TILLAGE, SOIL TEXTURE AND MINERALOGY EFFECTS ON SELECTED SOIL PROPERTIES ON FOUR SOIL TYPES IN LIMPOPO PROVINCE, SOUTH AFRICA

BY

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DECLARATION

I, Magagula Siyabonga Isaac, student No: 14005797, hereby declare that this dissertation for the Master of Science (MSc) in Agriculture (Soil Science) degree at the University of Venda, hereby submitted by me, has not been submitted previously for a degree at this or any other university, that it is my own work in design and execution, and that all reference material contained therein has been duly acknowledged.

Signature.................................. Date 21/06/2020

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LIST OF SYMBOLS AND ABBREVIATIONS

C	Carbon
Ca	Calcium
CO_2	Carbon dioxide
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
NT	No till
T	Tilled
CT	Conventional Tillage
AGS	Aggregate Stability
ANOVA	Analysis of Variance
POM	Particulate Organic Matter
NaOH	Sodium hydroxide
Rs	Soil respiration

ABSTRACT

The effects of tillage on soil structure and associated soil properties such as soil respiration may differ in different soils. The study determined the effects of tillage, soil texture and mineralogy in selected soil properties on different soil types. Soil samples were collected from four different sites in the Limpopo province, South Africa. The soils were classified as Glenrosa with sandy loam texture, Dundee with loamy sand, Hutton with clay, and Shortlands with clay. Glenrosa and Dundee were dominated by quartz, while Hutton and Shortlands with kaolinite. Soil samples were taken from the surface 0 – 20 cm under conventional tillage and no-till land. Soil organic matter, texture, and mineralogy were determined. The soils were wetted to activate the microorganisms and incubated for 70 days at 30℃ and soil respiration was determined using alkali trap method on a weekly basis. The study was conducted in triplicates and arranged in a completely randomized design. Data was subjected to analysis of variance using general linear model procedure of Minitab version 19. Means were compared using paired t-test at ($p \leq 0.05$). The Pearson correlation coefficient (r) was used to measure the strength of linear dependence between variables. There was a significant difference in soil organic matter ($p \leq 0.000$) among all studied soils. The mean values of soil organic matter were 2.19% in Hutton, 2.0% in Shortlands, 0.54% in Glenrosa, and 0.43% in Dundee. Quartz had a strong negative linear relationship ($r = -0.66$) with soil organic matter while kaolinite had a strong positive linear relationship ($r = 0.96$). Soil respiration increased in soils dominated with quartz and decreased in soils dominated with kaolinite. The soil respiration increased by 18.95 g CO_2 m^{-2} d^{-1} in conventional tillage and decreased by 13.88 g CO_2 m^{-2} d^{-1} in no-tillage due to increased exposure of soil organic matter under conventional. It was concluded that less intensive tillage such as no-tillage reduces soil respiration.

Keywords: Clay content, CO_2 efflux, soil organic matter, kaolinite, quartz

CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Soil is an important sink to capture and store atmospheric carbon dioxide (CO_2) in the form of organic and inorganic carbon. Fluxes of CO_2 from agricultural soils are the result of complex interactions between climate and several biological, chemical and physical soil properties (Oorts et al., 2007). Soil respiration is sensitive to climatic variability, expressed through soil moisture and temperature. Soil respiration rate is mainly influenced by soil moisture and aeration (Makhado and Scholes, 2011). Soil respiration increases with soil moisture. However, excess soil moisture limits oxygen availability, which interfere with soil organism's ability to respire. Rey et al. (2011) observed that soil water content was the main driving variable of soil respiration. Similarly, Zhou et al. (2012) inferred that reduced soil respiration was intertwined with high soil water content. Tillage influence soil moisture content (Curtin et al., 2000; Al-Kaisi and Yin, 2005) which directly affect CO_2 fluxes from the soil surface.

Soil moisture, the main driver of soil respiration is among others affected by soil texture. Soil texture influence water holding capacity, consequently affecting soil moisture (Wösten et al., 2001, Ghezzehei et al., 2019). Clay particles have a large surface area relative to their volume and therefore have the ability to bind large amounts of water. Sand particles are larger and more spherical and therefore have a lower surface to volume ratio (Buitenwerf et al., 2014). According to Filipovski (1996), the retention of moisture at different tensions is strongly correlated with the content of humus, clay, silt and the mineralogical composition of the clay. Likewise, soil texture also affects soil temperature, another driver of soil respiration. Sandy soils absorb heat very quickly than heavy textured clayed soils. Clay soil carry a greater quantity of water and due to this reason, it warms up very slowly.

Traditionally, conventional tillage is a common practice in South Africa. The adverse impact of soil disturbance by intensive (conventional) tillage on soil structure, concentration of soil organic carbon and faunal activities (Sainju et al., 2009; Curaqueo et al., 2011) is well documented. Tillage disturbs soil aggregates and accelerates the decomposition of soil organic matter (Paustian et al., 2000). Likewise, higher CO_2 emission was reported in tilled soils compared to no-till system (Morris et al., 2004). Bauer et al. (2006) also reported a greater soil CO_2 flux in conventional tillage than in conservation tillage after 25 years. Similarly, Babujia et al. (2010) noted greater CO_2 soil-atmosphere fluxes under conventional tillage than no-tillage.

Soil texture has a strong effect on soil CO_2 efflux. According to Bauer et al. (2006) in conservation tillage, sand content positively correlated with soil CO_2 efflux rate, while a negative correlation was recorded with clay content in the case when the soil was moist. Feiziene et al. (2012) reported 8% higher mean net CO_2 exchange rate on sandy loam higher than on loam soil. Soil organic matter is a key determinant of soil respiration (Birgé, 2013). Decomposition of soil organic matter is of importance for CO_2 exchange between soil and atmosphere (Dan et al., 2016). A small change in the amount of soil carbon stock may result in large impact on the atmospheric carbon dioxide emission (Lal, 2008). According to Baldock and Skjemstad (2000), the magnitude of the physical protection of soil organic matter is mostly influenced by soil texture and mineralogy. These are major determinants of physical and chemical properties of soils (Sumner, 2000). Soil texture influence soil organic matter concentration. Increased clay content increase protection of soil organic matter, by reducing substrate accessibility, of which would reduce soil organic matter decomposition rates, thereby reduce soil respiration (Umar, 2010). Proximity/accessibility of the existing available soil organic matter to microbial decomposers is an important control on soil respiration limits (Dungait et al., 2012). Soil clay minerals play a major role in protecting this organic matter by means of physical and chemical associations (Bolan et al., 2011). Different clay minerals give rise to different pore structure and different geometries of soil aggregates, which together governs the access of organic carbon to microorganisms (Six et al., 2000). Clay types have a strong influence on soil organic matter decomposition. 2:1 clay mineral such as montmorillonite, are characterized by high interlayer surface area and charge, which increases water retention, cation exchange capacity, aggregate formation, and protection of microbial metabolites from decomposers. Whilst 1:1 clay such as kaolinite have lower surface area, hold less water, and would be less protective of carbon metabolites released during the decomposition process. Despite having similar clay content, allophanic and smectitic soils retained more carbon than kaolinitic or vermiculitic soils (Saggar et al., 1999).

Conservation agriculture is gaining acceptance in many parts of the world as an alternative to conventional agriculture. It is considered as an effective technology on sequestering more CO_2 in the soil (Srinivasarao et al., 2015). No-tillage system conserve soil water and reduce temperature because of decreased soil disturbance and increased residue accumulation at the soil surface (Curtin et al., 2002; Al-Kaisi and Yin, 2005). La Scala et al. (2006) recorded higher short-term CO_2 in the conventional tillage plots in some cases like the ones registered in the minimum tillage plots. On the other hand, higher emissions in minimum tillage than in conventional tillage systems have also been observed, which indicates that the effect of soil tillage on soil CO_2 emission could be related to the duration, season, soil type, soil moisture and temperature.

Soil organic matter is important for soil fertility and carbon sequestration. The amount of soil organic matter depends on the rates of input and output. The output is mainly in the form of CO_2 release during decomposition which is governed by a range of factors including tillage and soil properties (Roychand and Marschaner, 2013; Jabro et al., 2008). Soil mineralogy, which is closely linked to soil texture, is a major determinant of physical and chemical properties of soils (Sumner, 2000). Despite the relationship, the combined effect of soil texture and mineralogy on soil respiration under different tillage system have not been adequately addressed.

1.2 Problem statement

Tillage destroy soil structure. The changes in physical properties as well as the mechanical disturbance of aggregates influence soil organisms and the decomposition of soil organic matter. Whereas conservation tillage is known to preserve soil structure. The magnitude of the changes depends on soil type as well as soil texture especially clay and mineralogy. To date, the effect of tillage in soil physical properties is unclear and often contradictory. The effect of tillage on soil structure and associated soil properties such as soil respiration may not be the same in different soils.

1.3 Justification

Traditionally, conventional tillage is a common farm operation in South Africa that breaks down soil aggregates, at the same time conservation agriculture is receiving prominence. The two have a huge impact on soil structure and related soil properties which are key to soil productivity. It is imperative that specific effects of tillage on soil properties that depends on soil structure such as respiration be well understood to address the declining soil productivity.

1.4 Aim and objectives

1.4.1 Aim

To determine the effects of tillage, soil texture and mineralogy in selected soil properties on different soil types

1.4.2 Objectives

(1) To determine the effect of soil texture and mineralogy on soil organic matter in different soil types of Limpopo province

(2) To determine the effects of tillage carbon-dioxide (CO_2) efflux in different soil types of Limpopo province

1.5 Hypothesis

(1) Soil texture and mineralogy has no effect on soil organic matter in different soil type of Limpopo province

(2) Tillage has no effect on carbon-dioxide (CO_2) efflux in different soil types of Limpopo province

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Tillage implements effects on soil properties

Soil physical properties are key to soil productivity. Tillage is one of the fundamental agrotechnical operations in agriculture because of its influence on soil properties, environment, and soil productivity. Tillage embraces a range of operations, these operations are using various types of implements to loosen, invert, and mix the soil, modify the surface configuration, change aggregate size, incorporate materials (fertilisers, manure, crop residues, etc.), eradicate weeds, and form openings for seed placement. The first tillage after the last harvest and usually the most aggressive one is called primary tillage. The mouldboard plough is the most common primary tillage tool in the world. For special applications, there are different types of mouldboard plough including stubble, general purpose, stiff-sod, and slatted plough. Tillage implement vary due to equipment factors (depth and speed of tillage) and soil factors (Unger, 1991). Çarman (1997) noted that different methods produced different yields, which appeared to relate to the soil conditions produced by tillage.

The influence of tillage implements on soil physical properties is significant. Boydas and Turgut (2007) evaluated the effects of different primary implements speeds and their influence on physical properties of loamy soil. The compared tillage implements were mouldboard plough; slatted mouldboard plough, disk plough, chisel plough; and primary tillage+rotary harrow systems (mounted at the back of each primary tillage). The highest aggregate stability (34.78 and 10.5%) was noted under mouldboard plough and lowest (17.16 and 6.08%) under chisel plough+rotary harrow, soil moisture content was high in chisel and chisel+rotary plough. The highest bulk density (1.17 $Mg\,m^{-3}$) was observed under chisel+rotary harrow, while the lowest (1.01 $Mg\,m^{-3}$) was noted under slatted mouldboard plough. Similarly, Carman (1997) used four different treatments (mouldboard plough, rotary tillage, stubble cultivator, and heavy globe disc) to investigate the effect of different tillage tools on soil properties. The author observed higher bulk density (1.7 $Mg\,m^{-3}$) in mouldboard plough and lower bulk density (0.99 $Mg\,m^{-3}$) in rotary tillage at 0-10 cm depth. On the contrary, Parvin

(2012) evaluated the effect of shallow tillage and mouldboard ploughing on some soil physical properties. The author observed a significantly higher bulk density (1.54 $Mg\, m^{-3}$) under mouldboard plough at 35 - 40 cm depth. Likewise, Husnjak et al. (2002) reported higher soil bulk density (1.47 $Mg\, m^{-3}$) in mouldboard plough and lower bulk density (1.38 $Mg\, m^{-3}$) in chisel plough at 0-5 cm depth. In terms of soil moisture, higher soil moisture (27.59%) was recorded in no-tillage and lower soil moisture (23.43%) in mouldboard plough using disc harrow. Aggregate stability can be indicators of the effects of tillage system on soil structure. Well aggregated soils provide better moisture retention, adequate aeration, and good permeability. Aggregate stability is affected by soil tillage implements and agricultural activities which alter the organic matter content and biological activity of the soil. Carter (1996) observed that the aggregates formed by chisel plough were larger than those formed by mouldboard plough.

2.2 Tillage intensity effects on soil properties

Tillage affect soil physical properties and consequently soil productivity. The effect of tillage on soil properties depends on soil type, tillage practice, type of implements, and tillage intensity. Different tillage practices affect soil properties depending on the level of soil disturbance. Conventional tillage is based on intensive tillage practices. The negative impact of tillage on soil properties increased the interest on conservation tillage practices (Casagrande et al., 2015).

Reducing tillage intensity can generally improve biological and physical soil health. Vertical tillage with tine-type implements and no-tillage with direct planters do not invert the soil. These types of conservation tillage decrease the intensity of soil disturbance compared with conventional tillage. Conservation tillage technologies sustain soil structure and the stability of soil aggregates against water and facilitate the protection of the upper soil layer. Nunes et al. (2020) noted a 12.6% and 0.04 $g\, cm^{-3}$ increase in aggregate stability and bulk density, respectively within the topsoil when tillage intensity was reduced from mouldboard plough to no-tillage system and slightly decreased bulk density. Similarly, D’Haene et al. (2008) reported 40% higher aggregate stability under reduced tillage than conventional tillage. Tillage intensity effect on aggregate stability impact soil moisture. Kovac et al. (2005) concluded that soil moisture content was significantly greater under conventional tillage than under reduced and zero tillage systems in a loamy soil. Correspondingly, Karuma et al. (2014) observed higher soil moisture in ox-ploughing (14.10%), followed by subsoiling-ripping (13.43%), disc ploughing and harrowing (13.40%), followed by hand hoeing only (13.33%), hand hoeing with tied ridges (13.27%), and disc ploughing (13.08%).

Soil bulk density is also affected by tillage intensity. Blanco-Canqui et al. (2017) found that bulk density was greater (1.22 $Mg\ m^{-3}$) in soil under more intensive tillage as compared to no tillage (1.19 $Mg\ m^{-3}$). Inversely, Lampurlane and Cantero-Martınez (2003) studied the effect of fallow and tillage on soil properties in deep (Fluventic Xerochrept) and shallow (Lithic Xeric Torriorhnt) soils. Subsoil tillage, minimum tillage and no tillage were compared in the deep soil and no-till and minimum tillage in the shallow soil. In deep soil, the largest bulk density was recorded under no-tillage (1.34 $Mg\ m^{-3}$), followed by minimum tillage (1.27 $Mg\ m^{-3}$) and subsoil tillage (1.22 $Mg\ m^{-3}$). In shallow soil the bulk density was equal (1.10 $Mg\ m^{-3}$) in both tillage system. D'Haene et al. (2008) reported a lower bulk density (1.42$\pm$0.05 $Mg\ m^{-3}$) under reduced tillage as compared to conventional tillage (1.44$\pm$0.09 $Mg\ m^{-3}$) at 5-10 cm. A higher bulk density (1.41 $g\ cm^{-3}$) in minimum tillage than in reduced tillage (1.33 $g\ cm^{-3}$) and conventional tillage (1.36 $g\ cm^{-3}$) at 10-20 cm was also reported by Bogunovic et al (2020). Contrarily, Ozpinar and Cay (2005) reported higher bulk density (1.34 $Mg\ m^{-3}$) in conventional tillage and lower bulk density (1.20 $Mg\ m^{-3}$) in minimum tillage with rototiller at 0-10 cm depth. However, mouldboard plough showed a decreasing trend with depth. At a depth of 14-20 cm, bulk density was higher than at depth of 7-14 cm.

Tillage practices alter soil physical conditions and increase the decomposition rate of soil organic matter. Scholars reported rapid oxidation of soil organic matter with intensive cultivation practices relative to reduced intensity tillage practices. Haddaway et al. (2017) conducted a meta-analyses to investigate the influence of reducing tillage [from high to intermediate intensity, high intensity to no-tillage, and from intermediate intensity to no-tillage] on soil organic carbon concentration and soil organic carbon stock in the upper soil and at lower depths. At 0-15 cm depth, soil organic carbon concentration was significantly higher under no-tillage compared to both intermediate intensity (1.18 g/kg) and high intensity tillage (2.09 g/kg). Intermediate intensity tillage was also noted to be significantly higher (1.30 g/kg) in soil organic carbon concentration than high intensity. At 15-30 cm, intermediate intensity tillage was 0.89 g/kg lower compared to high intensity tillage. Dekemati et al. (2019) quantified the changes in soil physical properties under six tillage (disking, shallow tine cultivation, deep tine cultivation, loosening, mouldboard ploughing +levelling, and no-tillage) treatments on an Endocalcic Chernozem soil. They recorded the greatest soil organic carbon (2.3%) under no-tillage and lowest (1.8%) under mouldboard plough + levelling, at 0-10 cm depth. Likewise, Ozpinar and Cay (2005) evaluated the effect of three tillage system (conventional tillage, minimum tillage with rototiller and disc) on soil properties. They reported higher soil organic carbon (11.5 $g\ kg^{-1}$) in minimum tillage with rototiller, followed by minimum tillage disc (9.5 $g\ kg^{-1}$), and conventional tillage (8.8 $g\ kg^{-1}$). Contrarywise, Bilandžija et al. (2014) reported higher soil organic carbon (31073.6 kg/ha) when ploughing disk and harrowing used as compared to no-tillage system (28746.8 kg/ha). In another study by Blanco-Moure et al. (2016), they reported higher soil organic carbon (11.5 $g\ kg^{-1}$) under conventional tillage and lower (10.6 $g\ kg^{-1}$) under no-tillage at Periaflor CC, higher (11.2 $g\ kg^{-1}$) under native vegetation and lower (10.2 $g\ kg^{-1}$) under reduced tillage Periaflor CF. At Torres de Alcanadre higher soil organic carbon (11.5 $g\ kg^{-1}$) under native vegetation and lower (8.8 $g\ kg^{-1}$) under conventional tillage was noted. At Lanaja, soil organic carbon was higher under no-tillage (10.9 $g\ kg^{-1}$) and lower (8.7 $g\ kg^{-1}$) under native vegetation, and at Artieda soil organic carbon was higher under native vegetation (16.4$g\ kg^{-1}$) and lower under no-tillage (10.2 $g\ kg^{-1}$). Motta et al. (2002) assessed influence of four tillage systems (no-tillage, disk, mouldboard plough, and chisel plough) on chemical soil quality indicators in a Benndale fine sandy loam and a Lucedale very fine sandy loam. They observed higher soil organic carbon under no-tillage (27.6 $g\ Ckg^{-1}$), followed by disc (13.1 $g\ Ckg^{-1}$), chisel (12.7 $g\ Ckg^{-1}$), and mouldboard plough (10.4 $g\ Ckg^{-1}$) in the Benndale soil, similar trend was observed in the Lucedale soil, with no-tillage being 16.7 $g\ Ckg^{-1}$, disc 10.0 $g\ Ckg^{-1}$, chisel 9.8 $g\ Ckg^{-1}$, and mouldboard plough 6.9 $g\ Ckg^{-1}$.

Soil organic carbon are considerably affected by tillage intensity, as results affect soil carbon loss by CO_2 efflux (Yu et al., 2020). The intensity of tillage should be reduced in order to reduce the soil carbon loss. Soil CO_2 emissions are lower in reduced tillage comparing to intensive tillage, since reduced tillage retains more effectively the CO_2 stored in soil aggregates (Wang et al., 2017). Chatskikh et al. (2007) measured the effects of conventional tillage with ploughing to 20 cm, reduced tillage with harrowing to 8–10 cm depth and direct drilling on CO_2 emissions from a loamy sand soil. They observed higher soil CO_2 emission (0.89 0.43 $Mg\ C\ ha^{-1}$) in conventional tillage, followed by reduced (0.72 0.43 $Mg\ C\ ha^{-1}$) tillage, and direct drilling (0.43 $Mg\ C\ ha^{-1}$). Inversely, Bilandžija et al. (2014) evaluated soil carbon loss by soil CO_2 efflux under different tillage treatments (black fallow, ploughing up/down the slope up to 30 cm, ploughing across the slope up to 30 cm, very deep ploughing up to 50 cm, no-tillage, and subsoiling (50 cm) + ploughing (30 cm) across the slope). They reported higher CO_2 emission (24.4 $kg\ ha^{-1}day^{-1}$) under no-tillage and lower (7.9 $kg\ ha^{-1}day^{-1}$) under black fallow. They concluded that their findings were due to maintenance of higher soil moisture at the soil surface and higher biological activity. On the contrary, Bogunovic et al. (2020) reported significantly higher soil CO_2 fluxes (47.9 $kg\ ha^{-1}day^{-1}$) under conventional tillage than reduced tillage (39.1 $kg\ ha^{-1}day^{-1}$) and minimum tillage (41.7 $kg\ ha^{-1}day^{-1}$). Similarly, Buragienė et al. (2015) assessed the effects of tillage systems (deep ploughing using mouldboard plough, shallow ploughing by mouldboard plough, deep cultivation using tines, shallow cultivation by disc harrow, and no-tillage) with different intensities on CO_2 emissions. They recorded higher soil CO_2 (2.18 $\mu mol\ m^{-2}s^{-1}$) under deep ploughing using mouldboard plough tillage system, followed shallow ploughing system using mouldboard plough (1.95 $\mu mol\ m^{-2}s^{-1}$), deep cultivation using tines system (1.96 $\mu mol\ m^{-2}s^{-1}$), shallow cultivation using disc harrow system (1.89 $\mu mol\ m^{-2}s^{-1}$) and the no-tillage system (1.59 $\mu mol\ m^{-2}s^{-1}$).

2.3 Tillage depth effects on soil properties

Tillage depth has an important effect on soil properties and crop yield. Soil loosening by means of deep-tillage systems improves water infiltration, internal drainage, aeration and respiration. However, conventional tillage may increase compaction of soil below the depth of tillage. Different types of tillage systems have different tillage depths and capacity to change soil physical and chemical properties that affect the crop yield and quality (Strudley et al., 2008).

Tillage depth should be kept as low as possible while maintaining good conditions for plant growth. Shallow tillage is one of the several reduced or minimum tillage types and its usual tillage depth is about 10 cm (Carter, 1994). Many studies have examined the effects of the main primary tillage systems, but few have investigated tillage depth as an experimental factor. In an experiment in central Sweden in a weakly-structured silty clay loam soil, mouldboard ploughing with and without liming was compared and aggregate stability was improved in shallow tillage compared to conventional ploughing (Stenberg et al., 2000). Jabro et al. (2010) reported higher soil bulk density (1.57 $Mg\ m^{-3}$) in shallow tillage than in deep (1.54 $Mg\ m^{-3}$) tillage system. Further, slightly greater soil moisture was noted under deep tillage (0.135 g/g) as compared to shallow tillage (0.133 g/g) system. In another study, Jabro et al. (2016) reported that soil bulk density was not influence by tillage in all depths (10, 20, 30 40 cm) under zero tillage, shallow tillage, and deep tillage practices. However, bulk density was significantly lower in deep tillage (1.50 $Mg\ m^{-3}$) than in zero tillage (1.61 $Mg\ m^{-3}$) and shallow tillage (1.59 $Mg\ m^{-3}$). Similarly, soil moisture was not significantly influenced by tillage in any of the four depths.

Alamounti and Navabzadeh (2007) experimented the effect of ploughing depth effect on some soil physical properties. They used three-bottom plough with three depths (shallow ≈ 12 cm, semi-deep ≈ 22, and deep tillage ≈ 32) and four depth of soil (0-10, 10-20, 20-30, 30-40 cm). They observed higher soil bulk density in shallow tillage (1.65 $g\ cm^{-3}$), followed by semi-deep (1.53 $g\ cm^{-3}$), and deep tillage (1.15 $g\ cm^{-3}$). Soil organic carbon at the 0-10 cm depth of shallow tillage was higher than semi-deep and deep by 16 and 54%, respectively. Erbach et al. (1992) assessed the effect of four tillage treatments (no-tillage, chisel plough, mouldboard plough and para plough system) on three soils (poorly drained, medium and fine textured) in Iowa. The results indicated that all tillage tools reduced bulk density to the depth of the tillage. However, after planting, only the soil tilled with para plough remained less dense than before.

Wang et al. (2019) experimented the effect of subsoiling depth on soil physical properties and summer maize. They used four tillage depth which are conventional tillage (25 cm), subsoiling tillage (30 cm), subsoiling tillage (35 cm), and subsoiling tillage (40 cm). Compared with conventional 25 cm, subsoiling tillage 30 cm, subsoiling tillage 35 cm and subsoiling tillage 40cm the mean soil bulk decreased by 4.59, 7.13 and 8.27%, respectively, at the 20–50 cm depth. Raper et al. (2000) evaluated the effect tillage depth, tillage timing, and cover crop on cotton yield, soil strength, and tillage energy requirements. They observed that soil moisture content from the shallow (0 to 0.15 m) no-cover crop treatment (18.1%) was statistically less than the moisture content from the deep (0.15 to 0.30 m) no-cover crop treatment (18.4%) and the shallow (19.8%) and deep (20.0%) values obtained in the cover crop treatments. This was linked to increased evaporation near the surface and/or reduced infiltration in the no-cover crop treatment. Kouwenhoven et al. (2002) also reported that shallow ploughing was generally associated with higher moisture content.

2.4 Soil respiration

Soil is a major biospheric reservoir for carbon, containing globally twice as much carbon as the atmosphere and three times as much as vegetation (Lohila et al., 2003). The carbon is released through a process termed soil respiration. Soil respiration is estimated to contribute about 25% of total anthropogenic carbon dioxide emissions. Agricultural activities contribute CO_2 emission to the atmosphere from fossil-fuel combustion, farm chemical manufacture, and the loss of native soil organic matter (Follet, 2001).

Interest in finding techniques such as the no tillage system that reduce CO_2 emission or increasing CO_2 sequestration has greatly increased in recent years, such as the no tillage system (Pezzuolo et al., 2017). Gonzalez-Sanchez et al. (2019) conducted meta-analysis on carbon sequestration potential of conservation tillage. The authors reported that the potential estimate of annual carbon sequestration in African agricultural soils through conservation tillage amounts to 143Tg of C per year, that is 524Tg of CO_2 per year. This figure represents about 93 times the current sequestration figure. Conservation tillage offers substantial advantages for agriculture and can help to mitigate the effects of climate change (Olson et al., 2014). Lai et al. (2012) evaluated soil respiration of different agricultural and natural ecosystems. Five ecosystems distributed in five adjacent sites were selected, including two artificial ecosystems (winter wheat cropland and *E. angustifolia shelterbelt*) and three natural ecosystems (*P. communis* grassland, *T. ramosissima* scrubland and *H. ammodendron* + *R. soongorica* scrubland). The soil respiration was significantly different among different agricultural and natural ecosystems. Compared with the natural ecosystems, the mean seasonal soil respiration rates of the agricultural ecosystems were 96%–386% higher and agricultural ecosystems exhibited lower CO_2 absorption by the saline/alkaline soil. The major difference between the net carbon dioxide balances of agricultural ecosystems established on different soil types arises from the difference in soil heterotrophic respiration. Lohila et al. (2003) compared the soil respiration rates in peat and two different mineral soils growing barley, grass, and potato. Results showed that the soil respiration in the peat soil was 2-3 times high as that in the mineral soils, varying from 0.11 to 0.36 $mg\ (CO_2)m^{-2}s^{-1}$ in the peat soil and from 0.02 to 0.17 $mg\ (CO_2)m^{-2}s^{-1}$ in the mineral soils.

Important factors affecting soil respiration rate are soil temperature, soil moisture, soil organic carbon quantity and quality, soil texture, which also affect gaseous diffusion in the soil (Lohila et al., 2003). The no-tillage management system can reduce carbon dioxide emission, increasing carbon stock. Tillage has an impact on soil CO_2 emissions. Studies have shown contrasting results where CO_2 emissions have been both decreased and increased by no-till compared with conventional tillage. Table 1 shows the various factors that affect soil respiration.

Table 1. Factors affecting soil respiration

Factor	Effect	References
Soil moisture	Controls microbial activity and rate of soil organic matter decomposition	Ghezzehei et al. (2019)
Soil temperature	Regulate organic matter decomposition	Kirscbaum (2006)
Soil texture	Influence soil water dynamics which in turn affects soil biological and biophysical processes.	Cable et al. (2008)
Soil organic matter	It's a substrate for CO_2 efflux	Lai et al. (2013)
Tillage	Causes structural changes that affect soil porosity, water retention and storage, thus affect aeration which affect CO_2 efflux.	Filho and Tessier (2009)
Land use	Different cropping patterns, such as change in cultivation and in condition of irrigation and drainage, and physical characteristics of the soil.	Fan et al. (2015)

2.5 Conventional tillage effect on respiration

Tillage affects all soil physical conditions, especially porosity. Tillage changes the configuration, continuity, and size of soil pore, which allow greater movement of soil gases through the soils (Reicosky, 2002, Dam et al., 2005). Conventional tillage is the most efficient system to loosen a large volume of soil and to break up dense, massive soil clods into smaller units.

Conventional tillage of virgin soils improves soil aeration, consequently, increase respiration. Khan (1996) studied the effect of five tillage treatments (mouldboard, cultivator, rotary tiller, wedge and zero tillage) on soil oxygen diffusion rate. Among all treatments, the highest oxygen diffusion rate was recorded under mouldboard ($60.51 \times 10^{-8}\ gcm^{-2}min^{-1}$), followed by cultivator ($57.65 \times 10^{-8} gcm^{-2}min^{-1}$), and it was lowest under rotary tiller ($46.29 \times 10^{-8} gcm^{-2}min^{-1}$). Although conventional tillage may generate more short-term macropores in the surface soil than no-tillage; they may not be as continuous down the profile and may be more tortuous (Horne and Sojka, 2002). Agricultural tillage practices may be a significant contributor of CO_2 emission (Albert et al., 2016), but perhaps even more importantly can lead to the loss of soil carbon thus reducing soil quality and productivity (Gesch et al., 2007). Moussadek et al. (2014) quantified the effects of no-tillage and conventional tillage on soil organic carbon stock in three soil types. They noted the highest (31.89 $Mg\ ha^{-1}$) soil organic carbon stock under no-tillage in Verstisols, whereas the average soil organic carbon stock was 29.35 and 27.36 $Mg\ ha^{-1}$under no-till and conventional tillage, respectively. When soils are tilled, organically bound carbon is released, providing substrate for soil organic matter mineralization, nitrification, and denitrification (Pinto et al., 2004; Kassam et al., 2010). Morris et al. (2004) investigated if increasing the surface soil disturbance through tillage significantly increases the soil organic matter oxidation potential. The switchplough and disk had the highest oxidation potential (441 and 403 $nmol\ CO_2\ kg^{-1} soil\ h^{-1}$, respectively), followed by one-transit cultivation (344 nmol $nmol\ CO_2\ kg^{-1} soil\ h^{-1}$). The two-transit cultivations and no-till control had the lowest oxidation potential (249 and 238 $nmol\ CO_2\ kg^{-1} soil\ h^{-1}$soil h^{-1}, respectively).

The magnitude of carbon dioxide loss from soil due to tillage practices is highly related to the frequency and intensity of soil disturbance caused by tillage. Gesch et al. (2007) observed a 33 times and 2.3-fold higher CO_2 loss from the deepest and intermediate tillage treatment, respectively, than that of no tillage, but the shallower tillage was generally not different. Rusu et al. (2016) studied the effects of tillage practices on soil organic carbon and soil respiration. They observed lower soil respiration at no-tillage (315-1914 $mmoli\ m^{-2}s^{-1}$), followed by minimum tillage (318-2395 $mmoli\ m^{-2}s^{-1}$) and is higher in the conventional tillage (321-2480 $mmoli\ m^{-2}s^{-1}$). Soil tillage intensity greatly affects CO_2 emissions released. Krištof et al. (2014) reported 43% where reduced tillage was employed and 114% of this escalation under ploughing. Reicosky (2002) observed substantial short-term losses of CO_2 immediately after mouldboard tillage of mineral soils, with continued flux for at least 40 days. Kainiemi (2014) examined the effects of different tillage practices on short-term soil respiration, the results showed that mouldboard ploughing decreased soil respiration by up to 340 $kg\ ha^{-1}$ compared with no tillage and 140 $kg\ ha^{-1}$ compared with shallow tillage during the 10 days following tillage. Ellert and Janzen (1999) found a 2 to 3-fold increase in CO_2 flux during the first 30 minutes after tillage, but after 6 hours the flux had returned to the base level. Reicosky et al. (2005) also found a large loss of CO_2 during the first five hours following ploughing. Neogi et al. (2014) reported 37.1% CO_2-C increase in conventional tillage system with respect to minimum tillage on cumulative annual basis.

Tillage affects soil microbial activity, organic matter decomposition, and soil respiration (Reicosky, 2002). Mouldboard ploughing loosens and inverts soil and allow rapid carbon dioxide loss and oxygen entry. It also incorporates and mixes residues to enhance microbial decomposition and respiration. Similarly, Rusu et al. (2016) observed low soil respiration at no tillage, followed by minimum tillage and higher soil respiration was observed in the conventional tillage. Krištof et al. (2014) observed increased soil respiration with an increased tillage intensity. Conversely, studies on microbial biomass in no tillage shows stratification pattern and plays an important role in physical stabilization of aggregates and protect carbon from mineralization than conventional tillage (Nyamadzawo et al., 2009). More biomass on soil surface under no tillage consequently increases soil respiration. Table 2 contains a summary of the effects of conventional tillage on respiration.

Table 2. Effects of conventional tillage on respiration.

Effect	Magnitude	References
Improved soil aeration	$60.51 \times 10^{-8}\ gcm^{-2}min^{-1}$	Khan et al. (1996)
Increased soil organic matter oxidation potential	441 and 403 $nmol\ CO_2\ kg^{-1}soil\ h^{-1}$	Morris et al. (2004)
Increased soil respiration	321-2480 $mmoli\ m^{-2}s^{-1}$	Rusu et al. (2016)
Increased soil respiration	114% CO_2	Krištof et al. (2014)
Increased CO_2-C loss	37.1% CO_2-C	Neogi et al. (2014)

2.6 Conservation tillage effect on respiration

Tillage operation typical of conventional tillage lead to intense oxidation rates of soil organic matter (Al-Kaisi and Yin, 2005) which result in the release of substantial amount of CO_2 to the atmosphere (Marinello et al., 2017). Conversely, Lal (2003) observed significant reductions in CO_2 and increased levels of soil organic carbon when conservative soil management techniques have been adopted. No tillage is considered the least invasive conservation agricultural technique and has shown to be the most effective in increasing soil carbon stock, thereby abating CO_2 emissions, at least reducing losses compared to other tillage systems (Pacala and Socolow, 2004; Puget and Lal, 2005, Senthilkumar et al., 2009, Luo et al., 2010). A meta-analysis on impacts of farming on soil organic carbon by Haddaway et al. (2017) reported a significantly higher soil organic carbon in no-till relative to both intermediate intensity [1.18 g/ kg ± 0.34 (SE)] and higher intensity [2.09 g/kg ± 0.34 (SE)] in the upper soil layer (0–15 cm). Intermediate tillage was also found to be significantly higher [1.30 g/kg ± 0.22 (SE)] in soil organic carbon concentration than higher intensity for the upper soil layer (0–15 cm). Al-Kaisi and Yin (2005) noted 19 to 41% lower cumulative soil CO_2 emission under less intensive tillage treatments than mouldboard plough, and it was 24% less for no-tillage with residue than without residue.

Pezzuolo et al. (2017) observed 30% reduction in CO_2 emission when no-tillage method was adopted. Similarly, So et al. (2001) found that adoption of conservation tillage reduced CO_2 emission from the soil by 4.3 Mt per year relative to the release that would occur under conventional tillage. Conversely, Oorts et al. (2007) reported CO_2 emission of 3160 ± 269 and 4064 ± 138 $kg\ CO_2 - C\ ha^{-1}$ in conventional tillage and no-tillage, respectively. The differences in CO_2 emissions in the two-tillage system was intertwined with the soil climatic conditions, and the amounts and location of crop residues and soil organic matter.

2.7 Abiotic factors effect on respiration

Soil respiration results from a complex interaction between biotic and abiotic factors. The rate of soil respiration is essentially controlled by the rate of CO_2 production by biota within the soil but is modified by factors influencing the CO_2 movement out of the soil (Tufekcioglu et al., 2001; Han et al., 2007). A plethora of studies show that soil respiration is sensitive to climatic variability, expressed through soil moisture and temperature (Makhado and Scholes, 2011). Feizeine et al. (2012) investigated net CO_2 exchange rate and drivers (soil water and temperature, air temperature) as affected by soil type and tillage and fertilization. In wet weather conditions, the direct effect of soil water content on net CO_2 exchange rate was negative. The increase in temperature markedly suppressed the positive direct impact of soil water content on net CO_2 exchange rate in dry weather conditions but did not reduce the direct effect of soil water content in normal weather conditions.

Soil moisture is considered as the most influential environmental factor controlling soil surface CO_2 flux (Wiseman and Seiler, 2004, Lopes de Gerenyu et al., 2005). Soil water content controls the decomposition of soil organic matter, root respiration, and microbial activity (Belnap, 2003a; Jassal et al., 2008). Higher soil moisture content usually causes soil respiration increase, while under dry conditions soil CO_2 efflux is lower. In the case of soil water surplus, the total soil CO_2 efflux is reduced, because of limited diffusion of oxygen and subsequent suppression of CO_2 emissions. Fortin et al. (1996) indicated that no-tillage and conventional tillage produced similar CO_2 emissions in a wet year, but in a dry year conventional tillage produced lower CO_2 emissions than no-tillage. Rey et al. (2011) observed that soil water content was the main driving variable of soil respiration. Davidson et al. (2000) analysed seasonal variation in soil water content and soil respiration. The study recorded decreased rates of soil respiration from wet to dry seasons. Similarly, Zhou et al. (2012) inferred that reduced soil respiration was intertwined with high soil water content.

Soil temperature is the best predictor of the dynamics of the soil CO_2 flux rate. An increase in soil temperature accelerates organic matter decomposition, oxidation, microbial and root activity, and carbon mineralization processes, thereby increasing CO_2 emission from the soil (Jabro et al., 2008). Bao et al. (2016) reported increased soil respiration at higher temperature and low soil moisture limited the response of soil respiration to temperature only at high incubation temperature. A high positive correlation between CO_2 emissions and soil temperature was found in natural and agricultural ecosystems (Kudeyarov and Kurganova, 1998). Schaufler et al. (2010) revealed a non-linear increase in CO_2 emissions with temperature increasing.

2.8 Soil texture and mineralogy effect on soil moisture

Soil texture exerts a strong influence on many hydrologic and biogeochemical processes by affecting the ability of soils to retain carbon and water. Soil water holding capacity depend on soil texture and soil organic matter content. Soil organic matter tends to increase as the clay content increases (Rice, 2002). Zhong et al. (2018) compared the responses of soil organic carbon and clay to changes in vegetation and soil properties. The results showed that, from semi-arid to humid regions, soil organic carbon stocks, soil organic carbon, and clay content synchronously increased. However, correlation between soil organic carbon stock and clay content may be scale and climate dependent. Nath (2014) studied soil texture and total organic matter content and its influences on soil water holding capacity of some selected tea growing soils. Sandy clay loam and sandy loam were used. The total organic matter varied from 2.16 to 3.38% with mean value of 2.71%, whereas the water holding capacity ranged from 50.44 to 59.18% with a mean value of 54.41%. The results showed that the soil samples have medium water holding capacity and higher soil total organic matter. It was concluded that soil texture and soil organic matter content had influence on water holding capacity of the tea cultivated soil. Similarly, Hook and Burke (2000) found that soil carbon pools dynamics have strong correlation with both landscape position and soil texture. Giardina and Ryan (2000) reported that decomposition rate of organic matter decreases with decreasing particle size. The latter suggests that as particle size decreases, organic matter decomposition also decreases and hence a decrease in water holding capacity. Clay particles have a large surface area relative to their volume and therefore have the ability to bind large amounts of water. Sand particles are larger and more spherical and therefore have a lower surface to volume ratio (Buitenwerf et al., 2014). According to Filipovski (1996), the retention of moisture at different tensions is strongly correlated with the content of humus, clay, silt and the mineralogical composition of the clay.

2.9 Soil texture and mineralogy effect on soil temperature

Soil temperature is an important but often overlooked variable, affecting root growth, water and nutrient uptake, root metabolism, microbial activity, decomposition of organic matter, soil chemistry, and soil moisture levels. Soil texture has important role in temperature variation because each type of soil is made of unique textural characteristics. Sandy soils warm up more rapidly in the spring than do clay soils. Akter et al. (2015) reported 10ºC higher in sandy soil than clay soil around midday hours. Nwankwo and Ogagarue (2012) observed mean soil temperature range from 27.7℃ to 28.9℃ for clay soil, 28.2℃ to 29.1℃ for sandy soil and 28.3℃ to 29.0℃ for the loamy soil. This was due to lower heat capacity, lower thermal conductivity, and less evaporative chilling.

Soil temperature is also affected by soil moisture. Soil moisture is among other things is influenced by a clay content and mineralogy. The latter are key determinants of soil crusting. The tendency of a soil to form a crust increases with an increase in clay content (Kay and Angers, 2000, Boix-Fayos et al., 2001). Crusts affect many soil surface properties and processes, such as infiltration, runoff thereby affect soil moisture.

Soil temperature can be summarised within the context of thermal conductivity, heat capacity and thermal diffusivity. The thermal conductivity is influenced by the actual composition of the solid fraction – the type of minerals, size of the soil constituents and the amount of organic substances. Abu-Hamden and Reeder (2000) reported a decrease in thermal conductivity in connection with increasing amounts of organic substances. More-so, they confirmed that with the same water content sandy soil always had a higher thermal conductivity than sandy loam, clay loam or clay. Increased bulk density and soil moisture increases the differences in thermal conductivity between sandy soils and other soils. According to Tarnawski and Leong (2000), a significant increase in the thermal conductivity begins from a moisture content of 0.02-0.26 cm^3/cm^3.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Site description

The study was conducted at the University of Venda laboratories. Soil sampling was done in selected sites in Limpopo Province, South Africa. The sampling sites include Ha-Davhani, Tshamutore, Thohoyandou (University of Venda), and Mukula. The approximate altitude, latitude and longitude of each sites is shown in Table 3. Each site was under conventional tillage and no-tillage system. Under conventional tillage in Ha-Davhana and Mukula soils were tilled using disc plough followed by a hand hoe to prepare a proper seedbed and fertilizer was applied at planting. Under no-tillage system, the soils were left undisturbed from harvest to planting and stalks were left on the surface after harvesting. During planting, a small hole is opened with a stick to deposit a seed and no fertilizer is applied. Under conventional tillage in Tshamutore, soil was cultivated using a mouldboard plough, and hand hoes were used to create a proper soil tilth for seeding. Under no-tillage system, the soil was left undisturbed and planting was done direct into residues and stubble of previous crops. Like Ha-Davhani and Mukula, the University of Venda soil was tilled with a disc plough, hand hoes and rakes were used to prepare a seedbed. Under no-tillage system, soil was not tilled except where is necessary to place the seed in the soil, and leaves were used as mulch. Soil classification was done according to according to South African system of soil classification (Soil Classification Working Group, 1991) and their equivalent with World Reference Base for Soil Resources (WRB, 2006). The geographical location of the sampling sites is as shown in the Figure 1.

Table 3. Location description

	Soil Classification		Latitude	Longitude	Altitude
Location	**SA**	**WRB**	**(S)**	**(E)**	**(m)**
Ha-Davhani	Glenrosa	Leptosols	23° 13' 09''	30° 27' 25''	540
Tshamutore	Dundee	Fluvisols	22° 37' 30''	30° 40' 32''	886
University of Venda	Hutton	Ferrasols	22° 58' 48''	30° 26' 13''	596
Mukula	Shortlands	Luvisols	22° 51' 13''	30° 34' 44''	592

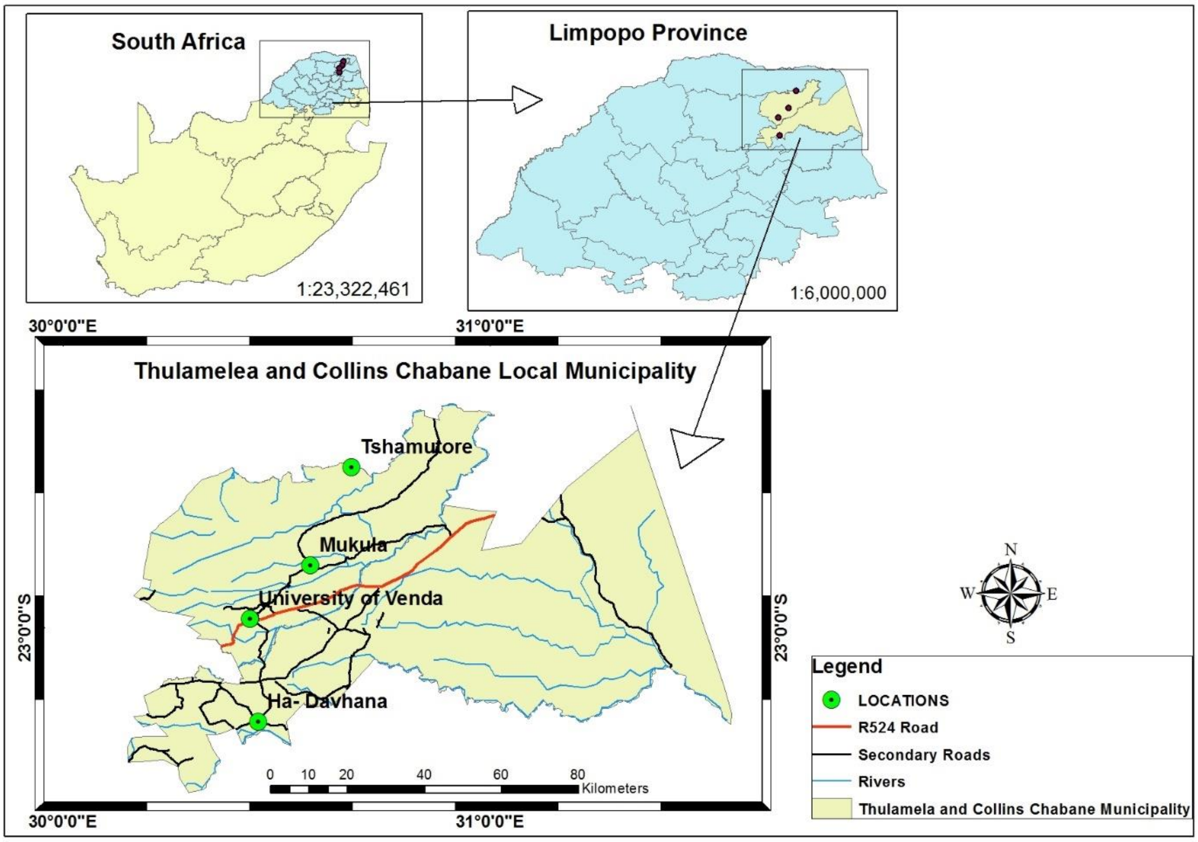

Figure 1: Soil sampling sites

3.2 Soils

Four commonly cultivated soil forms (Soil Classification Working Group, 1991) were used in this study. Their equivalent soil type (WRB, 2006) is provided in brackets.

Glenrosa (Leptosols)

The Glenrosa form has an Orthic A horizon overlying a Lithocutanic B horizon. These soils are generally shallow and have a variable fertility and water holding capacity based on the rock type which they are derived. Has a general organization in respect of colour, structure or consistency that has distinct affinities with the underlying parent rock. It is of a cutanic character expressed usually as tongues or prominent colour variations caused by residual soil formation and illuviation resulting in localization of one or more of clay, iron and manganese oxides. If the horizon shows signs of wetness, then more than 25% by volume has saprolitic character.

Hutton (Ferrasols)

The Hutton form consists of an Orthic A horizon on a red apedal B horizon overlying unspecified material. They are characterised by reddish uniform soil colour and weak structure in which water stagnation does not take place and they are very deep. This soil is clay enriched and reflecting oxidic mineralogy in association with a predominantly kaolinitic clay mineral assemblage. This criterion is only invoked in borderline cases of structure development, however, which means that light textured variants may still contain significant components of 2:1 phyllosilicate (e.g mica, illite) in the clay fraction.

Shortlands (Luvisols)

The shortlands form consist of an Orthic A horizon on a red structured B horizon. The structure of B horizon is more develop and the soils are well drained and aerated with good infiltration rate and low erosion hazard. It is usually more clayey and/or contain more smectitic clay than its counterparts, although kaolinite dominance of the clay fraction is still common.

Dundee (Fluvisols)

The Dundee form consist of Orthic A horizon overlying a stratified alluvium. These soils are generally deep, have a variable fertility (generally fertile) and water holding capacity depending on the texture, which is highly variable. The physical properties are good, and well drained with moderate erosion hazard.

3.3 Soil sampling

Soil sampling was conducted in May/June 2019. Glenrosa, Hutton, Shortlands, and Dundee soils were studied. Glenrosa soil was collected in Ha-Davhana, Dundee, Hutton and Shortlands was collected in Tshamutore, University of Venda, and Mukula, respectively. For each soil type, samples were collected from conventional tillage and conservational agriculture system. Soil samples were collected from 0-20 cm depth, air dried for a week and sieved using a 2 mm sieve to eliminate foreign material. Twenty soil samples were taken from each site using a spade and mixed to make one composite soil sample for both characterisation and soil respiration. The soil was transported to the University of Venda laboratory.

3.4 Soil analysis

Soil pH was measured in water at a soil: water ratio of 1:2.5 using a pH meter after shaking the suspensions for 30 min and equilibration for 30 minutes (Okalebo et al., 2000). Particle size distribution was determined using the hydrometer method after oxidising soil organic matter with hydrogen peroxide as described by Gee and Or (2002). Total porosity was determined using soil bulk and particle density. Air filled porosity was determined by the difference between total porosity and volumetric water content. Aggregate stability was determined according to the method developed by Kemper and Rosenau (1986). Soil mineralogy was determined by the Rietveld method for x-ray diffraction quantitative analysis as described by Zabala et al. (2007). Briefly, after milling, the samples were prepared using the back-loading method. They were analysed with a PANalytical X’Pert PRO powder diffractometer with a X’celerator detector and variable divergence and fixed receiving slits with Fe-filtered Co-KD radiation. The phases were identified using X’Pert Highscore Plus software. The relative phase amounts (weights %) were then estimated using the Rietveld method.

3.5 Soil organic matter

Soil organic matter was determined using the weight loss on ignition procedure as described by Cambardella et al. (2001). The samples were oven dried at 105℃ overnight, the weight was recorded after cooling. Thereafter, samples were left in the oven for 4 hours after the oven temperature reached 450 degrees Celsius. After ignition, the samples were cooled in a desiccator containing ascarite. After cooling, the ignited sample weight was recorded, and the amount of total soil organic matter was calculated as follows:

$$SOM = \left(\frac{Wt.at\ 105℃ - Wt.after\ 4h\ at\ 450℃}{Wt.at\ 105℃}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

3.6 Particulate organic matter

Particulate Organic Matter (POM) was determined using the weight loss on ignition procedure as described by Cambardella et al. (2001). Briefly, 30 g of soil was dispersed in 100 ml of 5 g/L sodium hexametaphosphate for 18 h on a reciprocating shaker at 120 reciprocations per minute. The dispersed soil samples were passed through a 0.053 mm sieve, washed with deionised water until the rinsate was clear and backwashed into an evaporation dish and dried at 55 °C for 24 hours. The oven-dried sand particles plus POM were placed in dry porcelain crucibles and heated in a muffle furnace at 450 °C for 4 hours. After cooling, the amount of POM was determined as follows:

$$POM = \left(\frac{Weight\ at\ 55℃ - Weight\ after\ 4h\ \ at\ 450℃}{Weight\ at\ 55℃}\right) \times 100 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

3.7 Incubation experiment

Soil samples for respiration were moistened to activate the microorganisms. The soils were transferred in beakers covered with a thin needle perforated foil to ensure gas exchange and stored in an incubation chamber at a temperature of 30℃. The water content of the samples was readjusted according to weight after they had lost not more than 10% of their initial moisture. The soils were incubated for periods of 0, 1, 3, 7, 14, 21, 28, 42, 56, and 70 days (Danga et al., 2013).

3.8 Soil respiration

Soil respiration was determined using alkali traps by absorbing CO_2 released from the soil into a sealed jar for a specific time using sodium hydroxide (NaOH) solutions (Rowell, 1994). 50 g of moistened soil was weighed into a Mason jar which had a 100 ml vial containing 10 ml 0.3 M NaOH to absorb CO_2. Samples were incubated at 25°C for 24 hours. At the end of the adsorption period, the total mass of CO_2 in the alkali traps was determined by titrating the NaOH solutions with a standard acid 0.1 M HCL to a set pH value after the carbonate had been precipitated with $BaCl_2$. The rate of CO_2 emission from the soil was calculated from the difference between the sample and a blank sample without soil. The equations used to calculate CO_2 rate are shown below.

$$2NaOH + CO_2 = Na_2CO_3 + H_2O \ldots \ldots \quad (3)$$

$$Na_2CO_3 + BaCl_2 = BaCO_3 + 2NaCl \ldots \ldots \quad (4)$$

$$NaOH + HCl = NaCl + H_2O \ldots \ldots \quad (5)$$

3.9 Data analysis

The data generated was subjected to analysis of variance (ANOVA) using general linear model, conducted by means of Minitab statistics version 19 software (Meyer and Krueger, 2004). The experimental model used in this study was completely randomized design with three replicates, tillage and soil type being the treatments. Means comparison was carried out using t-test for paired observations at significant level of 0.05. Principal component analysis was used to determine the relationships between soil organic matter, particulate organic matter, texture and mineralogy. The Pearson product moment correlation coefficient (*r*) was used to measure the strength of linear dependence between variables.

CHAPTER 4

4.0 RESULTS

4.1 Soil texture and mineralogy

The soil types were classified as Glenrosa in Ha-Davhani, Dundee in Tshamutore, Hutton in the university of Venda, and Shortlands in Mukula, with textural classes of sandy loam, loamy sand, and clay in both Hutton and Shortlands soils, respectively. The pH varied from moderately acidic with a pH of 6.4 in Hutton soil, to a strong acidic pH of 4.7 in Dundee. In terms of mineralogy, quartz was present in all the soils with the highest amount of 99.8% in Dundee soil. Amounts of 49.2 and 53.9% kaolinite were also noted in Hutton and Shortlands soils, respectively. There were other minerals present as shown in Table 4. However, smectite was noticeably absent.

Table 4. Taxonomy, textural class, and soil mineralogy.

Soils	Texture (%)			Textural class	pH	Soil Mineralogy (%)							
	Sand	Clay	Silt			Q	H	Ana	K	Mg	Mi	Alb	Cor
Glenrosa	74	11	15	SL	6.17	38.7	-	-	-	-	21.9	37.1	2.3
Dundee	77.33	6.33	16.33	LS	4.72	99.8	0.2	-	-	-	-	-	-
Hutton	30	40	30	Clay	6.40	32.8	14.7	1.9	49.2	1.4	-	-	-
Shortlands	24	53.67	22.33	Clay	6.04	37	6.8	1.9	53.9	0.5	-	-	-

Q= Quartz, H= Hematite, Ana= Anatase, K=Kaolinite, Mg= Magnetite, An= Anorthite, Mi= Microcline, Alb= Albite, Cor= Cordierite, SL= Sandy loam, LS= Loamy sand

4.2 Soil type effects on soil organic matter, particulate organic matter, and aggregate stability

The effect of soil type on soil organic matter, particulate organic matter, aggregate stability, and bulk density is shown in Table 5. The effect of soil type on soil organic matter was significant at ($p<0.05$). Soil organic matter was higher (2.19%) in Hutton soil and significantly lower (0.43%) in Dundee soil. The effect of soil type on particulate organic matter was significant at ($p<0.05$). Particulate organic matter was greater in Shortlands with 1.52% and lower in Glenrosa with 0.44%. The effect of soil type on aggregate stability was significant at ($p<0.05$). Aggregate stability was significantly higher in Hutton and Shortlands soils, with 55.32 and 53.53%, respectively, whilst significantly lowest (15.46%) was noted in Glenrosa soil. Bulk density was significant at ($p\leq0.05$). Significantly higher bulk density (1.48 $\mathrm{g\ cm^{-3}}$) and significantly lower (1.11 $\mathrm{g\ cm^{-3}}$) bulk density was noted in Dundee and Shortlands soil, respectively.

Table 5. Soil type effect on soil organic matter, particulate organic matter, aggregate stability, and bulk density.

Soils	**SOM (%)**	**POM (%)**	**AS (%)**	**Bulk density ($\mathrm{g\ cm^{-3}}$)**
Glenrosa	0.54b	0.44b	15.46c	1.29b
Dundee	0.43b	0.66b	31.18b	1.48a
Hutton	2.19a	0.54b	55.32a	1.21c
Shortlands	2.00a	1.52a	53.53a	1.11d
P value	0.000	0.006	0.000	0.000

The different letter indicate means were significantly different. SOM = Soil organic matter, POM = Particulate organic matter, AS = Aggregate Stability.

4.3 Tillage effects on soil organic matter, particulate organic matter, and aggregate stability.

The effect of tillage effect on soil organic matter, particulate organic matter, aggregate stability, and bulk density is shown in Table 6. Soil organic matter was significantly different ($p<0.05$) between no-till and conventional tillage system (Table 6). No-till had significantly higher soil organic matter (1.41%), whilst conventional tillage was significantly lower (1.17%). There was no significant difference ($p>0.05$) in particulate organic matter between the two tillage systems. Significant difference ($p\leq0.000$) was noted on the aggregate stability. Significant difference ($p<0.05$) was noted on bulk density. Conventional tillage recorded significantly higher (1.3 $\mathrm{g\,cm^{-3}}$) bulk density.

Table 6. Tillage effect on soil organic matter, particulate organic matter, aggregate stability, and bulk density.

Tillage	**SOM (%)**	**POM (%)**	**AS (%)**	**Bulk density ($\mathrm{g\,cm^{-3}}$)**
NT	1.41a	0.94a	42.97a	1.24b
CT	1.17b	0.64a	34.78b	1.30a
P value	0.032	0.155	0.000	0.017

The different letter indicate means were significantly different. SOM = Soil organic matter, POM = Particulate organic matter, AS = Aggregate Stability, NT = no-till, CT = conventional tillage.

The combined effect of soil type and tillage on soil organic matter, particulate organic matter, aggregate stability and bulk density is shown in Table 7. The effect of soil type and tillage on organic matter, particulate organic matter, and aggregate stability was not significantly different at ($p>0.05$). Higher soil organic matter was noted under no-tillage. Mean analysis of soil organic matter was significantly higher (2.41%) in the Hutton soils under no-tillage and significantly lowest (0.36%) in Dundee soils under conventional tillage. Likewise, higher particulate organic matter was noted under no-tillage but there was no significant difference amongst the soils. Greater aggregate stability was noted under no-tillage and was significantly higher (60.63%) in Hutton soil, whilst Glenrosa under conventional tillage was significantly lower (13.93%). The soil type and tillage effect on bulk density was significantly different ($p<0.05$). Higher bulk density was noted under conventional tillage. Higher bulk density (1.52 $\mathrm{g\,cm^{-3}}$) was noted in the Dundee soil under conventional tillage, whereas lower (1.09 $\mathrm{g\,cm^{-3}}$) bulk density was noted in the Shortlands soils under no-tillage.

Table 7. Effect of soil type and tillage on soil organic matter, particulate organic matter, aggregate stability, and bulk density.

Soils	**SOM (%)**		**POM (%)**		**AS (%)**		**Bulk density $(\mathrm{g\ cm^{-3}})$**	
	NT	**CT**	**NT**	**CT**	**NT**	**CT**	**NT**	**CT**
Glenrosa	0.57b	0.51b	0.46a	0.42a	16.67de	14.25e	1.32bc	1.27cd
Dundee	0.49b	0.36b	0.90a	0.42a	36.46c	25.91cd	1.43ab	1.52a
Hutton	2.41a	1.96a	0.63a	0.45a	60.63a	50.01ab	1.13de	1.28c
Shortlands	2.17a	1.84a	1.77a	1.27a	58.10ab	48.97b	1.09e	1.12e
Soils * Tillage	0.541		0.805		0.243		0.017	

The different letter indicate means were significantly different. SOM = Soil organic matter, POM = Particulate organic matter, AS = Aggregate Stability, NT = no-till, CT = conventional tillage.

4.4 Relationship between soil organic matter, particulate organic matter, soil texture, and mineralogy.

Correlation coefficients between all variable are presented in Table 8. Soil organic matter had a strong positive linear relationship with magnetite (r = 0.85), anatase (r = 0.96) kaolinite (r = 0.96), hematite (r = 0.90), and clay (r = 0.88). In contrast, quartz, cordierite, albite and microcline had a strong negative linear relationship with correlation coefficients of r = -0.66, r = -0.50, r = *-0.50* and r = -0.50, respectively. Particulate organic matter had a strong positive linear relationship with both clay (r = 0.74) and kaolinite (r = 0.54). Although, the relationship between particulate organic matter and hematite was positively linear it was, however, weak (r = 0.14). In contrast, quartz and particulate organic matter had a weak negatively linear relationship (r = -0.27).

Table 8. Correlation coefficients estimated between soil organic matter, particulate organic matter, texture, and mineralogy.

	POM	SOM	Mg	Cord	Albite	Ana	Mi	K	H	Q
SOM	0.42									
Magnetite	0.03	0.85								
Cordierite	-0.29	-0.50	-0.48							
Albite	-0.29	-0.50	-0.48	0.10						
Anatase	0.51	0.96	0.81	-0.57	-0.57					
Microcline	-0.29	-0.50	-0.48	0.10	0.10	-0.57				
Kaolinite	0.54	0.96	0.79	-0.58	-0.58	0.98	-0.58			
Hematite	0.14	0.90	0.99	-0.52	-0.52	0.87	-0.52	0.85		
Quartz	-0.27	-0.66	-0.54	-0.29	-0.28	-0.61	-0.28	-0.61	-0.56	
Clay	0.74	0.88	0.62	-0.47	-0.48	0.93	-0.47	0.96	0.70	-0.63

Mg = Magnetite, Cord = Cordierite, Ana = Anatase, Mi = Microcline, K = Kaolinite, H = Hematite, Q = Quartz

Principal components analysis was used to generate eigenvalues corresponding to each principal component as shown in Figure 2, Tables 9, and 10. The values represent a partition of the total variation in the multivariate mode. In this study, principal components 1, 2, and 3 explained about 98% (64.3%, 22.6%, and 11.4%, respectively) of the variation (Table 9). These three components had eigenvalues >1 and hence explained most of the variation. A two-factor loading was considered. The two-dimensional loadings plot (Figure 2) shows the relationships between some of the measured variables. The loadings plots showed that quartz, microcline, albite, and cordierite are correlated.

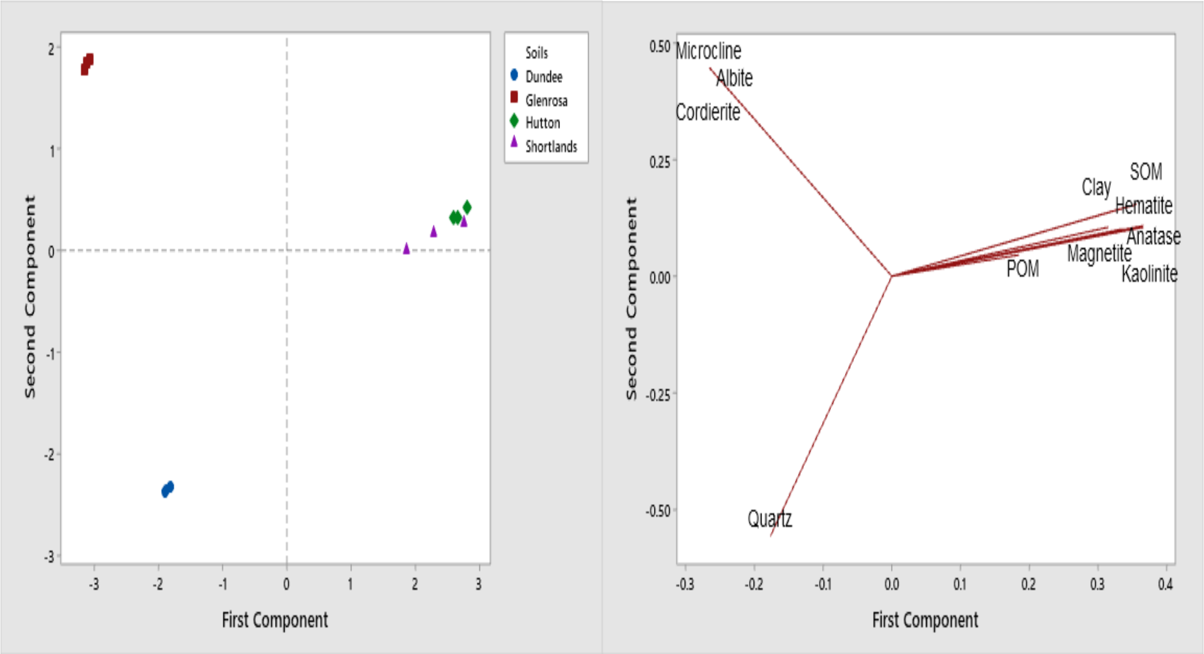

Figure 2. Two-dimension relationship between soil organic matter, particulate organic matter, soil texture, and mineralogy between component 1 and 2

Table 9. Eigenvalues and percentage of principal component analysis

Component	**Eigenvalue**	**Proportion of variance (%)**	**Cumulative variance (%)**
1	7.0782	64.3	64.3
2	2.4914	22.6	87
3	1.253	11.4	98.4
4	0.0991	0.9	99.3
5	0.049	0.4	99.7
6	0.0198	0.2	99.9
7	0.0051	0.000	100
8	0.0028	0.000	100
9	0.0016	0.000	100
10	0.0001	0.000	100
11	0.0000	0.000	100

Table 10. Loading of principal components 1 and 2

Variable	Principal component 1	Principal Component 2
POM	0.185	0.046
SOM	0.356	0.154
Magnetite	0.315	0.105
Cordierite	-0.266	0.447
Albite	-0.266	0.447
Anatase	0.366	0.108
Microcline	-0.266	0.447
Kaolinite	0.366	0.105
Hematite	0.336	0.101
Quartz	-0.177	-0.557
Clay	0.34	0.147

SOM = Soil organic matter, POM = Particulate organic matter

4.5 Soil type effects on carbon dioxide efflux

Carbon dioxide efflux was significantly different ($p \leq 0.000$) across all soils (Table 11). Dundee had significantly higher (34.03 g CO_2 m^{-2} d^{-1}) carbon dioxide efflux, whilst Hutton soil had the least carbon dioxide efflux (9.25 g CO_2 m^{-2} d^{-1}) which was not significantly different from Hutton and Glenrosa soils.

Table 11. Soil type effect on carbon dioxide flux

Soils	CO_2 efflux (CO_2 m^{-2} d^{-1})
Glenrosa	12.55b
Dundee	34.03a
Hutton	9.25b
Shortlands	9.83b
P value	0.000

The different letter indicate means were significantly different.

4.6 Tillage effect on carbon dioxide efflux

Carbon dioxide efflux was significantly different ($p \leq 0.05$) in both tillage system. Conventional tillage had a significantly higher (18.95 g CO_2 m^{-2} d^{-1}) carbon dioxide efflux as compared to no-till system (13.88 g CO_2 m^{-2} d^{-1}) (Table 12).

Table 12. Tillage effect on soil carbon dioxide efflux

Tillage	**CO_2 efflux** (CO_2 m^{-2} d^{-1})
NT	13.88b
CT	18.95a
P value	0.047

The different letter indicate means were significantly different. NT = no-till, CT = conventional tillage

The interaction of soil type and tillage is shown in Table 13. The effect of both soil type and tillage on CO_2 efflux was not significantly different at ($p>0.05$). The highest soil CO_2 efflux was noted under conventional tillage in all soils than in no-till. Dundee had a significantly higher (38.81 g CO_2 m^{-2} d^{-1}) CO_2 efflux among all soils under conventional tillage. Hutton, Shortlands, and Glenrosa had significantly lower CO_2 efflux under no-tillage system than Dundee.

Table 13. Effect of soil type and tillage on soil carbon dioxide efflux

Soils	**Tillage system**	
	NT	**CT**
Glenrosa	10.99c	14.11bc
Dundee	29.25ab	38.81a
Hutton	7.37c	11.13c
Shortlands	7.90c	11.75c
P value	0.783	

The different letter indicate means were significantly different. NT = no-till, CT = conventional tillage

The trend of CO_2 evolution in the Glenrosa soil over the 70-day period is shown in Figure 3. Rates of CO_2 evolution in the no-till and conventional tillage system increased from day 1, and a peak was observed at days 3. The CO_2 evolution slowly decreased with time until day 14, followed by a significant increase at day 28. The rates declined slowly and gradually approached a constant value after day 42. At peak evolution (day 3), the amounts of CO_2 released under-till and conventional tillage were 19.3 and 24.07 g CO_2 m^{-2} h^{-1}, respectively.

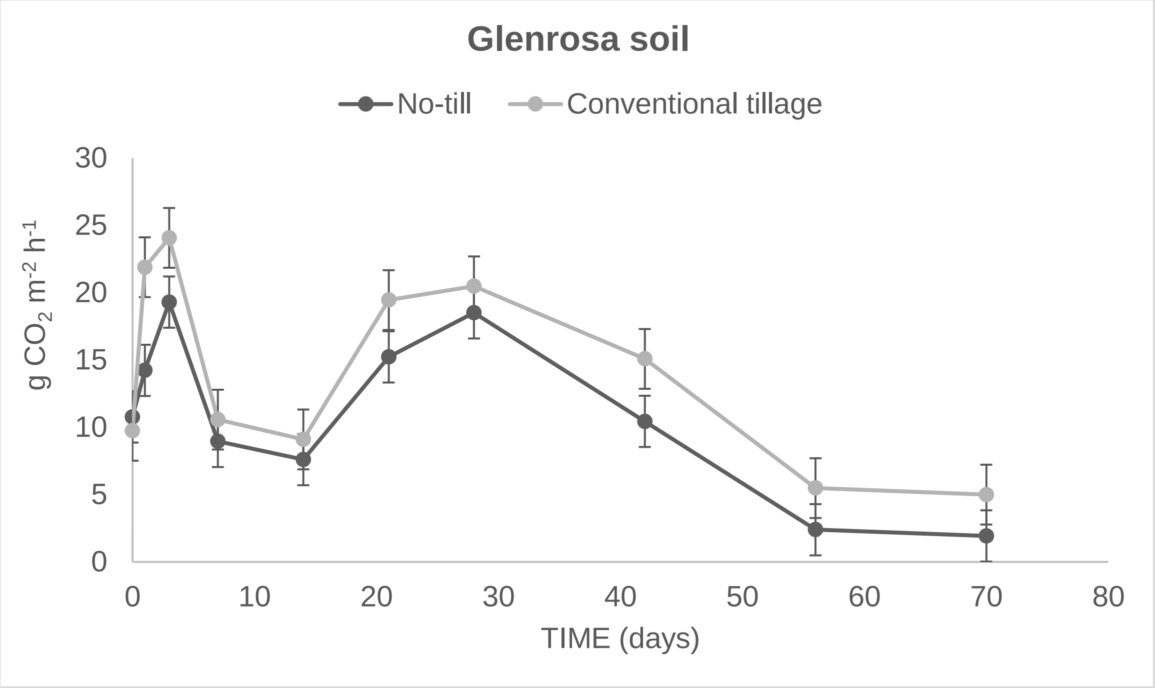

Figure 3. Rate of carbon dioxide evolution on Glenrosa soil under no-till and conventional tillage system. Bars indicate standard error

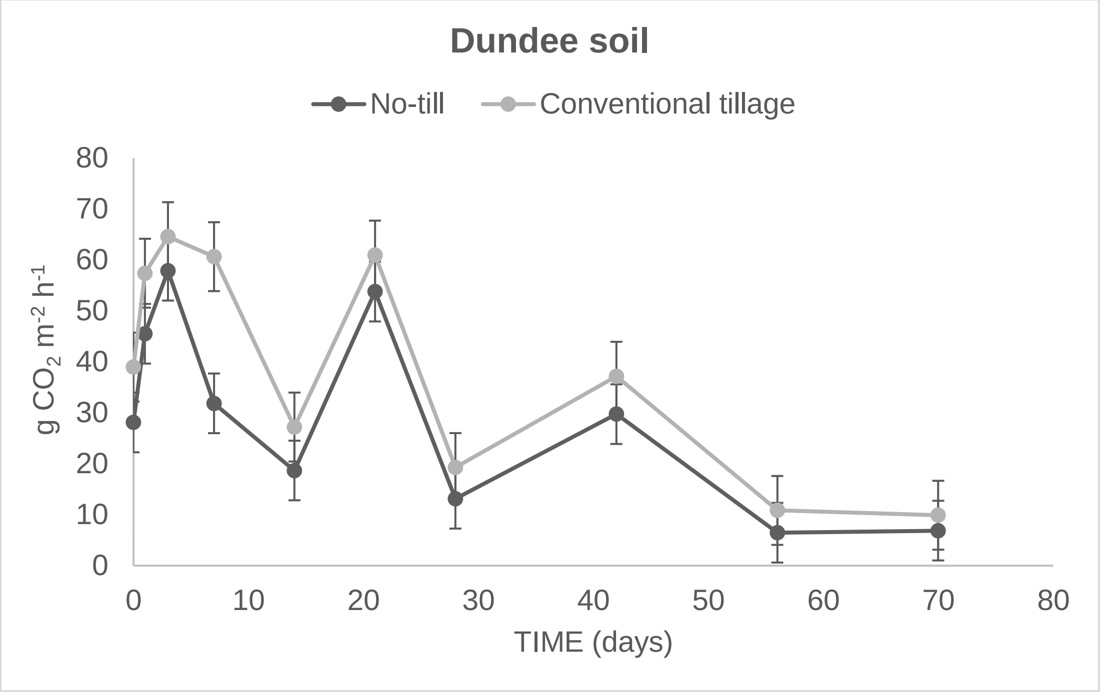

Figure 4. Rate of carbon dioxide evolution on Dundee soil under no-till and conventional tillage system. Bars indicate standard error

The trend of CO_2 evolution in the Dundee soil over the 70-day period is shown in Figure 4. Peak evolution of CO_2 in Dundee soil was attained on day 3 under both no-till and conventional tillage system. The CO_2 evolution decreased rapidly with time until day 14, followed by a significant increase at day 21. The rates declined slowly and gradually approached a constant value after day 42. At peak evolution (day 3), the amounts of CO_2 released under-till and conventional tillage were 57.89 and 64.58 g CO_2 m^{-2} h^{-1}, respectively.

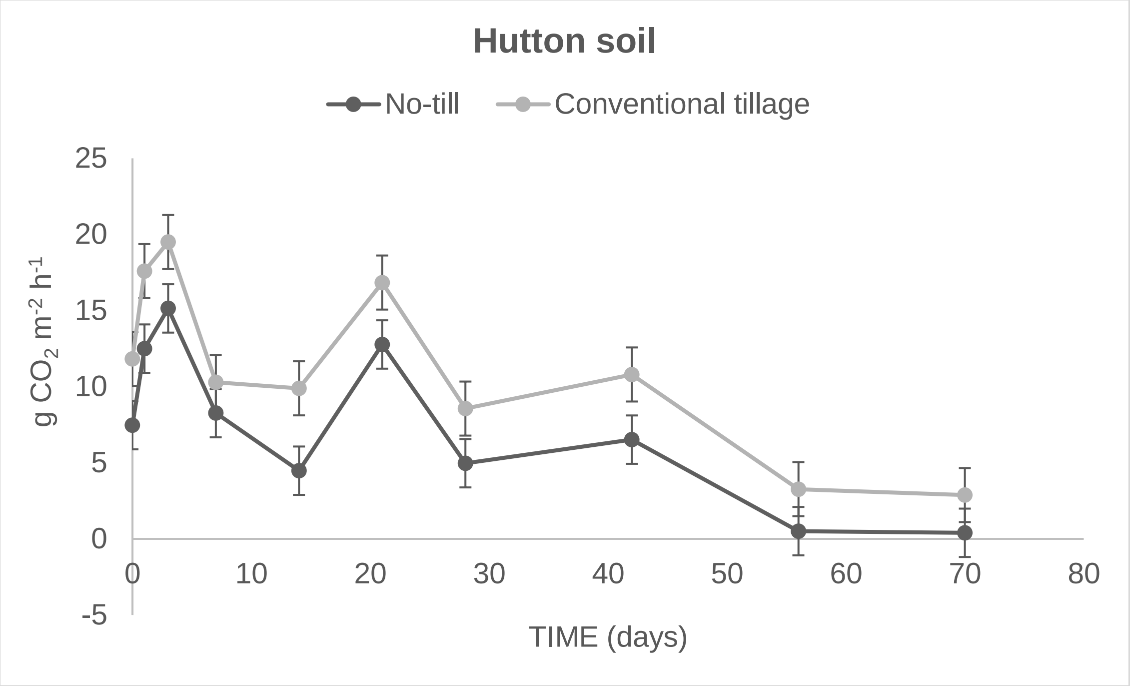

Figure 5. Rate of carbon dioxide evolution in the Hutton soil under no-till and conventional tillage system. Bars indicate standard error

The trend of CO_2 evolution in the Hutton soil over the 70-day period is shown in Figure 5. Peak evolution of CO_2 in the Hutton soil was observed on day 3 under both no-till and conventional tillage system with CO_2 rates of 15.14 and 19.5 g CO_2 m^{-2} h^{-1}, respectively. The rates declined slowly and gradually approached a constant value after day 56 with the rate of 0.51 and 3.27 g CO_2 m^{-2} h^{-1} was observed under no-till and conventional tillage, respectively.

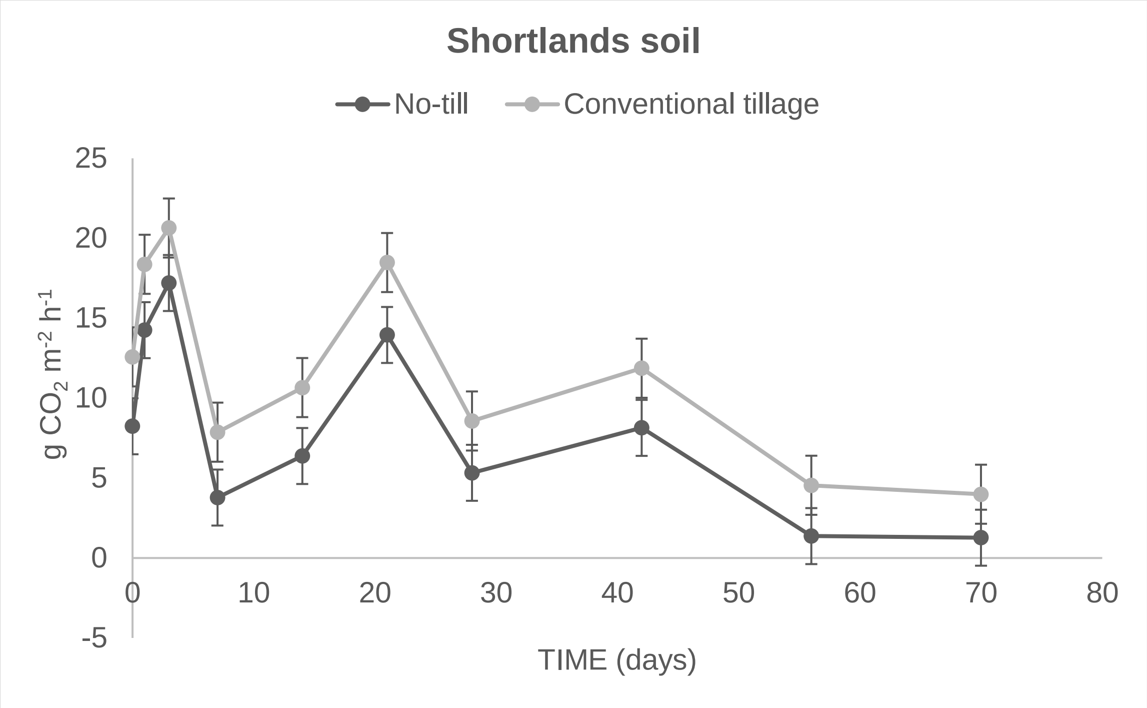

Figure 6. Rate of carbon dioxide evolution on Shortlands soil under no-till and conventional tillage system. Bars indicate standard error

The trend of CO_2 evolution in the Shortlands soil over the 70-day period is shown in Figure 6. Peak evolution of CO_2 in Shortlands soil was observed on day 3 under both no-till and conventional tillage system with the CO_2 rate of 3.78 and 7.87 g CO_2 m^{-2} h^{-1}. The CO_2 evolution decreased rapidly with time until day 7, followed by a significant increase at day 21. The rates declined slowly and gradually approached a constant value after day 42.

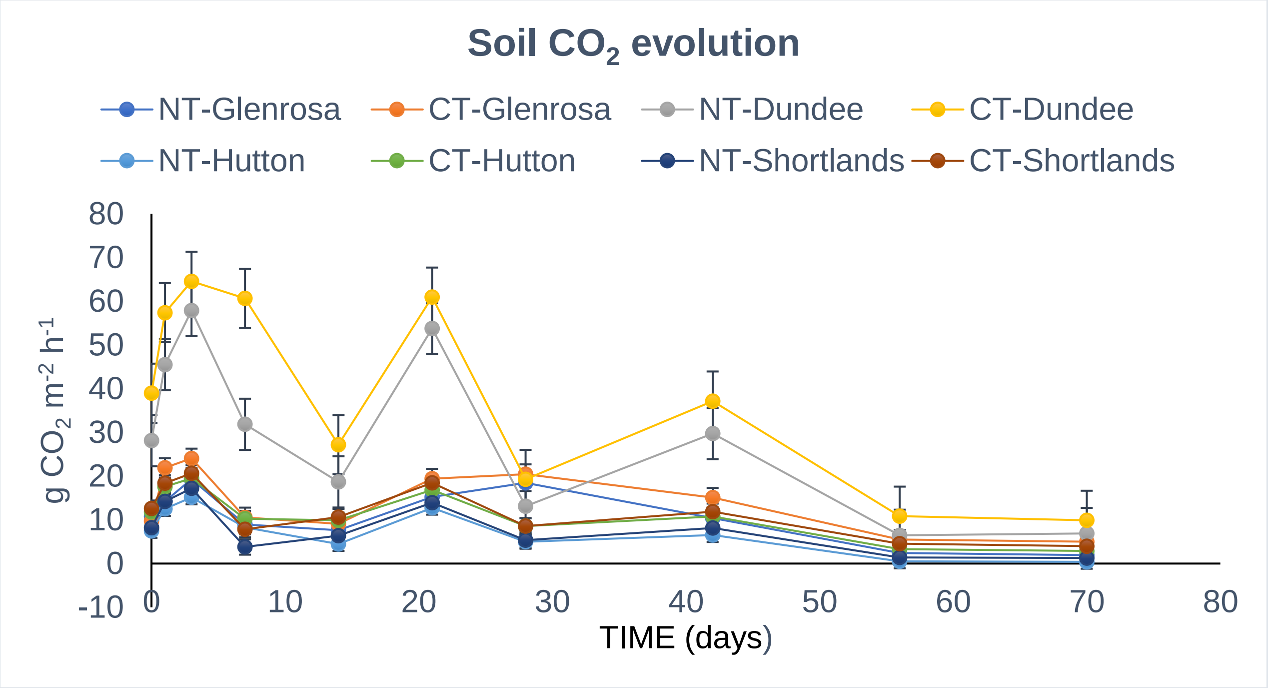

Figure 7. Rate of carbon dioxide evolution on Glenrosa, Dundee, Hutton, and Shortlands soil under no-till and conventional tillage system. Bars indicate standard error

The trend of CO_2 evolution in the Glenrosa, Dundee, Hutton, and Shortlands soils over the 70-day period is shown in Figure 7. Amongst all soils Dundee soil had the highest CO_2 rates on day 3 under both no-till (57.89 g CO_2 m^{-2} h^{-1}) and conventional tillage (64.58 g CO_2 m^{-2} h^{-1}) whereas Hutton had the lowest CO_2 rate under no-till (15.14 g CO_2 m^{-2} h^{-1}) and conventional tillage(19.5 g CO_2 m^{-2} h^{-1}). The CO_2 rates sharply decreased up until day 14, followed by a rapid increase up to day 28 under both tillage system. The CO_2 rates gradually decreased until it approached a constant value from day 56 to 70.

CHAPTER 5

5.0 DISCUSSION

5.1 Soil texture and mineralogy effects on soil properties

The specific objective was to determine the effect of texture (especially clay content) and mineralogy on soil organic matter and particulate organic matter in different soils. Consequently, soil organic matter, particulate organic matter and relationship between soil texture and mineralogy, and soil organic matter as well as particulate organic matter were analysed. There was a significant difference in both soil organic matter and particulate organic matter among the studied soils. The difference was perhaps because of the observed differences in soil texture and mineralogy among soils (Table 4). There is evidence that clay concentration may explain variation in rates of soil organic matter accumulation. Increase in clay particles protect some partition of soil organic matter from decomposition. Clay and silt have large specific surface areas and can sorb abundant soil organic carbon. However, McLauchlan (2006) reported that soil texture may not be a significant factor influencing soil organic matter accumulation. Glenrosa and Dundee soils was low in both soil organic matter and particulate organic matter. This could possibly be explained by the sand fraction, which was dominant across the soils and the primary minerals especially, quartz which was dominant in those soils. Sand which is dominated by quartz exhibits only weak bonding affinities to soil organic carbon, hence lower soil organic matter was observed in Glenrosa and Dundee. The soil organic matter increased as clay content increased. Similar observations were made by Nciizah and Wakindiki (2012) and Hassink (1997) and were attributed to the formation of organomineral complexes between clay and organic particles with strong bonds (Blanco-Canqui and Lal, 2004). Soil mineralogy has been shown to influence adsorption of soil organic matter to clay. However, adsorption mechanism and the extent of binding varies among clay types. Quartz, the most dominant mineral in most soils had a strong negative relationship (r = -0.66) with soil organic matter, which could be attributed to the low specific surface area of the quartz. The results of the present study, however, indicated a significant positive relationship between soil organic matter and kaolinite, clay, and hematite. Hematite had a high specific surface area of between 45 to 110 m^{-2} g^{-1} (Fontes and Weed, 1996) which result in high adsorption of soil organic matter (Baldock and Skemstad, 2000).

The results of this study showed higher aggregate stability in Hutton and Shortlands soil as compared to Glenrosa and Dundee soil. The higher aggregate stability could be due to higher clay content. Scholars have considered clay as a cementing agent. Bazzoffi et al. (1995) working on soils of central Italy indicated that the ratio of total sand to clay was the parameter that explained most of the variability associated with aggregate stability. The results of this study agree with the results reported by Lado et al. (2004) and Norton et al. (2006) who reported that aggregate stability increased with an increase in clay content. Similarly, Chappell et al. (1999) working in a tropical Ultisol in Malaysia found aggregate stability to be correlated with organic matter and clay content. Inversely, Ternan et al. (1996) found that soils with a higher clay content had a lower aggregate stability. Correspondingly, Six et al. (2002) did not find any correlation between clay content and aggregate stability. Genrosa and Dundee soils had lower aggregate stability. The lower aggregate stability could be due to higher sand content. Sands tend to have low aggregate stability due to their large size and low surface area compared with clays which have high surface area and negatively charged surfaces, which readily bond together via metal cations or organic molecules. Sand content has been reported to have negative influence on aggregate stability (Idowu, 2003), while clay content has positive influence (Fernandez-Ugalde et al. 2013). Similar results were observed by Almajmaie et al. (2017) who concluded that sand content contributed to lower soil aggregate stability.

The stability of soils is affected by the chemical properties and the kinds of clay minerals present (Morgan, 2005). Lado and Ben-Hur (2004) reported that clay mineralogy was found to be a dominant factor in controlling aggregate stability. The lower aggregate stability in Glenrosa and Dundee soil could also be due to higher quartz content. Quartz is chemically inert and is therefore unable to bond with other clay minerals or soil organic matter and is consequently highly dispersive (Zelazny et al. 1996). Almajmaie et al. (2017) concluded that quartz and sand content promoted aggregates disintegration. Similarly, Nciizah and Wakindiki (2014) reported that soils with quartz was least stable due to inability to bond with other clay minerals or organic matter whereas soil with high kaolinite were most stable. Hutton and Shortland's higher aggregate stability could also be due to the present of kaolinite. Kaolinite is known to promotes aggregate stability and reduces aggregate breakdown (Wakindiki and Ben-Hur, 2002). The results of this study compliments Moghimi et al. (2012)'s findings who also reported a positive correlation between kaolinite and aggregate stability.

Evolution of CO_2 in all soils were highest on day 3. However, maximal CO_2 evolution rates from Dundee soil were approximately twice as large as those from Hutton and Shortlands under both no-till and conventional tillage (Figure 4). The large difference could be attributed to the difference in clay content and mineralogy. Dundee soils were high in sand and is well known to increase organic matter decomposition and thus carbon loss through CO_2 efflux. Ding et al. (2014) reported more CO_2 in sand fraction that silt and clay. After day 56 the CO_2 evolution of all soils was gradually approaching a constant value. The latter could be due to reduced organic matter caused by prolonged decomposition. The high quartz content in Glenrosa and Dundee soil could also be reason of high soil respiration compared to Hutton and Shortlands. Quartz has low specific surface area and hence low adsorption and increased mineralization of soil organic matter, thus increased carbon dioxide emission. Nguyen and Marschner (2014) reported reduced cumulative respiration at higher clay rates of smectite clay. On the other hand, kaolinite clay contributed more to total respiration, although the amount clay soil in the mix was less. Roychand and Marschner (2013) observed increased cumulative respiration after clay addition with wheat residue and sawdust. Sandy soil are known to have low carbon sequestration capacity (Shi and Marschner, 2013).

5.2 Tillage effects on soil properties

No-tillage resulted in higher soil organic matter, particulate organic matter, and aggregate stability than conventional tillage (Table 6). The lower amount of soil organic matter under conventional tillage could be that each time the soil is tilled, it is aerated which enhance the decomposition of organic matter and thus the liberation of carbon. The greater soil organic matter under no-tillage could be due to reduced mineralization rate and increased microbial population. Similar results were also reported by Memon et al. (2018) who reported a significantly higher soil organic matter under reduced tillage as compared to conventional tillage. The results of this study were also supported by Kushwa et al. (2016) findings, they recorded higher soil organic carbon under no-tillage system at 0-5 cm layer. Similarly, Kubar et al. (2018) recorded 25% increase of soil organic matter under no-tillage system. Angers and Eriksen-Hamel (2008) found that no-tillage soils had significantly higher soil organic carbon than conventional tillage at the 0-20 cm layers. Conversely, Sithole et al. (2019) reported that total soil organic carbon did not vary across no-tillage, rotational tillage and conventional tillage.

Aggregate stability was greater under no-till than in conventional tillage. Studies have shown that tillage destroys natural soil aggregates and channels that connect the surface with the subsoil, leaving the soil susceptible to erosion. In general, aggregate stability and soil organic matter are lower under tillage than no-till or reduced tillage management (Bossuyt et al., 2002, Six et al., 2000, 2004; Zibilske and Bradford, 2007). The latter is due to the fact that ploughing re-exposes soil to the surface, and causes aggregates to breakdown (Bronick and Lal, 2005). The greater aggregate stability under no-tillage could be due to presence of residues which eventually decompose to form organic matter which bind soil particles and improve soil structure and thus aggregate stability. Plethora of studies reported similar results. Kubar et al. (2018) recorded 21% increase in aggregate stability under no-tillage compared to conventional tillage. Lal et al. (1994) reported that no-till improved soil aggregate stability. Wu et al. (2019) reported a 41.2%–56.6% increase aggregate stability under no-tillage compared with conventional tillage. Álvaro-Fuentes et al. (2008) found greater total soil organic carbon and greater formation of stable macroaggregates under no-tillage compared to conventional tillage at the soil surface. Somasundarama et al. (2018) noted a significant effect of tillage on aggregate stability. The aggregate stability was larger under no-tillage (70.74%) than conventional tillage system (59.50%). Inversely, Avanzi et al. (2011) reported equal aggregate stability between minimum tillage and conventional tillage.

The highest soil CO_2 fluxes were observed from conventional tillage, followed by no-tillage (Table 12). The higher amount of carbon dioxide emission on conventional tillage could be due the fact that conventional tillage alter the soil profile especially soil structure which strongly affect carbon dioxide emission by creating soil condition favourable for oxidation and mineralization of organic carbon in the soil. Conventional tillage accelerated soil carbon dioxide emission by improving soil aeration, increasing soil and crop residue contact (Roberts and Chan, 1990). Conventional tillage also incorporates and mix residues which stimulate microbial activity which result to high CO_2 emission. A no-tillage system or undisturbed soil, on the other hand, are less dissipative and produce lower levels of carbon dioxide fluxes, hence low carbon dioxide was emitted from no tillage system. The results suggest that tillage intensity should be minimized in order to reduce CO_2 emission from the soil.

6. CONCLUSION AND RECOMMENDATION

Soil texture and mineralogy influenced soil properties. Sand dominated soils had low soil organic matter and higher in CO_2 efflux rates whereas clay dominant soils were high in soil organic matter and low in CO_2 efflux. Soil CO_2 efflux was high in soil quartz dominated soils and low in kaolinite dominated soil.

There was positive relationship between soil organic matter, kaolinite, clay content, and hematite. More-so, quartz showed a strongly negative linear relationship with soil organic matter. Carbon dioxide evolution was higher in conventional tillage than in no-till soil in all soils. However, there was no significant difference between Glenrosa and Dundee. Therefore, adopting less intensive tillage such as minimum and no-till will prove remarkably effective in reducing soil carbon dioxide evolution. This will also contribute to defining environmentally and agronomically sound tillage practices to reduce carbon dioxide emission from agriculture and preserve soil fertility.

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