EFFECT OF CONSERVATION AGRICULTURE ON WATER RETENTION, SOIL PROPERTIES AND MAIZE YIELDS IN SEMI-ARID KAJIADO COUNTY, KENYA

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REG. A147/OL/CTY/24854/2014

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN THE SCHOOL OF AGRICULTURE AND ENTERPRISE DEVELOPMENT, KENYATTA UNIVERSITY

JULY, 2020

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University or any other award.

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Declaration by the supervisors

We confirm that the work reported in this thesis was carried out by the student under our supervision.

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DEDICATION

I take this opportunity to dedicate this work to the Almighty Father, late dad and mum, for laying my education foundation, my wife Irene Nashipae and my two kids, Kosen and Nairesiae for their unwavering support during my studies.

ACKNOWLEDGEMENT

I want to thank my supervisor, Dr. Benjamin O. Danga of Kenyatta University in the Agriculture Science and Technology Department in a big way for his passionate guidance during this work. He was very patient with me and gave a lending hand at every hour of need. His guidance, suggestions and commitment to supervise me in the work enabled me to complete this work on time. I also want to appreciate the help of Dr. Nguhiu who would give me a call and text regularly just to find out how I was progressing. This always motivated me to keep on track of my work. I also want to thank Kenyatta University technical, administrative and academic staff for their support during this work. All the colleagues I approached were always ready to help me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

ACTN	African Conservation Tillage Network
ANOVA	Analysis of Variance
CA	Conservation Agriculture
CEC	Cation Exchange Capacity
CT	Conservation Tillage
DM	Dry Matter
FAO	Food and Agriculture Organization of the United Nations
HI	Harvest Index
MALF	Ministry of Agriculture, Livestock and Fisheries.
MOA	Ministry of Agriculture
RT	Reduced Tillage
SOC	Soil Organic carbon
SOM	Soil Organic Matter
SSA	Sub-Saharan Africa
TT	Traditional Tillage
WAP	Weeks after planting

ABSTRACT

Food insecurity and hunger are global challenges attributed to poor crop harvests, land degradation, low soil moisture and declining soil fertility. Low maize yields and household food insecurity in Kajiado, Kenya could be alleviated by use of sustainable agricultural practices such as conservation agriculture (CA), integrated soil fertility management (ISFM) and increased water use efficiency. This study was carried out in Kajiado during the long rainy season of March-July, 2016 to (i) determine the effects of conservation tillage on maize growth and yields (ii) determine the effects of conservation tillage on soil physical properties (soil moisture retention and soil structure) and (iii) determine the effect of conservation tillage on soil chemical properties (Soil Carbon, soil pH, soil N, P, and K). The treatments were laid out in a RCBD with three replications. The treatments included: 1. Conventional tillage with residue removal (Control). 2. Conventional tillage with residue retention (3 ton/ha). 3. Conventional tillage with residue retention (5 ton/ha incorporation). 4. Reduced tillage – (one plough with 3 ton/ha stover incorporation). 5. Reduced tillage – (one plough with 5 ton/ha stover incorporation). 6. No-tillage practice – (no prior tillage, 3 ton/ha stover residue chopped, surface applied). 7. No-tillage practice – (no prior tillage, 5 ton/ha stover residue chopped, surface applied). Analysis was done using SAS version 8.

Results from the study show significant effects ($p<0.05$ *and* $p<0.01$) of CA on dry matter maize yields and water retention. The volumetric moisture content at 0-60 cm soil depth was highest in NT5 treatment, followed by NT-3 > RT-5 > CT-5>CT-3 > RT-3 and CTC (Control). At 0-20 cm depth, NT-5 had the highest volumetric soil moisture content of $0.299m^3m^{-3}$ which was significantly higher than the other treatments. NT-5 increased soil moisture by 9.7%, NT3 by 9%, RT5 by 5.4%, while RT-3 by only 3.8%. After wet sieving, treatments, RT-5, NT-3 and NT-5 significantly increased the 2-1 mm soil aggregate size, thus indicating improvement in aggregate stability of the soils. Up to RT-3 does not degrade the soil structure because there was no significant reduction of the fraction less than 0.5mm. NT-5 significantly gave the highest stover yields of 5334kg/Ha and grain yields of 3228.2kg/ha which was 37.3% increase from the control. CT3 had the highest plant height at (12.5cm) 2 weeks after planting (2WAP). However, NT5 had the highest significant effect ($P=0.01$) on plant height 4WAP, 6WAP and 8WAP at 58.2 cm, 122.8 cm and 140.2 cm respectively. No significant effects ($P<0.01$ *and* $P<0.05$) were recorded in pH before and after the experiment. However, soil organic carbon (SOC) recorded significant improvements across all the treatments with NT-5 being the highest followed by RT-5 > RT-3 > NT-3> CT-5 > CT-3 respectively in that order. The treatments had significant effects on soil mineral N (NH_4^+ and NO_3^-) and total N. On the other hand, the treatments also had significant effects on available P, Na^+, and K^+. Therefore, the results confirm that CA is very effective in enhancing crop yields and improving soil physical and chemical properties.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

According to Kamau *et al.* (2018), communities living in pastoral face increasing sub-division of land hence making it difficult to practice pastoralism. Additionally, increasing human population limits availability of free land space for practicing pastoralism. Within an estimated period of 30 years, the numbers of livestock kept by the pastoralists have been declining to the extent that it will be impossible for the pastoralist communities to purely depend on livestock for their livelihoods. This has forced some of the pastoralists to diversify their sources of livelihood to other business incomes such as cultivation of crops (Njeru, 2017). Ward *et al.* (2018), argue that there are various methods that can be used to improve land productivity in the ASALS. One of these methods is the use of crop residues and other organic materials to maintain the productivity of the soil and conserve soil water. In Kajiado County, unsustainable livestock production has led to diversification of livelihood earnings including crop production to improve food security.

Report by Ministry of Agriculture, Livestock and Fisheries, MALF (2019) estimate that maize productivity in Kajiado is practiced on a land area totalling 12,000ha with a projected area size of 110,310 hectares. However, land degradation and inadequate soil moisture content are key challenges facing crop production in the area. Interventions that could improve and control moisture regimes within the root zone are highly required in order to enhance maize productivity in this particular area.

According to Ngotho and Kangu (2016) conservation agriculture refers to the farming system which can prevent losses of arable land while regenerating degraded lands. CA has not been largely introduced in the maize farming community in Kajiado but it has great potential to reverse adverse land degradation effects and sustainably improve maize yields through reduction in soil loss, improved moisture conservation and soil fertility (Kihara, *et al.*, 2011). However, no tillage systems have been found to cause difficulties for soil workability and crop development hence other tillage methods should be evaluated (López-Garrido *et al.*, 2014). Root penetration resistance is significantly seen at the time of seedling emergence (6.04 MPa under no till versus 0.65MPa in reduced tillage and 0.40MPa in conservation tillage at surface), which contributes to an extreme reduction of the seeds yield of the maize crop. According to de Moraes *et al*. (2016), the practice of no tillage system and accumulation of the harvested crop materials on top of the soil surface improve water retention of between 50mm to 100mm compared to tilled soils. This technology can be employed to improve water retention in soils found in Kajiado.

Maize yields in Kajiado County have been greatly affected by inadequate soil moisture (FAO, 2017). This has impacted negatively on the performance of maize resulting to poor yields. Farmers in the region have been largely advised to grow drought resistant maize, and other crops that can withstand the little moisture contents in the soil like sorghum, millet, cassava, sweet potatoes, and pigeon peas. However, irrigation of horticultural crops and also farming in the green houses has taken a formidable shape (MALF, 2019). Maize is believed to be the staple crop in Kenya and therefore grown by majority of Kenyans, Kajiado included. It is on view that other likely ways of improving maize yields can be explored. In this regard, the research was aimed at relating tillage practices and residue management to soil water retention and maize yields in Ilbisil, Kajiado County.

1.2 Statement of the Problem

The soils in Kajiado have been largely characterized as cambisols which are deficient in organic matter when these soils are subjected to continuous cultivation may lead to soil physical degradation (Danga & Wakindiki, 2009). Increasing drought and flood events in Kenya, as a consequence of climate change has caused a drop in maize yields by 50% in Kajiado County and according to Kihara *et al.* (2011), this has resulted in increased importation of maize by the Kenya Government. This has been aggravated by increased land degradation and declining soil fertility in the county due to continuous cultivation.

Maize yields in Kajiado County are currently low and have been reported to range between 1.12 – 1.42 tons/ha. This is due to inadequate rainfall, low soil moisture and declining soil fertility. This can be reversed through conservation agriculture to boost water retention and improve soil nutrients. Past studies have shown that weather variability has huge implications on maize yields in semi-arid areas (Choudhary *et al.*, 2018). There is an upward trend of temperature in Kajiado County which has resulted in high losses of soil moisture, physiological stress of crops and increased rates of evapotranspiration. The aspect of tillage practices and residue management with respect to soil moisture retention and maize yield has not been explored in this particular area. The result of this study is crucial in addressing the productivity of maize and food security at large in this county.

1.3 Study Objectives

1.3.1 Overall Objective

The general objective was to determine the effect of conservation agriculture and management of crop residues on soil water retention and maize yield in semi-arid, Ilbisil, Kajiado County.

1.3.2 Specific Objectives

The study was guided by the following specific objectives:

1. To determine the effects of conservation tillage (reduced and no-tillage) on maize performance in semi-arid area of Ilbisil, Kajiado County

2. To determine the effects of conservation tillage on soil physical properties (soil moisture and soil structure) in semi-arid area of Ilbisil, Kajiado County
3. To determine the effect of conservation tillage on the soil chemical properties (soil carbon, soil pH, soil N, P and K) in semi-arid area of Ilbisil, Kajiado County.

1.4 Hypotheses of Study

1. Conservation tillage (reduced and no-tillage) significantly improves dry matter maize yields.
2. Conservation tillage significantly improves soil physical properties (soil moisture and structure)
3. Conservation tillage significantly improves soil carbon, soil pH, soil N, P and K.

1.5 Significance of the Study

Food security in Kenya is an important aspect of economic development which the government strives to attain (MALF, 2019). In this respect, some interventions have been put in place to achieve this objective. Key among them is the establishment of a projected one million acres under irrigation in Galan Kulalu (Kamau *et al*., 2019). Kenya is focused on improving food deficits through increased production of majorly staple crops and diversification of farming to fill the food security gaps. Interventions that improve productivity of crops in Ilbisil, Kajiado County is in line with the government's focus in addressing the food security situation. This research is founded with the aim of improving soil productivity in Ilbisil, Kajiado County through conservation agriculture. Better maize yields through conservation agriculture will be important in improving the living standards of the people of Ilbisil, Kajiado and extrapolated nationwide in areas with similar climate. Idle land majorly used as grazing land could be put into more profitable use should the experiment produce sustainable and promising results.

1.6. Conceptual Framework

1.6. 1 Conceptual Framework

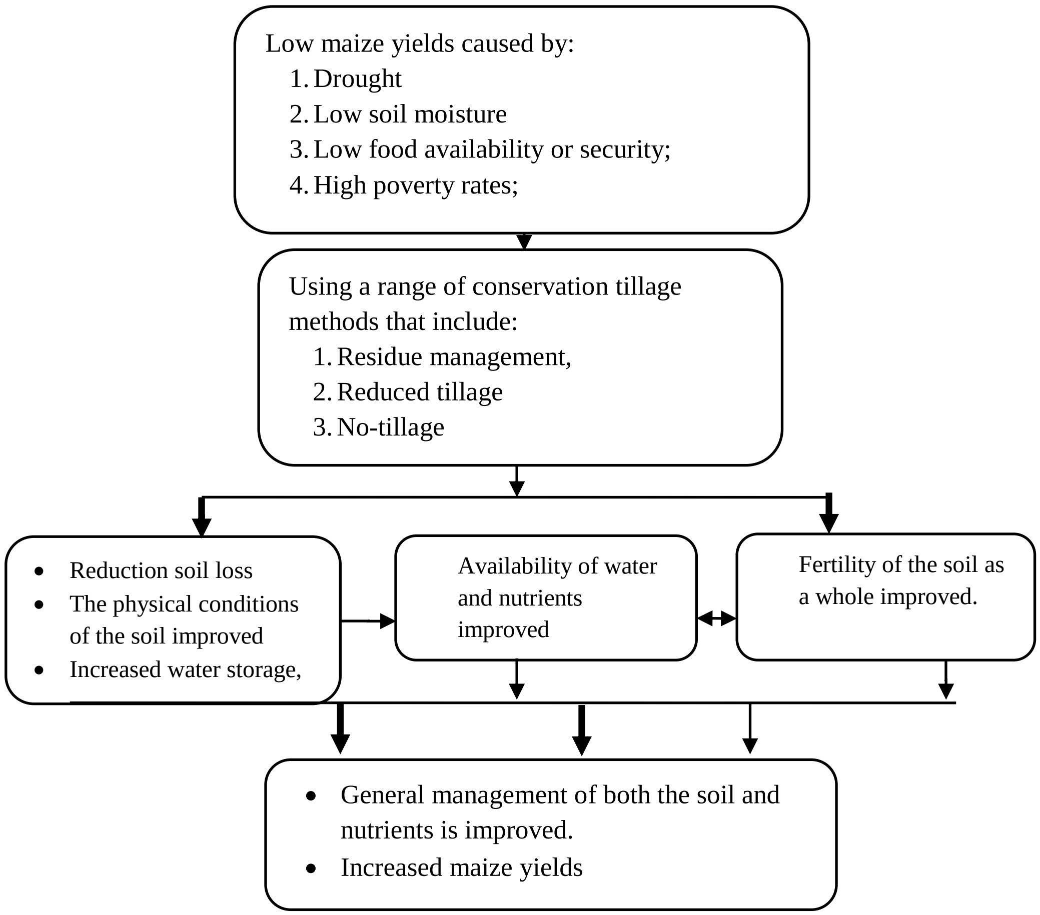

Figure 1: Conceptual Framework of This Study

Source: Adapted by Author

Low maize yields in Kajiado County is majorly attributed to the deficient moisture levels in the soil and frequent droughts. This has worsened the food security situation and poverty prevalence at large. However, the residents of Kajiado have not relented on maize production. Past studies have confirmed that conservation agriculture and majorly tillage practices that include reduced tillage, residue management and no tillage practices offer positive responses to yield in areas where soil moisture seems to be deficient (Adimassu, *et al.,* 2017). Conservation agriculture which has not been largely used in Ilbisil, Kajiado County was used in this study to improve maize yield in the context of solving soil moisture deficiency. Its benefits have been numerated as; reduction in soil moisture loss, better soil physical conditions, increased availability of nutrients and increased water uptake by plants. This will go long way in enhancing nutrient and soil management, increased maize yields, increased food security and better livelihoods.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Conservation agriculture (CA) emerged and became acceptable in the 1970s mostly in the USA, Brazil, Argentina, Canada and Australia because of its ability to combat increased soil erosion and land degradation (Kassam, Friedrich & Derpsch, 2019). CA was mostly adopted by large-scale mechanized farmers with the associated widespread use of glyphosate for weed control. It was developed and adopted widely by farmers because it significantly reduced soil erosion, decreased labour costs and generally led to higher income for the farmers (Lahmar, 2010; Mitchel, *et al.,* 2016).

According to Sithole, Magwaza and Mafongoya (2016) CA involves minimal disturbance on the soil through various practices that include maintaining permanent cover on the soil, zero, tillage, minimum tillage and crop rotation. The widespread use of CA globally is because of its resource-saving nature, enhanced sustainable crop production and improved soil characteristics. Studies have confirmed that CA is a farming systems approach for sustainable farming in Africa, USA and Asia (Kuhn *et al.,* 2009). Therefore, agriculture stakeholders are championing the adoption of CA to improve crop productivity and overcome the effects of climate change. Therefore, the steady fertility decline in SSA can be overcome through adoption of CA practices.

2.2 Conservation Agriculture and Its Importance in Sub-Saharan Africa

World uptake of CA tends to be concentrated amongst relatively large-scale farmers located in North America, South America, Australia and New Zealand which account for an estimated 95% of the world area currently using CA practices (Kassam *et al.,* 2019). Proponents argue that the potential benefits of CA can be equally extended to Africa and Asia region (Dougil*,* *et al.,* 2017 largely dominated by smallholder farmers, who often combine crop and livestock production in mixed farming systems (Hague *et al*., 2016). In tropical Africa and Asia smallholder mixed systems contribute to the livelihood of two-thirds of the population, producing a large part of the staple food and animal products consumed by poor people (Thornton *et al*,. 2010).

Conservation agriculture is proposed as perfect solution to agricultural problems in smallholder farming systems in the tropics (Van Hulst, Freddy & Helena, 2016; Farnworth, *et al.,* 2019; Jat, *et al*., 2018). It specifically aims to address the problems of soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil and also to address the problem of intensive labour requirements in smallholder agriculture (ACTN, 2018). Advocates of CA suggest that it offers a solution to these problems by providing the means that can prevent further destruction of soils, increase rainwater use efficiency and labour productivity, thereby ensuring higher and more stable yields while reducing production costs (Giller *et al.*, 2009).

Given the continuing poor productivity of smallholder agriculture in sub-Saharan Africa (SSA), and the reports of soil degradation due to nutrient depletion and soil erosion (Corbeels, *et al.*, 2019; Wekesa, Mutua & Izugbara, 2019). CA appears to offer great potential to address these problems. In Kenya for example agriculture is a major contributor to the economy and to the livelihoods for a majority of the population. Nevertheless the adoption of CA has been low with the adoption activity being spearheaded by non-government institutions (Mann *et al.*, 2009). The country's potential to increase agricultural productivity is largely unexploited partly due to high agricultural production costs and unsustainable farming practices especially in the arid and semi-arid regions of the country (Kang'ethe, 2011).

2.3 Effect of Conservation Agriculture on Crop Productivity

The impact of tillage on crop performance can be explained through its impacts on the root growth of crops, NUE and water absorption. Das *et al*., (2016) report that improved root length density has been confirmed to occur in RT and NT soils in comparison to the CT systems because increased soil compaction in deeper soil layers impede proper root development. Thierfelder *et al.* (2017) found that root mass increased by 22% in NT in comparison with CT because of improved bio-pores, cracks and work channels. This enhanced root growth under NT. Improved root mass improved water and nutrient uptake which significantly improved the crop yields.

Conservational tillage revolves around three main principles: minimum soil disturbance; permanent soil cover, primarily by retaining crop residues as mulch; and crop rotation, especially with legumes (Thiombiano & Meshack, 2009). These practices are characterized by the combination and interdependence of crop production and livestock husbandry. While the crop component of these systems provides feed to the animals, the livestock component provides manure and traction (Nyagumbo, *et al.,* 2017), and is an important saving option and source of cash income enabling farmers to purchase inputs, food and other goods.

Organic remnants of the previous crops can be beneficially used for improved soil characteristics and increased yields of crops. Kihara *et al.* (2011) in his study done in the sandy soil of Eastern Kenya recorded a decline in maize yields (35-65%) lower than the conventional tillage) over the first two seasons of the experiment. However, after the fourth season maize yield were 7-40% higher than in the conventional system of tillage. The N cumulative range over the four seasons was 77 to 196 kgN/ha. If the same yields can be realized in the project area, then food security situation would be reduced.

2.4 Effect of Conservation Agriculture on Soil Physical Properties

The positive effects of conservation tillage on soil physical and chemical properties (Vaezi, Ahmadi & Cerdia, 2017; Margenot, *et al.,* 2017; Ranaivoson, *et al*., 2017) have been demonstrated in many environments. In China, several long-term experiments (Sun, et al., 2018; Li, et al., 2018) have generally confirmed the improvements in soil quality and productivity achieved by conservation tillage, however, results vary due to the variability of climate and time requirements for soils to adapt to a new management system (Kuhn *et al*., 2009). No-tillage (NT) has been shown to improve soil properties, thereby enhancing water transmission, water retention, and crop yield in many parts of the world (He *et al*., 2009).

Jat *et al*., (2018) and Choudhary *et al.* (2018) further report that the bulk density of the soil does not show significant difference in both no tillage and conventional tillage, however, bulk density tends to increase with increased soil depth. Saturated hydraulic conductivity measurements imply better water movement in soils that are not tilled in comparison to the traditional conventional tillage. A study by Bera *et al.,* (2018) reports that the physical properties of the soil improved and no deterioration was recorded after a period of 10 years.

Most farmers in Kenya usually apply traditional conventional tillage (TT) with soil inversion to avoid potential problems of soil compaction after repeated application of no tillage (NT) (Lopez *et al.,* 2014). NT might cause some difficulties for soil workability and crop development derived from the original soil conditions, and, consequently, other tillage options are equally important (Brown, *et al.,* 2017). However, tillage practices that are less aggressive such as reduced tillage (RT) can be used to mitigate the problem in a manner that do not compromise the benefits of using conservation agriculture particularly in Kajiado County (Sommer, *et al*., 2018)). Tillage systems have a considerable effect on soil micro and macro aggregate fractions with the order being no tillage followed by tied ridges and the lastly the normal conventional tillage (Lopez *et al.,* 2014). No till has been found to be very effective in improving the uptake of nutrients from the soil, the structure of the soil and crop yield and an application of one tone/Ha of crop residue and manure has been found to be very effective (Brown, *et al*., 2018).

Many studies have reported that conservation agriculture leads to better soil structure compared to other soil amendment technologies (Kay, 2018)). Conservation tillage also leads to improved levels of the soil organic carbon especially on the top levels of the soil surface (Schlüter, *et al.,* 2018; Tarolli, Cavalli & Masin, 2019; Margenot, *et al*., 2017).

No-tillage practices have been reported to maintain and enhance soil aggregation (Li *et al.,* 2018; Turgut *et al*., 2012) and increase infiltration in presence of surface mulches (Zhai, *et al.,* 2017; Opala, Odendo & Muyekho, 2018). Larney *et al*., (2017) studied the effect of minimum tillage of soil and water conservation and reported that minimum tillage disturbs the plough soil as little as possible leaving large soil particles and pore space to soak up water as against repeated tillage which tend to compact the soil.

Further, in cases where the residues of the crops are used as mulching material to cover the soil surface during reduced tillage, more rain water have been found to be conserved which leads to an improvement in the amount of water that becomes available for crop uptake. Kiboi *et al.,* (2017) report that about 70% of rainwater is currently being lost through evaporation from the runoff on the surface and percolation into the deep layers of the soil. Therefore, applying mulches on the surface of the soil play a key role in ensuring that runoff of water on the surface is reduced and that evaporation of water from the soil is also minimized (Adimassu, *et al.,* 2020). Forte *et al*., (2017) have found the no tillage (NT) as an effective practice for clay soils to minimize sub-soil compaction and to induce natural structure formation through shrink-swell cycles (Singh *et al*., 2014)

2.5 Effects of Conservation Agriculture on Soil Chemical Properties

Soil organic matter (SOM) is an important determinant of soil fertility and dynamics are influenced by agricultural management practices such as tillage (Hati *et al*., 2014). Removal of crop residues from the fields hastens decline in SOC especially when coupled with conventional tillage (Jat, *et al.*, 2018). Studies conducted under a wide range of climatic conditions, soil types, and crop rotation systems showed that soils under no-tillage and reduced tillage have significantly higher SOC contents compared with conventionally tilled soils (Ranaivoson, *et al.*, 2017).

Li *et al.*, (2018) established that soil organic carbon, nitrogen, magnesium, potassium, PH, extractable phosphorous and exchangeable calcium recorded significant values with no till in comparison to conservation tillage within the 0-5cm soil depth. It is very interesting that below the 5 cm depth, Mehlich III P, magnesium, potassium, exchangeable calcium and pH were relatively higher with conventional tillage compared to no tillage at all. Choudhary *et al*. (2018) found that the values for organic carbon and nitrogen increased as the number of residues on the surface of the soil was being increased at the same time. Additionally, the exchangeable calcium, pH and magnesium is observed to reduce when higher rates of nitrogen are applied. Bera *et al.* (2018) further report that the bulk density of the soil does not show significant difference in both no tillage and conventional tillage, however, bulk density tends to increase with increased soil depth.

The beneficial effects of CA on the chemical properties of the soil have been demonstrated in many studies (Thomas *et al*., 2007; Parihar, *et al.*, 2018; Hishe, Lyimo & Bewket, *et al*., 2017) and crop yields (De Vita *et al*., 2007; He *et al*., 2007). Many long-term experiments with CA in China (Li *et al.*, 2018; Sun, *et al*., 2018; Liu, *et al.*, 2017; Wang *et al.*, 2008) have shown positive effects on soil chemical properties although results vary depending on the nature of climate. Studies conducted by Liu *et al.* (2017) found that SOM and available K and P within 0-10 cm soil depth range increased by10% in NT treatments in comparison to the traditional/conventional tillage systems after four years of study in a semi-arid area. Swanepoel *et al.* (2018) carried out a 3-year NT experiment in a semi-arid experiment and found that no till enhances nutrient cycling which supply S and N to the soil. Studies conducted by Khan *et al.*

(2007) found that residue incorporation using rice straw improved Zn, P, K and Mn. This implies that a combination of tillage practices and residues improve the chemical properties of the soil.

Corsi *et al.* (2012) report that soil chemical properties on the upper surface layers of the soil are generally more balanced in CA compared to the conventional farming methods. Continual no-tillage system enhances the SOC and structure. The total N loss is also minimized under NT compared to other traditional methods of farming. However, NT has been found to have no effect on the pH of the soil. However, studies by Okubo *et al*. (2008) show that no tillage systems slightly reduce the pH of the soil. However, the reduction in soil pH is attributed to the concentration of organic matter on the upper surface layers of the soil. This increases electrolytes concentration on the upper soil layers thereby reducing the soil pH. However, Cookson *et al*. (2008) found that soil pH showed continual reduction with increased tillage disturbance. However, Ranaivoson *et al*. (2017) found that the soil pH was significantly higher in NT plots in comparison to those of tilled plots. Therefore, tillage does not have a direct effect on soil pH, but its effect is only inherent in different climatic conditions, the type of soil and the farming management practices carried out.

Telles, Reydon and Maia (2018) and Rahman *et al.* (2008) exhibited in their studies that exchangeable K, Ca, and Mg significantly increased in NT treatments on the surface layers of the earth in comparison to the conventional tillage treatments. Vastola *et al.* (2017) explain that low level of Mg, N, K, SOM, P and Ca in conventional tillage treatments could be due to soil pulverization during tillage which exposes the infertile sub-soil to the surface. Moreover, Busari and Salako (2013) conducted studies in Nigeria and found that NT soil recorded significantly higher pH within the first year of the experiment. However, in the second year, the level of pH declined significantly in NT compared with the conventional tillage. Besides, the CEC and SOC was higher in NT at the end of the two-year experiment under NT compared to the CT. Therefore, this study show that reduced tillage practices improved the pH and SOC. Therefore, less disturbance of the soil is important in improving the chemical quality of the soil.

2.6 Summary Review and Research Gaps

The studies reviewed above confirm the beneficial effects of CA in improving soil and crop productivity. However, despite the several benefits of CA, many studies reviewed focus on Asia, USA and few parts of Africa. Therefore, there is still need to conduct more studies in SSA and specifically Kenya, on CA and its effects in semi-arid climates. Moreover, these studies do not specifically monitor the performance of crops under CA in semi-arid conditions. Focus is on different climates other than the semi-arid climate which is the main setting of this study. Therefore, there is gap on the impact of CA in semi-arid conditions. Besides, most studies focus on enhancing nutrient levels of the soil through CA without looking at the physical aspects of the soil into detail like bulk density and soil structure. There are also inadequate studies on the impact of CA on soil moisture characteristics. Finally, several studies try to compare NT and CT systems without looking at other tillage systems like reduced tillage. The combination effects of these tillage systems and residue management is also lacking. A link is also not made between tillage properties and soil moisture. Therefore, this study was set-up to investigate the effect of conservation agriculture on water retention and maize yields in semi-arid, Kajiado.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Site Characteristics

Experiments were conducted in Ilbissil, in Kajiado Central, Kajiado County. Its geographical coordinates are 2.0940°S, 36.7873°E. Kajiado County is one of the major Counties in the expansive Rift-Valley and borders Taita Taveta and Makueni counties to the East, Tanzania to the south, Narok and Kiambu counties to the West and Nairobi and Machakos Counties to the North. It lies on the Southern edge approximately 95 km from the capital city, Nairobi. It receives an annual rainfall of 500 mm per annum with average annual temperatures of 18.5 degrees Celsius (MALF, 2019). The area's major economic activity is pastoralism at 52% though agro-pastoralism has taken shape over the last few years (MALF, 2019). The area still boasts of huge tracks of land though as a result of increased population pressure and proximity to the rapid expansion of the city Nairobi, land fragmentation and subdivision has been on the rise in the recent years (Kihara, 2014). The site lies within livestock – Sorghum Zone (UM6) but borders LM6 which is the livestock herding / Ranching zone. The Ilbissil site was chosen for the study because farmers in the area have started integrating crop production with livestock herding and would therefore benefit from any moisture conservation technology that could increase food crop production.

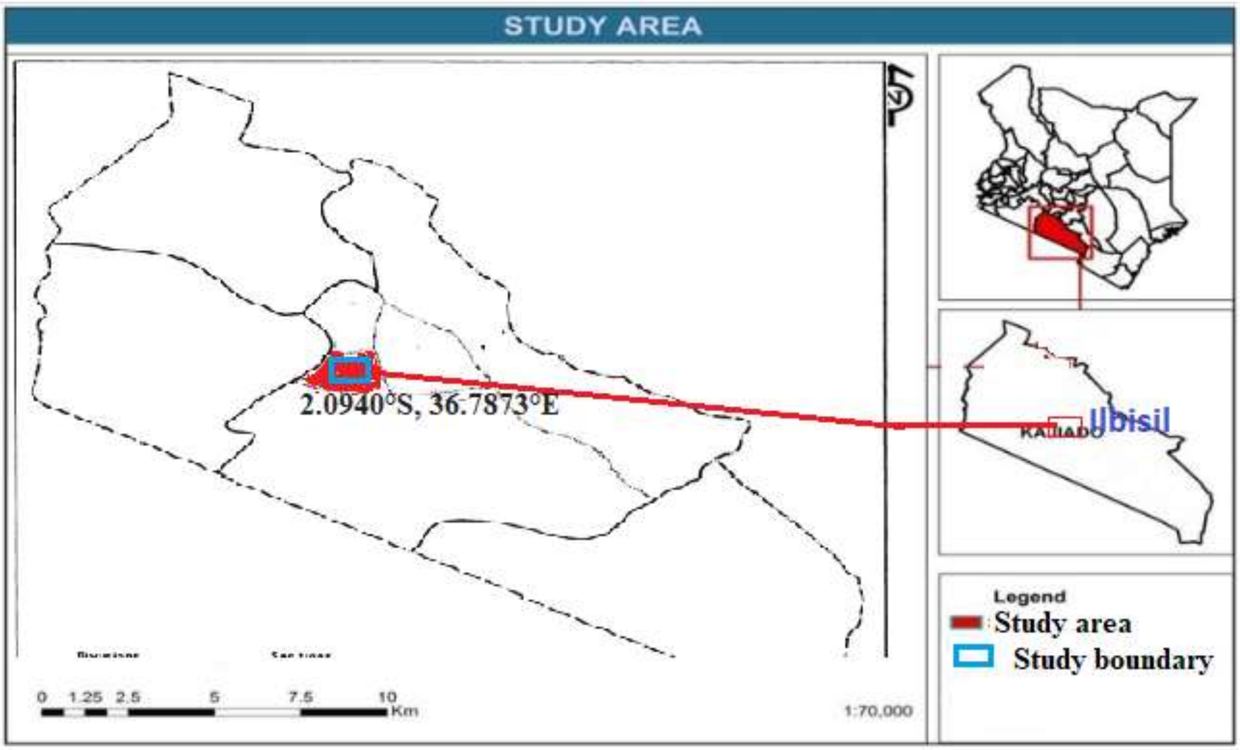

Figure 2: Map of Study Site

Source: Survey of Kenya (2019)

3.2 Experimental Treatments and Design

The experimental treatments were laid out in a RCBD with 3 replications. The treatments were seven and included

1. Conventional tillage with residue removal (Control treatment) (C)
2. Conventional tillage with 3 ton/ha residue incorporation (CT-3)
3. Conventional tillage with 5 ton/ha incorporation (CT-5)
4. Reduced tillage (one plough) with 3 ton/ha stover incorporation) (RT-3)
5. Reduced tillage (one plough) with 5 ton/ha stover incorporation) (RT-5)
6. No-tillage practice – (no prior tillage, 3 ton/ha stover residue chopped, surface applied) (NT-3)

7. No-tillage practice – (no prior tillage, 5 ton/ha stover residue chopped, surface applied) (NT-5)

This gave 21 experimental plots, each plot measured 5m x 4m. The field experiment was carried out between March to July 2016 during the long rains. The maize residue used was chopped into small pieces of approximately 5 cm.

Table 1: Experimental layout showing randomized treatments in plots in the three blocks

Block 1	CT-5	C	NT-3	RT-3	CT-3	RT-5	NT-5
Block 2	CT-3	NT-5	CT-5	RT-5	C	NT-3	RT-3
Block 3	RT-3	RT-5	CT-3	NT-3	NT-5	C	CT-5

The treatments were randonly assigned to blocks and subsequently to plots. Between blocks was a 1.5 m walkway and 1m between plots.

3.3 Soil Sampling

Soil samples were drawn randomly from 0 - 60 cm using soil auger in every plot to determine gravimetric soil moisture at zero, 2, 4, 6, and 8 weeks during plant growth. Zigzag method of soil sampling was done in triplicate from each plot to determine other soil physical properties and chemical properties (texture, aggregate stability, bulk density, and soil pH, soil N, P and K) at the start and end of the experiment. The analyses were carried out at the Kenyatta University Soil Science laboratories except for moisture retention which was done at the Kabianga University Soil Laboratory which had the requisite equipment.

3.4 Soil Analysis Methods

3.4.1 Soil Moisture Determination

Soil moisture was determined through oven drying at 105°C using gravimetric method and converted to volumetric soil moisture by multiplying with the bulk density $\theta v = \theta g * BD$. Soil water retention was done by using the pressure plate apparatus as outlined by Okalebo et al. (2002).

3.4.2 Soil Bulk Density

The bulk density was determined using the core method as outlined in Okalebo *et al.* (2002).

3.4.3 Soil Texture Determination

The soil texture was measured using the hydrometer method as stipulated by Okalebo *et al.* (2002).

3.4.4 Soil pH

Soil pH_w (1:2.5 H_2O) was determined using hand held electronic pH meter (Ryan *et al.*, 2001). This means that 20g of soil was mixed with 50ml distilled water in $100cm^3$ plastic bottle.

3.4.5 Total Nitrogen Determination

Soil Total nitrogen was determined by the Kjeldahl method as outlined in Okalebo *et al.* (2002).

3.4.6 Soil Available Phosphorus

The soil extractable P was determined using the Mehlich 1 method (Mehlich, 1953). After 5 g of soil was dried in the air is extracted with 25 ml of a solution mixture of 0.1M HCl and 0.025M H_2SO_4 the suspension was shaken for a period of 60 minutes using an automatic shaker. The suspension was then centrifuged and filtration done using filter paper number 42. The extractable P was found calorimetrically by using a spectrophotometer (430 nm wavelength) after adding 1ml of ammonium molybdate and ammonium vanadate mixture to 5 ml of the extraction for color development, after standing for 1 hour.

3.4.7 Soil Potassium and Sodium determination

Potassium and sodium in soil were determined using the flame photometry.

3.4.8 Soil Organic Carbon

The soil total organic C was determined by using the Walkley and Black method (Okalebo *et al.*, 2002).

3.4.9 Soil Calcium and Sodium Determination

The concentration of Ca was determined by Atomic Absorption Spectroscopy (AAS).

3.5 Land Preparation, Application of Treatments, Planting and Crop Management

Land preparation was done early in the dry season before the onset of rains (12th February, 2016) for the plots where tillage was a treatment. Rainfall was measured with manual rain gauges installed at the site besides the plots. In conventional tillage plots, ploughing was done with hand tools followed by one harrowing after two weeks. In reduced tillage, after initial ploughing, no harrowing was done. Residue was incorporated with initial tillage where it was necessary, and applied at the appropriate rates. Surface application of stover (chopped to 5 cm length) was only done to no-tillage plots (NT plots) at planting which was done on 8th March, 2016. Maize seeds (variety DH 04) was planted at a spacing of 90cm x 30cm. Maize stover residues from the previous cropping was sourced in advance and surface applied according to respective treatment rates. Normally, residue application on the soil surface smothers weeds and gives them little space for regeneration (Corbeels, *et al*., 2019) Additionally, weed growth was controlled by herbicides. Their control limited the intervening factors that would have an influence on the results. Yield data was taken at harvesting time by harvesting and weighing the yield at the end of the experiment.

3.6. Determination of Plant Height

Three maize plants were randomly selected and tagged and monitored for height per plot before harvesting. Their heights were obtained using a tape measure. Measurements were taken from the highest photosynthetic tissue to the ground level (Boomsma, *et al.,* 2010). Plant height was determined at 2, 4, 6 and 8 weeks after planting (WAP).

3.7. Harvesting and Yields Determination

The maize crop was harvested per plot from four central lines on July 13th 2016 when the maize cobs were dry. This was approximately 16 weeks after planting. Plants were cut at the ground level and then dried to a moisture content of 13% in the field. After threshing, a moisture meter was used to determine the grain moisture. The maize grain yields and dry matter maize yields were weighed using weighing balances. The Dry Matter (DM) weight was determined as weight of 1000 seeds. Thereafter, the calculation for the yields (tonha^{-1} basis) was done and adjusted to 13% (standard) of moisture content by applying the following formulas (2, 3, and 4).

$$\text{DM(kg)} = \frac{\text{Sample fresh Weight (g)} - \text{Sample Dry Weight(g)}}{1000} \quad (2)$$

$$\text{Yield (tonha}^{-1}) = 10 * \frac{\text{DM (kg)}}{\text{Harvested area (m2)}} \quad (3)$$

$$\text{Yield}_{\text{adjusted}}\ (\text{tonha}^{-1}) = \text{Measured yield} * \frac{(100 - \text{Sample moisture content})}{(100 - \text{Standard moisture content})} \quad (3)$$

Harvest Index (HI), that expresses the efficiency of a variety of a crop and its ability to convert the dry matter into economic yield, was calculated using the formula below;

$$\text{Harvest Index} = \frac{\text{Grain yield (kg)}}{\text{Total Dry Matter yields (kg)}} \quad (4)$$

3.8 Statistical Data Analysis

The data generated was analysed in terms of ANOVA using the SAS version 8 (SAS Institute, 1999). However, before this, data was first be entered into an excel spreadsheet before a transfer is done. Means was separated using Least Significant Difference (LSD) of means at 95 and 99 percent of significance level (*$p<0.05$ and $p<0.05$*) to test means differences.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Rainfall Data for the Study Site

The rainfall data for the study site was obtained for all the months for the duration of the experiment (January-July 2016) (Table 1)

Table 2: Mean monthly Rainfall (mm) Data at the Ilbissil study site, Kajiado

Month	Rainfall	Number of days
January	23	3
February	0	0
March	113.3	8
April	166.9	13
May	61	3
June	0	0
July	0	0
Total	309.1	27

From Table 1 the cumulative rainfall totals for which the experiment was run (January-July 2016) was 309.1mm. This was slightly higher than the long-term average of 280mm. Specifically, no rainfall was recorded for the months of June and July during the experimental season. However, substantial amount of rainfall was recorded during the months of April and March which was also fairly well distributed within the months. The rainfall data obtained confirms the semi-arid nature of the study area. The rainfall patterns during the growing season can have significant effects on maize growth if conservation agriculture measures are not taken into consideration.

In this context, agricultural technologies capable of enhancing water retention and conservation within the soil horizons becomes very important. Ngotho and Kangu (2016) found that the agro-pastoral areas of Kajiado have food security challenges because of low rainfall that nearly reach 500mm per annum. Moreover, farmers are forced to be keen on ensuring correct planting dates failure to which crop growth is adversely affected. On this background, the results of the study are in agreement with the existing literature that Kajiado County is a largely semi-arid area (MALF, 2019).

4.2 Conservation Tillage Effects on Soil Moisture Retention

Particle soil analysis indicates that textural composition of the soil was 50% sand, 18% silt and 32% clay. Therefore, the texture of the soil at the site was sandy-clay- loam based on the USDA soil classification system. This has moderate to good water retention capacities.

The volumetric moisture content at 0-60 cm soil depth was highest in NT-5 treatment ($P<0.05$) (Figure 3), followed by NT-3 > RT-5 > CT-5>CT-3 > RT-3 and CT-C (Control). At 0-20 cm depth, NT-5 had the highest volumetric soil moisture of $0.299m^3m^{-3}$which was significantly higher than the other treatments. However, the volumetric water content reduced in the 20-40 cm and 40-60 cm soil depths to $0.296m^3m^{-3}$ and $0.294m^3m^{-3}$ respectively.

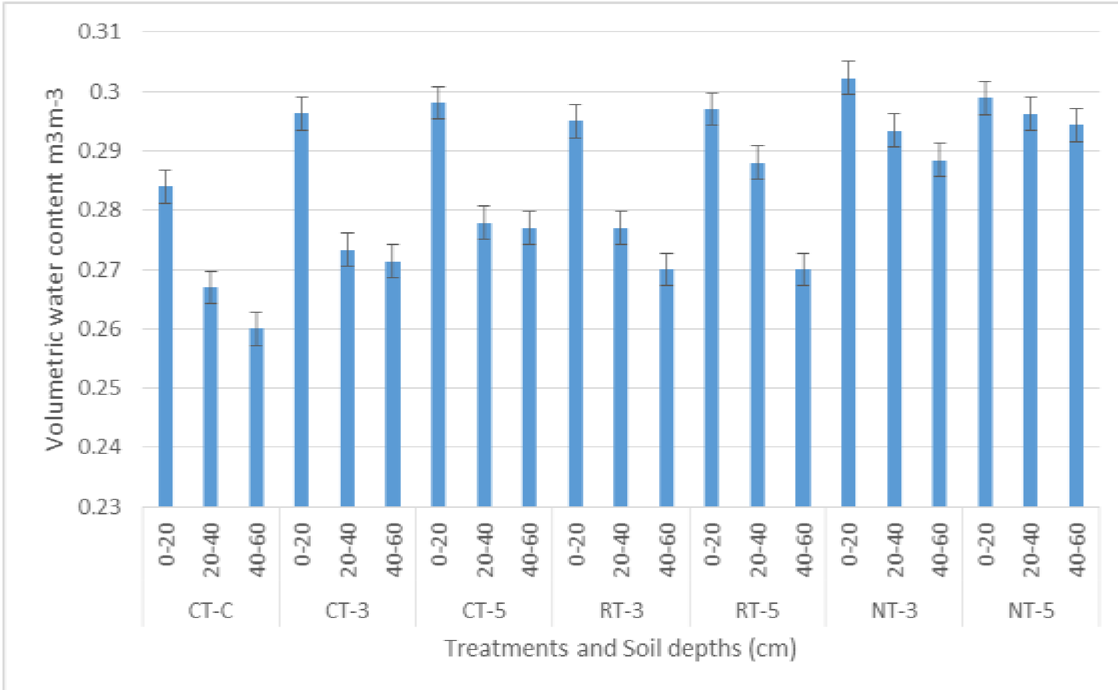

Figure 3: Volumetric soil moisture for the experiment

Results in figure 3 show that water retention within the 0-20cm soil depths was significant in all the treatments except the control which recorded much lower volumetric water content within the top 0.20cm soil depth. The low moisture content in CT-C (Control) could associated with huge water loss from the soil due to higher evaporation losses attributed to increased soil exposure and pulverization caused by conventional tillage system. This is in agreement with observations of Mitchel *et al.* (2016) who reported that conventional tillage reduces particle cohesiveness hence enhancing water loss through evaporation. The highest moisture content in the NT-5 treatment could be explained by the effect of higher mulch cover which could have suppressed evaporation. Lack of soil disturbance reduced exposure of soil to evaporative moisture loss.

Compared to the control, the NT-5 increased soil moisture by 9.7%, NT-3 by 9%, RT-5 by 5.4%, while RT-3 by only 3.8% (table 2). Except for the latter, these increases in soil water contents were significant (p = 0.05). These results are supported by the work of Danga and Wakindiki (2009); Njeru (2017); Moussa-Memon *et al.* (2016) who reported that mulching effect reduces evaporative water loss by 14%-29% around the crop root zone. Therefore, mulching increases moisture availability for plants thereby promoting good plant growth and productivity.

Volumetric soil water content (Figure 4) decreased with soil depth across all the treatment with the highest reduction being recorded in the CT-C and least decrease recorded in the NT-5. The least decrease in CT-5 is associated with ample cover provided by the crop residues which minimizes soil exposure to the heat of the sun hence low decrease in soil water loss. Similarly, the ample soil cover enhances water seepage into the deeper horizons of the soil because water is held on the surface for long. Vaezi, Ahmadi and Cerdia (2017); Ramos *et al.,* (2010) and Ngotho and Kangu (2016) found that surface organic mulches improve internal water status of crops by reducing soil water loss in semi-arid environment. Further studies by Jiménez *et al.* (2017) also indicate that mulching using straws encourage water infiltration and soil water storage at 20, 40 and 70cm of soil depth. However, mulch shortens the days of physiological stress while encouraging temporal soil moisture distribution patterns.

Soil moisture characteristic curve (Figure 4) indicate that NT-5 had the highest significant effect at $P = 0.01$ significance level on volumetric water content at different matric potentials. At saturation, NT-5 had the highest water retention at 54.35m^3m^{-3} followed by NT-3 > CT-5 > CT-3 >RT-3 > RT-5 > CT-C (54.18m^3m^{-3}, 52.88m^3m^{-3}, 51.33m^{3}m^{-3}, 50.46m^{3}m^{-3}, 50m^{3}m^{-3} and 48.97m^{3}m^{-3} respectively. These results show higher porosity where residues were incorporated as compared to the control. Thus, the control had the lowest water retention at different matric potentials in the soil as shown in Figure 4.

Table 3: Volumetric Water content at different matric potential

	Volumetric Water content						
Suction (bars)							
	C	CT-3	CT-5	RT-3	RT-5	NT-3	NT-5
0	48.97	51.33	52.88	50.46	50	54.18	54.35
0.1	38.49	40.91	41.47	41.3	39.09	41.07	45.61
0.33	35.06	37.78	40.12	39.56	37.31	38.57	42.85
1	32.92	35.99	38.19	37.7	35.42	36.97	41.81
5	28.75	33.3	35.93	34.32	32.58	34.23	38.59
15	25.33	30.5	33.22	30.62	29.85	31.61	35.26

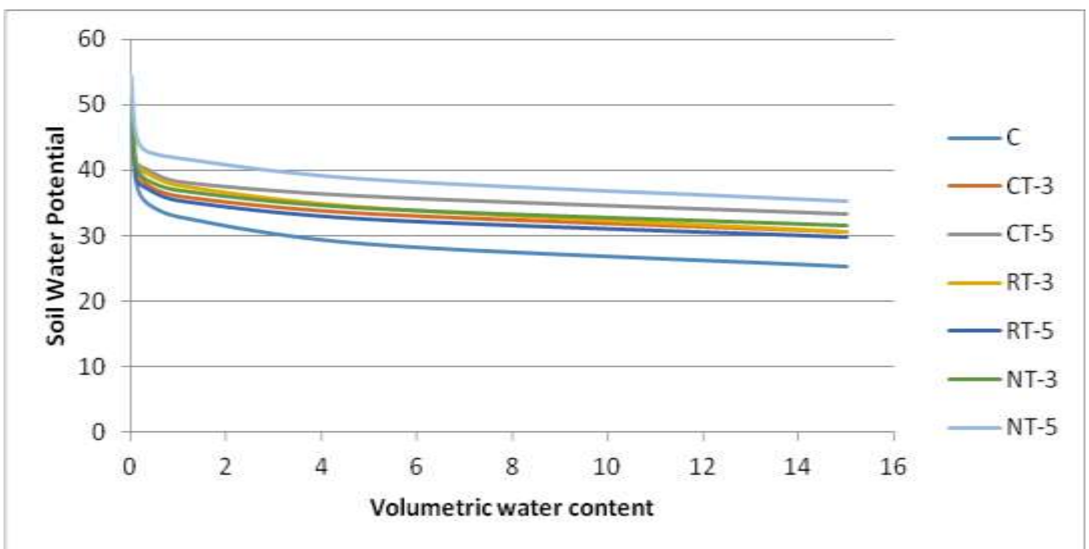

Figure 4: Soil Moisture Characteristic Curve

The high organic matter content in NT-5 can be explained by the effect of mulch which increased soil water retention. Therefore, the maize roots exerted less suction pressure to obtain soil water which was more available as exemplified by the high difference of soil moisture (7.60 m^3) between 0.33 bars (Field capacity moisture, 42.85 m^3m^{-3}) and permanent wilting point (15 bars, 35.26 m^3m^{-3}). Low volumetric water content in CT-C can be explained by high soil exposure to evaporation. Conventional tillage systems encourage soil pulverisation. The inner layers of the soil are therefore exposed to evaporation by wind and heat of the sun. These findings agree with those of Jat *et al.*, (2018), Hishe *et al*, (2017) and Forte *et al*. (2017) that mulching lowers the soil water potential hence making roots to exert less suction pressure. This reduces crop stress while enhancing crop productivity and performance.

4.3 Effect of Treatments on Aggregate Stability

After wet sieving, treatments, RT-5, NT-3 and NT-5 significantly increased the 2-1 mm aggregate size, thus indicating improvement in aggregate stability of the soil (Table 4).

Table 4: Aggregate size distribution (%)

	% aggregate size distribution after wet sieving					
Aggregate sizes	2 – 1 mm		1 – 0.5 mm		< 0.5 mm	
	Initial	After	Initial	After	Initial	After
CONTROL	27.84a	25.19b	33.34a	32.96a	38.82b	41.85a
CT-3	28.42a	28.32a	32.56a	32.20a	39.02	39.48
CT-5	28.01a	28.56a	33.34	33.02	38.65	38.42
RT-3	30.74a	30.89a	31.28	31.27	37.98a	37.84a
RT-5	28.69b	30.56a	32.66a	32.04a	38.65a	37.4b
NT-3	27.94b	31.50a	33.28	31.98	38.78a	36.52b
NT-5	27.70b	31.98a	33.28	33.42	39.02a	34.60b

In CT-3, CT-5 and RT-3, there was no significant difference between the initial and final values of the 2-1 mm size aggregates while in CT-C (control), the percent reduction of this fraction was significantly different at *P= 0.01 and P=0.05*.

Up to RT-3 does not degrade the soil structure because there was no significant reduction of the fraction less than 0.5mm. Improvement from RT-5 when significant percent increase in 2-1mm aggregate size was observed as well as reduction of the less than 0.5 mm size. NT-5 reduced <0.5 mm fraction by 4.42% almost twice the reduction caused by NT-3 of 2.26%., and only 2.13% reduction by CT-5 treatment. Conversely, this fraction increased by 3.03% after the experiment in conventional tillage control. 1.0 – 1.05 mm was not sensitive to treatment effects. Reduced tillage had a higher effect of reducing the less than 0.5 mm size than residue cover. Conversely, residue cover had higher effect of increasing 2.00 mm aggregate size probably due to higher protection from impact of raindrops (Table 4)

These results agree with those of López-Garrido *et al.* (2014) and Liang *et al.* (2011) who reported that aggregate soil distribution and mean weighted diameter were significant in different tillage treatments at 0-15 cm. However, in NT treatments, aggregates greater than 2mm and 2-1 mm had significantly higher aggregate stability compared to other treatments. Similarly, low yields were recorded in the control treatment but the structural stability of the soil significantly improved especially in the <0.5 mm aggregates.

4.4 Effect of Treatments on Soil Chemical Properties

4.4.1 Soil pH

Table 4 show no significant effects *($P<0.01$ and $P<0.05$)* were recorded in pH before and after the experiment (Table 5).

Table 5: Soil chemical properties of the experimental surface soil (0-20cm) at the Kajiado site

Soil property	**Initial**	**At harvest**						
		CT-C	CT-3	CT-5	RT-3	RT-5	NT-3	NT-5
pH in water (1:2.5)	6.6	6.7	6.8	6.5	6.6	6.7	6.8	6.6
Organic carbon (%)	1.25	1.15	1.35	1.88	2.02	2.16	1.96	2.35
NO_3^- (ppm)	8.07	9.84	10.95	10.26	11.33	12.51	10.38	12.14
NH_4^+ (ppm)	4.09	5.63	4.77	4.49	4.85	5.72	5.66	6.86
Total N (%)	0.18	0.184	0.204	0.172	0.212	0.198	0.212	0.198
Available P (ppm)	13.5	13.8	16.90	26.53	16.59	23.78	25.16	24.79
Na^+ (ppm)	8.98	7.82	7.86	10.52	11.54	10.45	11.54	11.54
K^+ (ppm)	80.01	84.7	88.7	89.2	86.7	88.6	91.2	89.0
Ca^{++} (ppm)	53.62	54.98	55.3	58.21	56.23	58.35	55.65	58.45

Soil pH results in Table 5 show that crop residues and tillage treatments have no effect on soil pH. Thus, is in line with the arguments of Lahmar (2010) and Sun *et al.* (2018) that changes in the pH depends on the values of initial pH, species of the crop planted and effects of nutritional constraints which the planted crops are required to respond to. The effects of treatments on soil pH also depends on the length of the experiment. Shorter duration experiments record significant changes in pH due to decomposition processes of the organic matter which produce organic acids. However, longer term experiments record no significant differences within treatments.

Shorter experimental period is also associated with microbial respiration which produces acids that alter soil pH. These findings are very much consistent with those reported by other researchers (Sithole, *et al.,* 2016; Zhai, *et al.,* 2017; Kihara *et al.,* 2011) who reported lower PH for NT treatments after five years. However, this effect was attributed to the acidifying effects of mineralization of organic matter and nitrification effects of the surface N for a sandy loam soil with different tillage treatment effects.

4.4.2 Soil Organic Carbon

From table 5, significant improvements in soil organic carbon (SOC) were recorded across all the treatments with NT-5 being the highest followed by RT-5 > RT-3 > NT-3> CT-5 > CT-3 respectively in that order. Conversely, the treatment CT-C significantly showed a decline SOC by 0.1% from 1.25% to 1.15%. Standard fertilization guidelines classify <2% of humus as low, 2-4.5% as medium and >4.5% and high (Swanepoel, *et al*. 2018). Based on this classification, NT-5, RT-5 and RT-3 significantly enhanced SOC from 1.25% to 2.35%, 2.16% and 2.02% respectively.

Therefore, reduced tillage and no tillage practices can lead to sustainable maize production compared to conventional tillage practices.

Documented data show that SOC peaks in 5-10 years while equilibrium is attained in 15-20 years. The significant increase in SOC in NT-5 could be explained by high residue retention thereby increasing soil organic matter in the soil root depth. High residue cover limited the effects of erosion hence leading to greater carbon stocks within the crop root zone. De Vita *et al.* (2007); Jat *et al.* (2018); Kamau *et al*. (2018) found that residue retention increased total soil organic carbon by 3.3% after 10 years.

4.4.3 Soil Nitrogen Content

Results in table 5 show that the treatments had significant effects on soil mineral N (NH_4^+ and NO_3^-) and total N. RT-5 had the highest significant effect on nitrate N-NO_3^- at 12.14 ppm from an initial content of 8.07. However, total N in NT-5 treatment had similar results with RT-5 treatment at 0.198%. Similarly, RT-3 and NT-3 had the highest increase in total N at 0.212% for the two treatments. N- NO_3^- was highest in RT-5 treatment at 12.51 ppm. Moreover, nitrate N (NO_3^- (ppm) increased in NT-5 by 50%, RT-3 by 40.4%, CT-3 by 35.69%, NT-3 by 28.62%, CT-5 by 27.14% and finally CT-C by 21.93% (table 4). CT-C recorded the lowest increase in mineral N-NO_3^-. This could be explained by the exposure of the soil to N-NO_3^- volatilization. Comparatively, NT-5, RT-5 and RT-3 had significant increase in NO_3^- in comparison to NT-3, CT-5, CT-3 and CT-C that recorded much lower levels of nitrate N. Alternatively, CT-C treatment recorded the lowest values for total N and mineral N at initial periods before the experiment and after harvest.

The general significant increase in nitrate N can be associated with the sufficient increase in mineralizable N. This is because N dynamics is affected by substrate availability which is provided by the crop residues. Liebhard *et al*. (2014) reported higher total N and mineral N on the upper surface layers to medium surface layers of the soil for CT treatments and NT treatments. Also, De Vita *et al.* (2007); Danga and Wakindiki (2009) and Memon *et al.* (2016) reported higher total N and mineral N on the upper soil surface layers in NT and conventional tillage systems. In this regard, it can be deduced that accumulated residues on the uppermost surface layers of the soil are viable sources of mineralizable N. Therefore, residue accumulation is directly related to total N and mineral N availability.

4.4.4 Other Soil Chemical Soil Properties (Ca, P, K and Na)

Table 5 show significant effects on Ca^{2+} with the highest positive results being recorded in treatments NT-5 and RT-5 at 58.45ppm and 58.35ppm, respectively (Table 4). CT-5 also produced significant increase in Ca^{++} (58.21ppm) though this was higher than treatments NT-3 (55.65ppm), RT-3 (56.23ppm), CT-3 (55.3ppm) and CT-C (54.98). CT-C had the lowest effect on Ca^{2+} at harvest. Other researchers have reported significant effects of tillage on Ca^{++} (Liu *et al.*, 2017; Imaz *et al*., 2010; He, *et al.*, 2009). However, a reduction on Ca^{++} was recorded in NT treatments due to high water retention in the soil profile. This shows that conservation tillage treatments with residue application enhance the accumulation of Ca^{++} within the crop root zone. Melero *et al.* (2011) found similar results which demonstrated a significant increase Ca^{++} after five years of conservation tillage.

Particularly, the treatments also had significant effects on available P, Na^+, and K^+ (Table 4). NT-5 recorded the highest effect on N^+ (11.54 ppm). However, NT-3 treatment had the highest effect on Na^+ (91.2ppm) while NT-3 produced the highest results on available P (25.16). These are similar to the ones found by other researchers (Ramos *et al.*, 2010; Chintala *et al.*, 2014).

4.5 Effect of Treatments on Dry Matter Maize Yields

Treatment NT-5 (Table 6) gave significantly highest stover yields of 5334 kg/ha. This was followed by RT-5 = CT-3 = RT-3 = CT-5. The treatment NT-3 and CT-C had the lowest stover yields of 4235kg/ha and 4018kg/ha, respectively.

Table 6: Summary of maize growth (plant height) and maize DM yields

Treatment	**Plant height, cm**				**Maize stover,**	**Grain yield,**	**Total DM yields**
	2WAP	4WAP	6WAP	8WAP	kg/ha	kg/ha	kg/ha
C	9.0	38.6	82.3	95.5	4018c	1861.6cd	5879.6
CT-3	12.5	58.4	103.6	122.4	4916b	2016.5c	6932.5
CT-5	9.3	55.0	116.8	137.1	4634ab	1736d	6370
RT-3	9.4	57.4	113.6	119.8	4820b	2311.7b	7131.7
RT-5	9.6	43.5	89.2	122.2	5116b	2965ab	8081
NT-3	10.9	56.9	120.6	131.4	4235c	2889.5ab	7124.5
NT-5	9.6	58.2	122.8	140.2[a]	5334a	3228.2a	8562.2
P	**<.0001**	**<.0001**	**<.0001**	**<.0001**			
LSD	**1.621**	**3.423**	**5.142**	**4.442**	**440**	**302**	

Figure 5: Treatment effects on maize growth

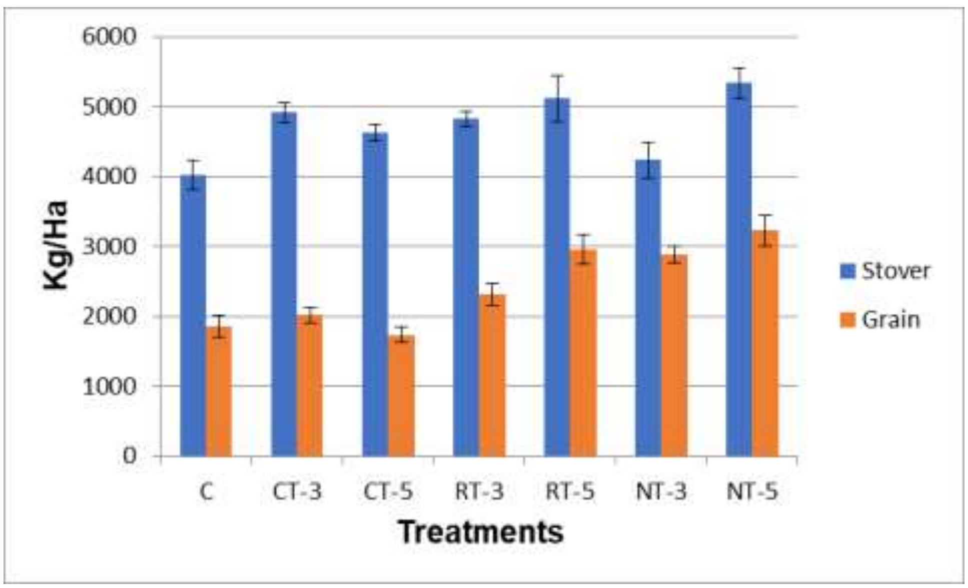

Figure 6: Maize dry matter yields for stover and grain

From Figure 6 and Table 6, NT-5 had the highest dry matter yields at 5334kg/ha and 3228.2kg/ha for stover yields and grain yields respectively. These results show that the treatments effects were significant (*$p<0.05$ and $p<0.01$*) in improving dry matter maize yields except treatments NT-3 and CT-C. Significant high yields in NT-5 could be associated with its effects in improving soil structure, bulk density, moisture and organic matter. Moreover, this treatment effect improved the CEC of the soil. Soil nutrients were easily availed, soil pH was buffered and there was greater soil structure stability in comparison to other treatments. These findings closely resemble those found by Memon *et al.* (2016) who found significant differences among tillage treatments in terms of emergence of seedlings, height of plants, number of leaves per plant and dry matter and grain yields. This research further found that direct tillage system gave the tallest plants with the highest dry matter maize yields while conventional tillage had the lowest dry matter maize yields, grain yields and shortest plants.

Analysis of the maize growth (plant height in cm) and yield (kg/ha) (maize stover yield and grain yield) was also conducted. Results show that CT-3 had the highest plant height at (12.5cm) 2 weeks after planting (2WAP). This could be explained probably by the greater root penetration into the soil since tillage loosened the soil. Root growth was quickened and this enhanced the general growth of maize. Residue application in CT-3 also improved water retention leading to moisture availability for crop growth. However, NT-5 had the highest significant effect ($P=0.01$) on plant height 4WAP, 6WAP and 8WAP at 58.2 cm, 122.8 cm and 140.2 cm respectively (figure 5). CT-C recorded the lowest plant height at 2WAP, 4WAP, 6WAP and 8WAP (9.0 cm, 38.6 cm, 82.3 cm and 95.5 cm respectively). NT-5 produced the highest effect on plant height from planting to harvesting followed by NT-3 > RT-3 > RT-5 > CT-5 > CT-3 and CT-C.

The performance of maize in the NT-5 could be explained by high increase in readily available nutrients. Li *et al.* (2018); Kihara *et al*. (2011) and Boomsma *et al.*

(2010) reported enhanced soil enzyme activities responsible for nutrient cycling in the surface layers of the soil under no tillage treatments with 5 tons of residue application compared to the conventional tillage systems. Therefore, there is a significant difference in tillage treatments and their effects on plant growth.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

5.1.1 The Effects of Conservation Tillage (reduced and no-tillage) on Dry Matter Maize Yields

Conservation tillage significantly improves maize productivity. NT-5 produced the greatest dry matter maize yields. Both the stover yields and grain yields showed significant improvements with conservation tillage compared to the conventional tillage treatments. The traditional conventional tillage produces significantly low yields probably due to soil pulverization and disturbance. Therefore, conventional tillage produces the best stover and maize grain yields in a semi-arid area. Regarding maize growth, conservation tillage produces significant effects in terms of improving maize growth. Therefore, this report concludes that use of conventional tillage is a solution to moisture availability and nutrient deficiencies in arid and semi-arid areas such as Kajiado. This goes a long way in improving maize growth and yields.

5.1.2 The Effects of Conservation Tillage (reduced and no-tillage) on Soil Physical Properties (soil moisture and soil structure)

The study concludes that CA has significant effects on the soil physical properties. NT-5 had the highest dry matter maize yields from the experiment. The conventional tillage system encourages soil moisture loss which lead to significantly low yields. Soil cultivation exposes the soil to soil water loss through evaporation. However, CA offer cover to the soil that reduces excessive water loss. Moreover, all the CA treatments have been shown to be effective in conserving water at 0-20cm soil depth. On the other hand, CA is effective in enhancing the aggregate stability of the soil. CA treatments are effective in improving the 2-1mm aggregate soil size leading to better soil aggregate stability.

5.1.3 The Effect of Conservation Tillage on the Soil Chemical Properties

The study concludes that CA significantly improves soil chemical properties except pH which remain unaffected. Specifically, CA significantly improves social organic carbon, mineral N (NH_4^+ and NO_3^-) and total N within the 0-20cm of soil depth and also other elements such as Ca^{2+} available P, Na^+, and K^+ in the soil. However, NT-5 is the most effective treatment in improving the soil chemical properties.

5.2 Recommendations from the Study

Based on this study the following recommendations were drawn:

- The smallholder farmers in Kajiado can adopt no tillage with 5 tons of maize residue application, being the best in improving soil moisture retention, soil chemical properties and dry matter maize yields in Kajiado
- Farmers need to be encouraged to incorporate residues into the soil for better crop growth and soil productivity.
- Small scale farmers should use chopped maize stalks as the crop residue.
- There is need for further investigations especially on the long-term effects of CA on the soil properties and maize yields in Kajiado so as to determine the limits of CA in the area.
- Further research needs to employ use of other residues and determine their effectiveness in enhancing soil properties and crop yields.
- Further research to include other crop other rather than maize

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7.0 APPENDICES

Appendix 1: Analysis of Variance for Volumetric Soil Water Content Season 1, 2016 at Ilbissil, Kajiado (Whole Model)

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	20	3334.031	166.72	38.95
Error	102	436.584	4.28	Prob > F
C. Total	122	3770.615		<.0001**

** Significant at 1% level

Appendix 2: Analysis of Variance for Maize Grain Yield 2016 (Effect Tests)

Source	DF	Sum of Squares	F Ratio	Prob > F
Tillage method	3	14.3645	6.4912	0.0005**
Residue Rate	2	4.9327	3.5625	0.0100*
Tillage method*Residue rate	6	1.3314	0.3841	0.0287*
Replicate	2	3.2138	2.0179	0.0563^{ns}
Tillage method*Replicate	9	7.2219	0.5907	0.8564^{ns}

** Significant at 1% level; * Significant at 5% level; ns = Not significant at 5% level

Appendix 3: Research Authorization from Graduate School

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 020-8704150

Our Ref: A147/OL/CTY/24854/14

DATE: 8th November, 2017

Director General,
National Commission for Science, Technology
and Innovation
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR MR. LEONARD LEAKEY RITEI – REG. NO. A147/OL/CTY/24854/14

I write to introduce Mr. Leonard Leakey Ritei who is a Postgraduate Student of this University. He is registered for M.Sc. degree programme in the **Department of Agricultural Resource Management**.

Mr. Ritei intends to conduct research for a M.Sc. thesis Proposal entitled, **"Effect of Conservation Agriculture on Water Retention and Maize Yields in Semi-Arid, Kajiado County, Kenya."**

Any assistance given will be highly appreciated.

Yours faithfully,

MRS. LUCY N. MBAABU
FOR: DEAN, GRADUATE SCHOOL

Appendix 4: Approval letter from Graduate School

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke
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P.O. Box 43844, 00100
NAIROBI, KENYA
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Internal Memo

FROM: Dean, Graduate School

DATE: 8th November, 2017

TO: Mr. Leonard Leakey Ritei
C/o Department of Agricultural Resource Management

REF: A147/OL/CTY/24834/14

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

We acknowledge receipt of your Research Proposal after fulfilling recommendations raised by the Graduate School Board of 27th September, 2017.

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking Forms per semester. The form has been developed to replace the Progress Report Forms. The Supervision Tracking Forms are available at the University's Website under Graduate School webpage downloads.

Thank you.

ELIJAH MUTUA
FOR: DEAN, GRADUATE SCHOOL

CC. Chairman, Agricultural Resource Management Department

Supervisors:

1. Dr. Benjamin Danga
C/o Agricultural Resource Management Department
Kenyatta University

2. Dr. Purity Nguhiu
C/o Agricultural Resource Management Department
Kenyatta University