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Short-term effect of reducing conventional tillage intensity on some physical and chemical properties of volcanic soils in Rwanda

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Volcanic soils which comprise a minor portion worldwide are generally characterized by their high natural fertility yet susceptible to soil erosion due to their fragility. Regardless of which, the success in soil management to maintain its quality depends on the understanding of how the soil properties respond to its disturbance through tillage practices over time. This study was conducted in the highland region of Rwanda, Musanze District, Busogo Sector from December 2016 to June 2017, to evaluate the short term effect of conventional and reduced tillage on certain physical and chemical properties of volcanic soils. Bulk density (BD) and total porosity (TP) as induced soil compaction and aeration respectively were selected as soil physical properties. Soil pH, soil organic matter (SOM) and soil organic carbon (SOC) as generally used in soil fertility assessments and land suitability were selected as soil chemical properties. Soil samples were collected at the end of May 2017 from the plots laid out in RCBD replicated four times, then analyzed and data were subjected to ANOVA using GeniStat software. The results showed no significant difference in SOM and BD ($p>0.05$) while soil pH was significantly different ($p<0.05$) in these tillage systems. The results of this study evinced that reduced tillage is suitable in this region, since it is promising in the SOM enhancement. Evidences of this study will expose researchers and policy makers to new strategies to improve the soil structure stability, yet minimizing soil vulnerability in this highland region and countrywide.

Key words: Tillage, soil properties, soil disturbance, volcanic soils.

INTRODUCTION

Pedological surveys indicated that soils derived from Quaternary volcanic eruptions are widely distributed in the northwestern highlands of Rwanda hence the eight major volcanoes of Virunga Mountains are found in this region and around (Mizota and Chapelle, 1988). Soils that form in volcanic regions have andic soil properties

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and are classified as Andosols (World Reference Base WRB) or Andisols (Soil Taxonomy). These soils are often fragile characterized by lower bulk density, higher porosity, lower coarse fragment content and a disproportionate concentration of nutrients such as OM and total Nitrogen (N) in the upper 30 cm of the soil profile, hence are susceptible to physical disturbance such as compaction, landslides and erosion (Craigg and Howes 2007). This is worse in Rwanda due to the hilly nature of its topography interacted with excessive cultivation; these soils are particularly more vulnerable (Twagiramungu, 2006).

Despite their small proportion worldwide (1%), volcanic soils are highly fertile and support 10% of the world's population, including some of the highest human population densities (Neall, 2006; Astier et al., 2006). For Rwanda with the driving force of the economy being agriculture (Uwituze et al., 2017), soils derived from volcanic materials have a great importance as they support a large population of more than 445 inhabitants/km^2 (NISR, 2015) and much of the potatoes, cereals, and vegetables production are carried out in these soils. However, there is still a paucity of information about the nature, properties and proper management of these soils (Uwitonze et al., 2016).

Although Shoji et al. (1993) affirmed that farming practices change chemical and biological properties of volcanic soils; these soils continued to be under intensive cultivation which obviously led to their degradation (Uwitonze et al., 2016). Indeed, alteration of soil properties through disturbance mechanisms is not necessarily harmful, since all types of soils represent their unique nature and properties (Craigg and Howes, 2007; Valle and Carrasco, 2017). However, worthwhile soil disturbance standards or objectives must be based on measured and documented relationships between the degree of soil disturbance and subsequent soil properties response; studies designed to determine these relationships are commonly carried out as part of controlled and replicated studies for the purpose of determining threshold levels for detrimental soil disturbance exists (Craigg and Howes, 2007).

Tillage is an extreme form of soil disturbance that changes the soil properties and throughout the world many different tillage practices take place. For many centuries, the conventional tillage system was used in agriculture to control the development of weeds, to incorporate crop residues into the soil, to recycle leached nutrients back to the surface, and to create adequate structure before planting (Oorts, 2006). With the introduction of herbicides the need for ploughing continued to be questioned and reduced tillage systems were adopted. Recently, tillage practices with minimum soil disturbance attracted much attention from researchers and policy communities due to their nature of increasing carbon storage, reducing erosion, increasing soil stability against compaction and overall soil structure (Palm et al., 2014; Schlüter et al., 2018)

Reduced tillage which consists of both superficial tillage and no tillage systems represents a relatively widely adopted soil management practice (Oorts, 2006). Thus, research on no-tillage oftentimes occurred within the context of conservation agriculture (Pittelkow et al., 2015). No wonder these terms may here in after be referred interchangeably (Quintero and Comerford, 2013; Lopez-Garrido et al., 2014; Pittelkow et al., 2015; Kabirigi et al., 2015; Schlüter et al., 2018). These reduced tillage systems have two main characteristics: The soil is not entirely turned over and the soil is always entirely or partially covered by residues; the main benefits of residue cover include improved soil water storage, enhanced soil organic matter content, nutrient recycling and protection against water and wind erosion (Oorts, 2006; Kabirigi et al., 2015). Although there is the potential for reduced tillage systems to contribute to impressive soil management practices, some recent reports argued that these benefits may not be as widely observed as previously thought or expected (Powlson et al., 2014; Palm et al., 2014; Brouder and Gomez-Macpherson, 2014; Pittelkow et al., 2015). Concerns expressed that reduced tillage systems can lead to excessive soil compaction which affects the crop growth (Steyn et al., 1995; Salem et al., 2015). Considering the harmful effects of soil compac¬tion in the field, the government of China, for example, started a campaign to pay allowance to the farmers who engage in conventional deep moldboard tillage practice instead of the conventional low moldboard tillage since 2009, encouraging farmers to solve the soil compaction by deep tillage (Ji et al., 2013). It is all clear that the amount of tillage to be employed to improve the soil properties is determined by many factors, these include: climatic conditions, soil types, crop rotation systems, etc. (Powlson et al., 2014; Kabirigi et al., 2015; Uwitonze et al., 2016). Thus, the effects induced by tillage also depend on different factors but generally the time of treatment (Da-Veiga et al., 2008).

On one hand, on a short-term scale, tillage operations mainly affect nutrient dynamics through altering of physical properties of the soil and by incorporating crop residues and mineral or organic fertilizers; and on a long-term scale, the short-term effects accumulate, thereby an additional system effect builds up (Pekrun et al., 2003). Mrabet et al. (2001) reported that reduced tillage systems increase soil organic matter (SOM) content in 3 to 5 years or more of continuous treatment, complemented with crop rotations and leguminous cropping, for the soils to become stabilized. On the other hand, McCauley et al. (2017) reported that tillage practices play a big part in soil pH change and Changes can occur within a season or last for decades.

Similarly, Da-Veiga et al. (2008) observed that change in Soil physical properties depends on tillage and time. Overall, the success in soil management to maintain the soil quality depends on the understanding of how the soil responds to tillage practices over time (Da-Veiga et al., 2008; Kiflu and Beyene, 2013). In recent decades, Rwanda adapted many policies and framework to improve soil quality and enhance soil conservation in which many of them did not even have a glimpse of success (Rushemuka et al., 2014). The arguments on conservation tillage systems (Kabirigi et al., 2015) and recent recommendation of their adaptation in this region (Uwitonze et al., 2016) left researchers a lot to debate. Thus, today's farmers in Rwanda are still unaware of the amount of tillage to be employed to improve the soil quality for seed bed preparation and cultivation (Kabirigi et al., 2015).

It is against the above background that this study aimed to employ the conventional tillage and reduce its intensity to evaluate the possible effects induced by tillage treatments on certain soil physical and chemical properties of volcanic soils in highland region of Rwanda on short-term basis. This enabled us to predict the amount of appropriate disturbance that improve properties of soil quality indicators, and consequently, minimizing overall the impact caused by soil mismanagement for long-term soil structure stability and agriculture prosperity as well.

MATERIALS AND METHODS

Study area description

The field experiment was conducted in UR-CAVM Busogo farm (University of Rwanda- College of Agriculture Animal Sciences and Veterinary Medicine)/Busogo Campus, Busogo Sector, Musanze District, Northern Province. Musanze is the most mountainous district of Rwanda as it contains the largest part of the Virunga National Park. Five of the eight volcanoes of the Virunga chain (Karisimbi being the highest peak of Rwanda with 4507 m, Bisoke, Sabyinyo, Gahinga and Muhabura) are within the district boundaries (Figure 1). Musanze District has many different agricultural possibilities as it is characterized by volcanic soil type, loose, well aerated and full of organic matter. According to National Soil Map of Rwanda (la Carte Pédologique du Rwanda) developed by Rwandan ministry of Agriculture, Livestock and Forestry in cooperation with Belgian government through Ghent University between 1981 and 2000; the soils of Busogo area as well as Rwanda's northwestern soils fall into the Andisol or Andosol type by soil taxonomy and this reflect to Virunga mountains. Busogo Sector is one of 15 Sectors of Musanze District in Northern Province of Rwanda which is made of 4 cells: Gisesero, Sahara, Kavumu and Nyagisozi respectively (Imerzoukene and Van-Ranst, 2002; NISR, 2015).

In general Busogo Sector has a mean altitude of 2300 m with the highest point being at 2800 m a.s.l. The climate has a mean temperature of 16.7°C and much rainfall comprising between 1400 and 1800 mm and is located at latitude of 1°33'26'' S and longitude of 29°32'39''E; Musanze-Rubavu road. Busogo Sector has 4 seasons divided as follows: light dry season from end-December to mid-February, heavy rainy season from mid-February to June, heavy dry season extending from June to end-August, and light rainy season from end-August to end-December. Volcanic soils of Busogo are very permeable with low depth on mountains and moderate depth in lower altitude characterized by Sandy loam texture. This kind of soil is subject to many erosion phenomena in the area of abrupt slope. According to Rwanda 4th Population and Housing Census, 2012 data; the population of Busogo sector is around 21,512 inhabitants, with the population density of 1069/km^2 and is the third sector with high population density after Muhoza and Cyuve respectively (NISR, 2015). Most people in Busogo Sector live in rural areas and they involve in agriculture; the main crops cultivated there are potatoes, maize, wheat, beans and vegetables (Uwituze et al., 2017).

Field experimental design

Before conducting experiment, the field of 25 m ×18 m has gone fallow for 5 years, and before that it was always under the intensive cultivation with seasonal crop rotation and carrying out experiments occasionally. Two types of tillage systems were used manually with the intention of leaving residue at the surface in one type of tillage system (Lopez-Garrido et al., 2014).

Experimental design was laid out in randomized complete block design (RCBD) with three treatments and four replications (Figure 2). Tillage treatments were; conventional tillage (T1) in which we dug the soil with a hoe up to more than 30 cm and the residues were fully incorporated, no residue was left at the surface and this technique is what is generally adapted for seed preparation by many farmers countrywide. The second was reduced tillage (T2) in which the soil was slightly disturbed and dug within 15 cm with the intention of leaving the residues on the soil surface, this system left in fact more than 50% of residues on the surface and the last treatment was control (T3), so the surface was left intact without any slight disturbance. The size of each plot was 5.0 m long and 5.0 m wide. A buffer zone of 0.50 m spacing was provided between plots with 1 m and 1.5 m space left at the Treatments' extremity and Blocks' extremity respectively. The cultivated plots were treated with cattle manure as one of the most affordable and commonly used means of soil fertilization countrywide equivalent to 12 t/ha. The composted cattle manure was applied by hand broadcasting prior to cultivation and fully incorporated in conventional tillage without being fully incorporated in reduced tillage. In the end of December, the activities of cultivation and sowing were over and the maize (*Zea mays*) was selected for the cultivated treatments. The space between rows was 1 and 0.5 m within rows, 2 seeds per stand were sown to give the population of 36000 seeds/ha, although after 8 weeks the second plant was removed to grow one plant per stand. The weeding was done manually with a hoe and hands after 2, 4, 8 and 12 weeks respectively. The corns with good stands in both tillage systems were harvested in mid-June two weeks after data collection for soil analysis.

Soil sampling

Since the primary purpose of our study was to determine how the soil properties were affected by each tillage type, the soil samples for determination of soil organic matter and soil organic carbon, soil pH, the soil bulk density and the total porosity were collected in the end of May in hope that some external pressure was acted on soil and became slightly stable.

Data for soil bulk density and total porosity as selected physical properties were collected after removing weeds, with the standard procedures adopted for recording the data for soil bulk density (Blake and Hartge, 1986); 12 undisturbed samples were taken from all plots by core samplers of nearly the same, transported directly to the laboratory and dried for 72 h at 105°C in the oven dry. Soil porosity was obtained from soil bulk density (Danielson and Sutherland, 1986).

Composite soil samples for SOM, SOC and soil pH analysis were collected in 0-30 cm of soil depth as discrete samples from each plot with a hand auger. The randomized quadrate sampling

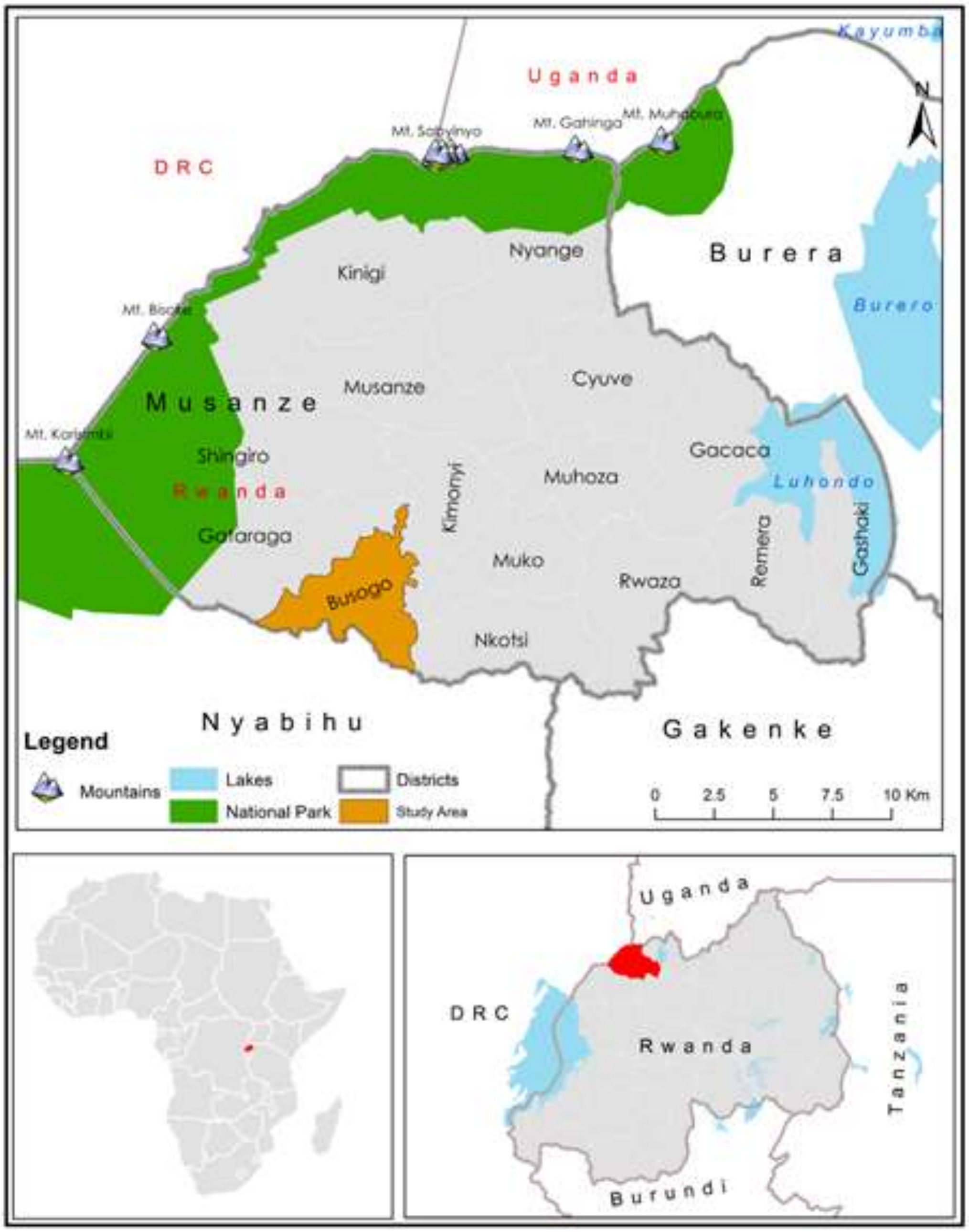


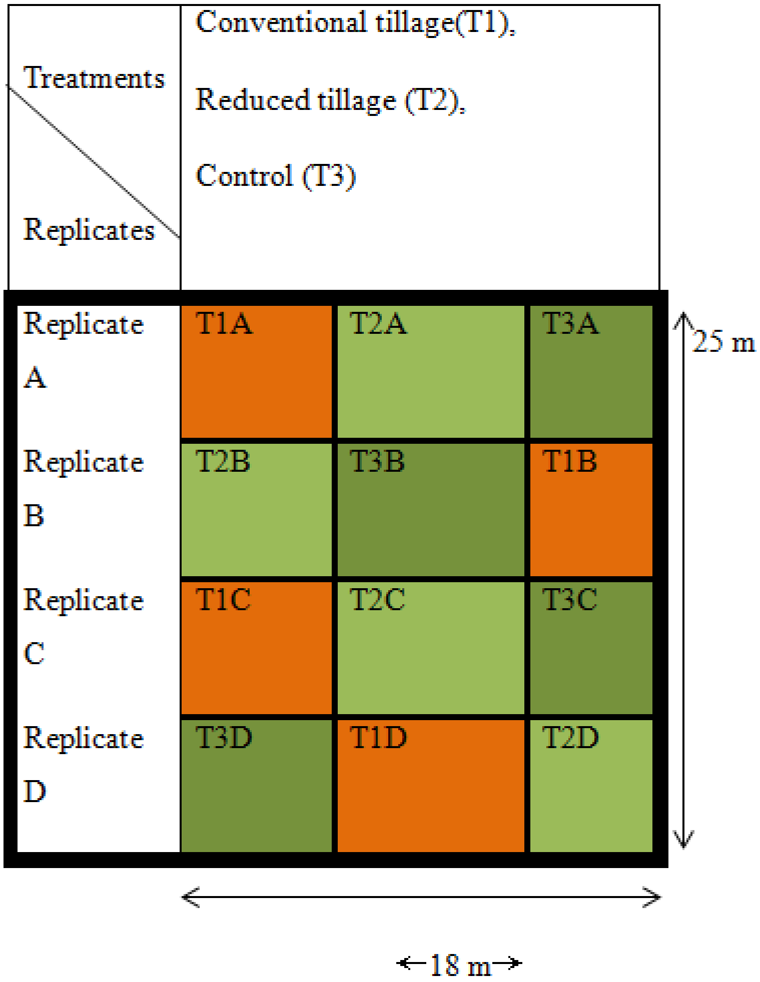
Figure 1. Musanze district administration map showing the position of Virunga Mountains and National Park, Busogo sector (the study area) and its location in Rwanda.

approach technique was used in which several sampling sites were chosen randomly within each plot, the samples from each plot were mixed in one plastic bag designating the plot and 12 plastic bags of mixed samples each were transported to the laboratory of soil science- UR-CAVM. They were dried for two weeks at room temperature, thereafter ground by mortar and pestle, and sieved by griddle mesh, divided into sub-samples depending on which parameters to be determined. SOM was determined from the soil sample ground to pass through 0.5 mm sieve, while soil pH was determined from the soil sample ground to pass through 2 mm sieve. They were all stored in sealed plastic containers at 25°C for laboratory analysis. Thereafter, the following parameters were analyzed and calculated according to the respective methods of their determination described in soil analysis.

Soil analysis

Determination of soil pH

Soil pH (H_2O) was determined on 2.5:1 water suspension of soil using a soil solution by the potentiometric method, using a glass



Treatments Replicates	Conventional tillage(T1), Reduced tillage (T2), Control (T3)		
Replicate A	T1A	T2A	T3A
Replicate B	T2B	T3B	T1B
Replicate C	T1C	T2C	T3C
Replicate D	T3D	T1D	T2D

Figure 2. Diagram showing randomized complete block design used in experimental lay out.

electrode as outlined by (Okalebo et al., 2002).

Determination of soil bulk density and total porosity

Bulk density (BD) was measured using core method; by measuring soil mass of dry soil in the cylinder and volume of the cylinder according to the following equation (Blake and Hartge, 1986):

$$\text{BD (g/cm}^3\text{) = weight of oven dry solid (g) / volume of soil (cm}^3\text{)} \quad (1)$$

Soil mass was measured after dried at 105°C for 72 h. Volume of the cylinder was obtained from ($R2\pi h$), Where R is the radius of the core cylinder, h is the height of the core cylinder; which coincides with the volume of the soil.

From this information, TP was calculated for each sample by using the method of TP from moisture loss; according to the following equation (Danielson and Sutherland, 1986):

$$\text{TP (\%)} = 1 - \text{BD} / \text{PD} \times 100 \quad (2)$$

Where BD is the soil bulk density (g/cm^3) and PD is average particle density (2.65 g/cm^3).

Determination of soil organic matter and soil organic carbon

SOM content was determined using loss on ignition method (calcination) by destruction of OM in soil at an elevated temperature in a muffle furnace and measuring the weight loss (Nelson and Sommers, 1996). The weight of each crucible was weighed and a soil sample of 2 g sieved to pass through 0.5 mm mesh was placed on crucible and heated at 105°C in the oven machine for 3 h to remove the moisture and the weight was recorded; the soil sample was transferred to the furnace at 450°C for 3 h to extract organic matter. The sample was then cooled in desiccators and weighed. Organic matter content was calculated by the following equation (Nelson and Sommers, 1996):

$$\text{OM (\%)} = [\text{weight (g) at 105°C - weight (g) at 450°C}] / [\text{weight of soil sample (g) - moisture (g)}] \times 100\% \quad (3)$$

Then, from this equation OC was calculated as follow based on the assumption that OM contains 58% of OC (Nelson and Sommers, 1996):

$$OC (\%) = OM (\%) / 1.724 \quad (4)$$

Statistical analysis

The results from the collected data were statistically analyzed using analysis of variance (ANOVA) by GeniStat 14th edition software. The least significant difference (LSD) was used to test the significant difference between the means of different soil properties from three different treatments (at p = 0.05) (Habimana et al., 2015).

RESULTS AND DISCUSSION

All the results obtained from the treatments replicated four times each (Table 1). The mean values of the parameters which gave the true estimation of soil properties statuses were calculated and are summarized within the table.

Soil pH

The results showed that reduced tillage recorded a slightly lower pH value (5.700) relative to conventional tillage and naturally undisturbed (control) soil; 5.800 and 5.850 respectively (Table 1), yet the difference was statistically significant ($p<0.05$). The drop of soil pH in reduced tillage is probably due to the faster decomposition of the concentrated layer of organic residues lying at the surface with subsequent leaching of resultants organic acids induced by cattle manure application into mineral soil and due to the root exudates (Subbulakshmi et al., 2009). Our results showed that the conventional tillage have mixed the acidic layer with higher pH sub-surface layers (McCauley et al., 2017). Hulugalle and Weaver (2005) also reported that a decrease of soil pH is among the short-term events of soil properties which can result during the decomposition of residues due to the production of organic acids and microbial respiration; although some reports claim that tillage does not consistently increase or decrease soil pH without crop rotation throughout many years (Oorts, 2006). This was supported by López-Fando and Pardo (2009) who reported a lower pH in 20-30 cm depth of soil treated with no till than in conventional tillage after 5 years of rotating grey pea (*Pisum sativum* L.) and barley (*Hordeum vulgare* L.) and the attribution of these acidifying processes goes to mineralization of organic matter, nitrification of surface-applied N fertilizer and root exudation. Limousin and Tessier (2007) argued that the occurrence of these three phenomena in the upper layers of soil profile is reflected by the concentration of the leaf residues and higher roots density. Nevertheless, some previous studies reported a lower pH in No tillage compared to conventional tillage in 5 years of continuous corn treatment; without crop rotation (Blevins et al., 1977)

On the other hand, in his study Paul et al. (2003) demonstrated that 1.7 ton/acre residues in the top 1 inch can change pH by 0.02 units, these plants residues subsequently become SOM which has many benefits, the main benefit of SOM is that it buffers soil pH change (McCauley et al., 2017). These authors explained the process; SOM offers many negatively charged sites to bind with H+ in an acidic soil, or from which to release H+ in a basic soil, in both cases pushing soil solution towards neutral. Other controversial results were reported by Astier et al. (2006) in different tillage types treated with different green manure under maize. In their study, a significant difference in soil pH was observed in tillage systems treated by oat though conventional tillage recorded a lower pH than reduced tillage, on the other hand reduced tillage treated with Vetch recorded lower pH than conventional tillage but without a significant difference; however overall interaction of tillage with green manure was observed to lower the soil pH significantly than the bare tillage. Based on our results in this study, reduced tillage is not suitable since it tends to increase soil acidity, but based on what we reviewed there is a lot of controversy in literature. Thus whether the shift of soil pH in the short term and in the long term tillage practices still remain unclear and depends on many factors (Astier et al., 2006). So, much attention should be maintained on the regulations of soil pH in tillage systems.

Soil organic matter and soil organic carbon

One of the expected outcomes of this study from the beginning was the significant difference in Organic matter content that should be recorded by the treatments. But, this turned out not to be the case ($p>0.05$), despite SOM tended to be higher in reduced tillage (8.125%) than conventional tillage (7.500%), as well as the control treatment which recorded a value of 8.375%. Obviously, SOC also showed no significant difference after dividing by a common factor of 1.724 (Table 1). The record of higher Organic matter in reduced tillage relative to conventional tillage is probably due to the plant residue and litter left on the soil surface and to a slight disturbance of soil in the reduced tillage (Limousin and Tessier, 2007). Conventional tillage marked lower carbon content due to high rate of mineralization, faster litter and other buried organic residues decomposition and uneven redistribution caused by soil turnover (Astier et al., 2006; Wang, 2014; Ferrara et al., 2017).

Our results were consistent with the findings of previous studies which reported that conventional tillage operations result in more or less even distribution of SOM in topsoil, but in minimum disturbance the concentration of organic matter found in the superficial horizons of soil profile (Staley et al., 1988). Similar studies confirmed that reduced tillage practices often increases soil organic matter content while conventional tillage mix organic matter homogeneously, and also enhance its mineralization rate (Wang, 2014), although a significant

Table 1. T The soil properties values recorded in treatments after being experimented.

Types of tillage	Replicate	pH (water)	OC (%)	OM (%)	BD(g/cm^3)	TP (%)
T1	(A)	5.7	4.64	8.0	0.98	63.02
	(B)	5.8	4.35	7.5	0.96	63.78
	(C)	5.9	3.77	6.5	0.99	62.64
	(D)	5.8	4.64	8.0	0.99	62.64
Mean values		5.80	4.35	7.5	0.98	63.02
T2	(A)	5.6	4.64	8.0	1.03	61.13
	(B)	5.7	5.22	9.0	0.97	63.40
	(C)	5.8	4.64	8.0	0.98	63.02
	(D)	5.7	4.35	7.5	1.00	62.26
Mean values		5.70	4.71	8.12	0.995	62.45
CK	(A)	5.8	4.35	7.5	1.00	62.26
	(B)	5.9	5.22	9	1.11	58.11
	(C)	5.8	4.93	8.5	0.99	62.64
	(D)	5.9	4.93	8.5	1.05	60.38
Mean values		5.85	4.86	8.38	1.038	60.85
p value		0.027	0.244	0.244	0.208	0.208
l.s.d		0.099	0.674	1.162	0.072	2.715

T1: Treatment 1, Conventional tillage; T2: Treatment 2, Reduced tillage; CK: Control; l.s.d.: Least significant difference.

impact can take considerable years to occur (Mrabet et al., 2001; Ferrara et al., 2017). Continuous studies were suggesting that the increase in soil organic carbon associated with reduced tillage practices will continue for a long period of time (25 to 50 years) depending on climatic conditions, soil characteristics, and production management practices (Quintero and Comerford, 2013). A higher organic carbon in reduced tillage than conventional tillage without significant difference on short term basis was also reported by Tesfahunegn (2015). Still, our results were in line with that of Astier et al. (2006) who reported a higher organic carbon in reduced tillage relative to conventional tillage with non-significant difference in short term tillage under maize with different green manure treatments, similarly Quintero and Comerford (2013) reported a higher OM and OC content in reduced tillage than in conventional tillage; thus attributed these results to the remaining effects of oat cover crop roots on the organic matter content. In our case the remaining effects of grass roots induced by long fallow might be responsible, this is because intensive tillage systems accelerate the decomposition of soil organic matter in relation to vegetation, which allows organic carbon to rehabilitate. Kiflu and Beyene (2013) also emphasized that the roots of the grass and fungal hyphae in the grassland soils left intact are responsible for the higher organic matter accumulation. Tillage systems that reduce soil disturbance and residue incorporation was generally observed to increase SOM. Quintero and Comerford (2013) recommended these systems, emphasizing that due to higher OC concentration (and OM) recorded in tillage practices with minimum soil disturbance; then they can be used to restore soil carbon. This positive effect of reduced tillage practices on SOM and SOC contents not only reported by these authors since many studies observed the same benefits in different parts of the world (Curaqueo et al., 2010; Haddaway et al., 2016). Given that the purpose of this study was based on a limited time, it is not surprising that the results did not differ significantly (Mrabet et al., 2001).Still, these results reported here give the credits to reduced tillage for improving SOC and SOM, so they can be used by decision makers for future plans instead of waiting the reports from studies that usually take a long period of time (Tesfahunegn, 2015).

Soil bulk density and total porosity

The results of BD showed a slight difference in the treatments yet statistically not significant ($p > 0.05$). Undisturbed soil recorded a slightly higher bulk density (1.038 g/cm^3), followed by reduced tillage (0.995 g/cm^3) and conventional tillage (0.980 g/cm^3) (Table 1). The results clearly show that both undisturbed soil and reduced tillage were relatively more compact than conventional tillage. It was observed that bulk density of light textured soils increase in the tillage practices with the least soil disturbance in the top 200 mm of the soil when compared with the soils treated by conventional tillage systems (Steyn et al., 1995). The natural consolidation of intact soil and minimal disturbance of soils treated by reduced tillage should be condemned.

Our results were in line with that of Afzalinia and Zabihi (2014) who reported a non-statistical significant difference in BD between conventional tillage and reduced tillage at the end of corn growing season. These findings are also consistent with that of Manyiwa and Dikinya (2014) who reported that conventional tillage type can lead to a lower bulk density; which has significant effects on the soil’s ability to allow easy water and solute movement and soil aeration and in crop and land management practices, yet their findings were not statistically significant. This is because compacted soils are associated with small pores of capillary size and therefore not penetrable by most roots (Steyn et al., 1995; Gbadamosi, 2013). Hence, would probably restrict water and air movement, as shown that reduced tillage and undisturbed soil are less porous compared to conventional tillage (Table 1).

However, some reports claim that tillage does not consistently affect bulk density since soil texture, aggregation, organic matter content and moisture conditions can induce the sensitivity of the soil to compaction (Steyn et al., 1995). Oorts (2006) argued that the bulk density in No till system remains fairly constant throughout the year while in Conventional tillage after the soil has been loosened by tillage, then soil bulk density will increase again by reconsolidation under the weight of the soil mass and machinery and due to the impact of raindrops and to drying/rewetting cycle. Still, this was supported by the findings of Afzalinia and Zabihi (2014) and Salem et al. (2015) who demonstrated that the bulk density in conventional tillage was lower than that of reduced tillage in the earlier months of corn growing season until it reaches its level of stability at the end of the growing season where there is no much significant difference between tillage treatments. On the other hand, “the total porosity is considered to be relatively low when it ranges from 13 to 27%”, Pengthamkeerati et al. (2011); Manyiwa and Dikinya (2014) reported. Our study reflected extremely high porosity values in all treatments; reduced tillage (62.45%), undisturbed soil (60.85%) and conventional tillage (63.02%) with no significant difference ($p > 0.05$) (Table 1). This is because volcanic ash forms soils which are generally permeable, characterized by loose and well aerated physical status (Randy et al., 2008). The total porosity is smaller in the least disturbed soils due to higher bulk density but given the values of densities recorded by all tillage types it doesn’t matter whether you choose any type of them (Manyiwa and Dikinya, 2014).

Based on the results of our study it is clear that reduced tillage practices and residue retention are promising in improving the soil properties such as SOM as one of the most determinant of soil fertility, productivity and the best of soil quality indicators (Kabirigi et al., 2015), not to mention more but they also enhance SOC stabilization in volcanic soils (Quintero and Comerford, 2013). Thus, the results from short term tillage studies can help us to predict the possible outcomes from them in future and help decision makers to set policies based on them rather than relying on the results from the long run basis which consume much time and cost (Tesfahunegn, 2015). Although our results were able to affirm that the volcanic soils properties improved by reduced tillage, further studies on their correlation with crops performance and yield are needed in order to fully trust them.

Conclusion

In general, our results of the study of reduced and conventional tillage short-term effect on certain chemical and physical properties in volcanic soil of Rwanda show that there is no significant impact of any tillage system on soil organic matter content and soil bulk density despite slightly difference between the values, but tillage systems affected soil pH significantly. Conventional tillage method was found to be better in improving the soil physical properties. This indicated that the soils under reduced tillage were relatively more compact than conventional tillage type but this difference in our study is negligible, since porosity was extremely high in both tillage systems. Conventional tillage system marked the lowest soil organic matter compared to reduced tillage. The results showed that the soil treated by reduced tillage became slightly acidic than conventional tillage; although the difference was statistically significant. Normally, Tillage with minimum disturbance of soil like reduced tillage in our study will improve Soil Organic Matter and Soil Organic Carbon content as the soil properties which indicate the soil fertility but it takes a certain time to accumulate. The results of this study confirmed that reduced tillage is promising and will be used by policy makers and all stakeholders in implementation of soil management policies. On the other hand, researchers are invited to take a part in this subject as it is still abstruse in Rwanda.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Afzalinia S, Zabihi J (2014). Soil compaction variation during corn growing season under conservation tillage. Soil and Tillage Research 137:1-6.

Astier M, Maass JM, Etchevers-Barra JD, Pen˜a JJ, Leo´n Gonza´lez F (2006). Short-term green manure and tillage management effects on maize yield and soil quality in an Andisol. Soil and Tillage Research 88:153-159.

Blake R, Hartge H (1986). Bulk density. Methods of Soil Analysis Part 1 Physical and Mineralogical Methods pp. 363-376.

Blevins L, Thomas W, Cornelius L (1977). Influence of No-tillage and Nitrogen Fertilization on Certain Soil Properties after 5 Years of Continuous Corn. Agronomy Journal 69(3):383-386.

Brouder M, Gomez-Macpherson H (2014). The impact of conservation agriculture on smallholder agricultural yields: a scoping review of the evidence. Agriculture, Ecosystems and Environment 187:11-32.

Craigg L, Howes W (2007). Assessing Quality in Volcanic Ash Soils. Volcanic-Ash-Derived Forest Soils of the Inland Northwest: Properties and Implications for Management and Restoration, pp. 47-66.

Curaqueo G, Acevedo E, Cornejo P, Seguel A, Rubio R (2010). Tillage effect on soil organic matter, mycorrhizal hyphae and aggregates in a mediterranean agroecosystem. Journal of Soil Science and Plant Nutrition 10(1):12-21.

Danielson R, Sutherland P (1986). Porosity. Methods of Soil Analysis. Part I. Physical and Mineralogical Methods pp. 443-461.

Da-Veiga M, Reinert J, Reichert M, Kaiser R (2008). Short and long-term effects of tillage systems and nutrient sources on soil physical properties of a southern brazilian hapludox. The Revista Brasileira de Ciência do Solo 32:1437-1446.

Ferrara M, Mazza G, Muschitiello C, Castellini M, Stellaci A, Navarro A, Lagomarsino A (2017). Short-term effects of conversion to no-tillage on respiration and chemical - physical properties of the soil: a case study in a wheat cropping system in semi-dry environment. Italian Journal of Agrometeorology 1:47-58.

Gbadamosi J (2013). Impact of different tillage practices on soil moisture content, soil bulk density and soil penetration resistance in Oyo Metropolis, Oyo State, Nigeria. Transnational Journal of Science and Technology 3:9.

Habimana S, Karanyoye F, Munyensanga F, Nsanzumuhire A (2015). The influence of time and methods of application of D.I grow on growth and yield on irish potato under Busogo conditions in Rwanda. Merit Research Journal of Agricultural Science and Soil Sciences 3(1):9-17.

Haddaway R, Hedlund K, Jackson L, Kätterer T, Lugato E, Thomsen I, Jørgensen B, Isberg P (2016). How does tillage intensity affect soil organic carbon? A systematic review protocol. Environmental Evidence 5:1-8.

Hulugalle R, Weaver B (2005). Short-term variations in chemical properties of Vertisols as affected by amounts, carbon/nitrogen ratio, and nutrient concentration of crop residues. Communications in Soil Science and Plant Analysis 36:1449-1464.

Imerzoukene S, Van-Ranst E (2002). Une banque de données pédologiques et son S.I.G. pour une nouvelle politique agricole au Rwanda. Mededelingen Derzittingen, Koninklijke Academie Voor Overzeese Wetenschappen, Brussel 47:299-325.

Ji B, Zhao Y, Mu X, Liu K, Li C (2013). Effects of tillage on soil physical properties and root growth of maize in loam and clay in central China. Plant Soil Environment 59:295-302.

Kabirigi M, Musana B, Ngetich F, Mugwe J, Mukuralinda A, Nabahungu N (2015). Applicability of conservation agriculture for climate change adaptation in Rwanda's situation. Journal of Soil Science and Environmental Management 6:241-248.

Kiflu A, Beyene S (2013). Effects of different land use systems on selected soil properties in South Ethiopia. Journal of Soil Science and Environmental Management 4:100-107.

Limousin G, Tessier D (2007). Effects of no-tillage on chemical gradients and topsoil acidification. Soil and Tillage Research 92:167-174.

López-Fando C, Pardo T (2009). Changes in soil chemical characteristics with different tillage practices in a semi-arid environment. Soil and Tillage Research 104:278-284.

Lopez-Garrido R, Madejon E, Leon-Camacho M, Giron I (2014). Reduced tillage as an alternative to no-tillage under Mediterranean conditions: A case study. Soil and Tillage Research 140:40-47.

Manyiwa T, Dikinya O (2014). Impact of tillage types on compaction and physical properties of soils. Soil Environmental Management 33:124-132.

McCauley A, Jones C, Olson-Rutz K (2017). Soil pH and Organic matter. [Online] Available at: http://landresources.montana.edu/nm/documents/NM8.pdf [Accessed 28 May 2017].

Mizota C, Chapelle J (1988). Characterization of Some Andepts and Andic Soils in Rwanda, Central Africa. Geoderma 41:193-209.

Mrabet R, Saber N, El-Brahli A, Lahlou S, Bessam F (2001). Total, Particulate organic matter and structural stability of a calcixeroll soil under different wheat rotations and tillage systems in a semiarid area of Morocco. Soil and Tillage Research 57:225-235.

Neall E (2006). Volcanic Soils. Land Use, Land Cover and Soil Sciences.

Nelson W, Sommers E (1996). Total carbon, organic carbon, and Organic Matter. Methods of Soil Analysis 9:961-1010.

NISR (2015). Fourth Population and Housing Census, Rwanda, 2012, Kigali, Rwanda.

Okalebo R, Gathua W, Woomer L (2002). Laboratory methods of soil and Plant Analysis: A working Manual. Unesco/Rosta.

Oorts K (2006). Effects of tillage systems on soil organic matter stocks and C and N fluxes in cereal cropping systems on a silt loam soil in northern France, Leuven, Belge: Katholieke Universiteit Leuven.

Palm C, Blanco-Canqui H, Dederck F, Gatere L, Grace P (2014). Conservation agriculture and ecosystem services: an overview. Agriculture, Ecosystems and Environment 187:87-105.

Paul I, Black S, Conyers K (2003). Development of acidic subsurface layers of soil under various management systems. Advances in Agronomy 78:187-214.

Pekrun C, Kaul P, Claupein W (2003). Soil tillage for sustainable nutrient management. Soil tillage in agroecosystems (2003):83-113.

Pengthamkeerati P, Motavallic P, Kremer R (2011). Soil microbial biomass nitrogen and β-glucosaminidase activity response to surface compaction and poultry-litter application in a claypan soil. Applied Soil Ecology 51:79-86.

Pittelkow M, Linquist B, Lundya M, Liang X (2015). When does no-till yield more? A global meta-analysis. Field Crops Research 183:156-168.

Powlson S, Stirling C, Jat M, Gerard B, Palm C (2014). Limited potential of no-till agriculture for climate change mitigation. Nature Climate Change 4:678-683.

Quintero M, Comerford B (2013). Effects of Conservation Tillage on Total and Aggregated Soil Organic Carbon in the Andes. Open Journal of Soil Science 3:361-373.

Randy D, Felipe M, Marta A (2008). Encyclopedia of Earth Sciences Series. Encyclopedia of Soil Science pp. 39-46.

Rushemuka N, Bock L, Mowo G (2014). Soil science and agricultural development in Rwanda: state of the art. A review. Biotechnology, Agronomy, Society and Environment 18(1):142-154.

Salem M, Valero C, Muñoz M, Rodríguez M (2015). Short-term effects of four tillage practices on soil physical properties, soil water potential, and Maize Yield. Geoderma 237-238:60-70.

Schlüter S, Großmann C, Diel J, Gi-Mick W, Tischer S (2018). Long-term effects of conventional and reduced tillage on soil structure, soil ecological and soil hydraulic properties. Geoderma 332:10-19.

Shoji S, Nanzyo M, Dahigren A (1993). Volcanic ash soils: Genesis, properties and utilization. Amsterdam Elsevier P 277.

Staley E, Edwards M, Scott L, Owens B (1988). Soil micro biomass and organic component alterations in a no tillage chronosequence. Soil Science Society of America Journal 52:998-1005.

Steyn T, Tolmay P, Human J, Kilian H (1995). The effects of tillage systems on soil bulk density and penetrometer resistance of a Sandy Clay Loam Soil. South African Journal of Plant and Soil 12(2):86-90.

Subbulakshmi S, Saravanan N, Subbian P (2009). Conventional tillage vs conservation tillage - a review. Agricultural Research Communication Centre 30(1)56-63.

Tesfahunegn B (2015). Short-term effects of tillage practices on soil properties under Tef [Eragrostis tef (Zucc. Trotter)] crop in northern Ethiopia. Agricultural Water Management 148:241-249.

Twagiramungu F (2006). Environmental Profile of Rwanda, Kigali Rwanda 78 p.

Uwitonze P, Msanya M, Mtakwa W, Sirikare S (2016). Pedological Characterization of Soils Developed from Volcanic Parent Materials of Northern Province of Rwanda. Agriculture, Forestry and Fisheries 5(6):225-236.

Uwituze C, Rukangantambara H, Lelei J (2017). Effect of Mulch Types and Mineral Fertilizer Rates on Cabbage (Brassica Oleracea var. Capitata) Growth and Yield in the Highlands of Rwanda. International Journal of Plant and Soil Science 17(5):1-15.

Valle R, Carrasco J (2017). Soil quality indicator selection in Chilean volcanic soils formed under temperate and humid conditions. Catena 162 p.

Wang S (2014). Short- and medium-term effects of tillage systems on soil properties and organic spring wheat performance. Wageningen, Netherlands: Wageningen University Research. http://edepot.wur.nl/396645