soil health/quality. Farmyard manure and CP contain plant nutrients in organic form.

Application of CP and FYM into the soil, stimulated activities of soil microbes hence the release of Glucosidase and phosphatase enzymes playing major roles in the cleavage of the organic compounds to release simple sugars as energy source for soil microbes and inorganic P, which is important for microbial metabolism. Furthermore, the observed increase in soil enzymes activities corresponded to increase in soil OC as well as soil extractable P levels indicating improvement of soil quality. The observed increase in soil enzyme activities with increasing FYM and CP application rate was attributed to increasing levels of organic material (substrate) acted upon by soil microorganisms to release plant available nutrients. The increasing activity of microbes in the soil following application of FYM and CP was therefore associated with increased excretion of enzymes including ß- glucosidase and phosphatase. This observation is supported by low activities of ß- glucosidase and phosphatase recorded in the control plots under both maize and cassava crops due to the limited supply of the substrates for soil microbes. Similar findings were reported by Dinesh, *et al.* [40] and Mageshen, *et al.* [41]. Increased soil enzyme activities following application of FYM and CP have aso been reported by other research works by Chang, *et al.* [42] and Kuziemska, *et al.* [43] which associated the increase in activities of soil enzymes with increased microbial populations. This supports the augment that addition of different rates of FYM and CP stimulated the populations and activities of soil microorganisms hence increased activities of studied soil enzymes indicating soil quality improvement.

5. Conclusion

This study has indicated that, application of FYM and CP increases soil OC, extractable P and activities of ß-glucosidase and phosphatase in the soil. This has mainly been attributed to addition of organic matter contained in FYM and CP into the soil hence availing the substrate for soil microorganisms and stimulates their populations in the soil system. The increased activities of soil microbes in turn increased the rate at which soil organic matter was acted upon to release plant available nutrients including P and excretion of hydrolyitic enzymes (ß- glucosidase and phosphatase) indicating soil quality improvement. The study also indicated that activities of ß- glucosidase and phosphatase increased with increasing soil OC and extractable P thus the two enzymes can be used as sensitive indicators for change in soil OC and P availability following application of FYM and CP as soil organic amendments.

6. Recommendations

Based on current results, this study recommends application of FYM or CP at 5 t ha $^{-1}$ to gradually improve and sustain soil quality in maize and cassava based farming systems of Masasi and Mvomero districts. Further studies are required in order to generate area specific data to guide scaling and adoption of FYM and CP soil amendments for restoration of soil healthy in other zones.

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