STUDY ON TILLAGE SYSTEMS AND THEIR IMPACTS ON LAND DEGRADATION FOR EASTERN AGRO-ECOLOGICAL ZONE IN TANZANIA

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN LAND USE PLANNING AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

ABSTRACT

Soil tillage had been identified as a major cause of land degradation and soil erosion in Tanzania resulting in soil infertility and low crop yields. A study was conducted at Mkambalani village, in Mkambalani ward, Mikese division in Morogoro Rural District, Morogoro Region, Tanzania. The study aimed to assess tillage systems and their impacts on land degradation for eastern agro-ecological zone. Five (5) tillage systems were selected for the study. The selected systems were No Tillage (NT), Strip Tillage (ST), Basin Tillage (BT), Tied Ridges (TR) and Conventional Tillage (CT). A plot of size 20 m long with width of 1.8 m was established for each tillage system selected and replicated in three times in the slope of 6^{0} farm. The plots planted with maize crop variety TMV1. At the down slope end of each plot the modified Gerlanch troughs were installed to trap water flow and sediment. The study arranged in CRBD design to help in data analysis. Variables measured including, daily sediment for the rainy days, water runoff, daily rainfall, plant growth and yield and soil physical and chemical properties. The results shows that NT treatments produced high amount of runoff on average in most of rainfall events due presence of few cover in the first year of farming while TR treatment were the least. Significant differences were observed between the NT treatments and CT, TR and BT. It means that in first year of practising NT due to bare soil there was no soil protection from rainfall and water flow hence more water runoff. CT was found to be the biggest collector of sediment than other tillage treatments. Significant changes were observed among CT, NT and TR in collection of sediment. CT treatment produced sediment loss of 23.2ton/ha/season, while the TR produced the least amount of 14.4ton/ha/season. This reflects the extent of the productive soils lost in each year due to tillage. There were no significant differences in crop growth and yield were observed and also in soil physical and chemical properties in the first year of the experiment. Under natural rainfall conditions rainfall amount, intensity and distribution differs greatly and all affect soil properties and crop development, hence the one year trial is not enough to draw appropriate conclusion.

DECLARATION

I, Saidi Jambuya Mohamedi do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is the result of my own original work and has not been submitted for a degree award in any other University.

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DEDICATION

Above all my appreciation to the might God, who enabled me to achieve this academic level, I thank almighty God, and his name be glorified.

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LIST OF ABBREVIATION AND SYMBOLS

%	Percentage
>	Greater than
^{0}C	Centigrade, the measure of degree of hotness
AEZ	Agro- Ecological Zone(s)
Al	Aluminium
Am	Ante meridiem (before noon) time
Ava.	Available
AWC	Available water content
BACAS	Bureau for Agricultural Consultancy and Advisory Services (SUA)
BT	Basin Tillage
C	Carbon
CEC	Cation exchange capacity
Cm	Centimetre
CRBD	Completely Randomised Block Design
CT	Conventional Tillage
Dr	Doctor
et al	and others
FAO	Food and Agriculture Organization, United Nations
FC	Field Capacity
Fig.	Figure(s)
FWH	Flood water harvesting

G	gram(s)
ha	Hectare(s)
Hr	Hour(s)
K	Potassium
kg	Kilogram(s)
LSD	Least Significant Difference
m	meter(s)
m asl	Meter above sea level
MC	Moisture Content
MET.	Meteorological
Mg	Megagram(s)
mm	Millimetre
MoA	Ministry of Agriculture
MP	Mouldboard Plough
MS	Mass of Solids
N	Nitrogen
NT	No Tillage
OC	Organic carbon
OM	Organic matter
Org	Organic
P	Phosphorus
PWP	Permanent wilting point
S_a	Water readily available to plant
SOC	Soil organic carbon

SOM	Soil organic matter
ST	Strip Tillage
SUA	Sokoine University of Agriculture
TMV1	Tanzania maize variety
TR	Tied Ridges
UAN	Urea-ammonium nitrate solution
V_a	Volume of air
V_d	Unit volume of dry soil
Vol.	Volume
V_t	Unit volume of soil
V_w	Volume of water
W	Weight
yr	Year(s)
θfc	Water content at field capacity
θwp	Permanent wilting point
ρ_b	Bulk density
K	Hydraulic conductivity

CHAPTER ONE

1.0 INTRODUCTION

1.1 General

Land degradation is a global process, where by sub-Saharan Africa is affected most, with arid and semi-arid zones being particularly affected (Mesfine *et al.*, 2005). In all areas of Sub-Saharan Africa land degradation is widespread but the most serious affected country is Ethiopia, where topsoil losses amounting to 290 metric tons/ha/yr have been reported from steep slopes (Mrema, 1996). In Tanzania land degradation is much documented by many researchers as a growing problem because of increasing population (Kimaro *et al.*, 2006; Mganilwa *et al.*, 2007; Masanja, 2009). The increase in population has increased food demand which in return putting more land under different tillage practices resulting in land degradation (Mganilwa *et al.*, 2007; Mati *et al.*, 2008). Tillage has been recognized as a cause of intense landscape modification and as a major source of soil erosion and redistribution along hill slopes (Govers *et al.*, 1999; Papiernik *et al.*, 2005; Kimaro *et al.*, 2006).

Tillage erosion amounting to significant soil losses and land degradation has been reported in various parts of the country including Morogoro Region (Magunda *et al.*, 1999; Kimaro *et al.*, 2005, 2006; Mganilwa *et al.*, 2007). Land degradation due to soil losses of more than 100 tons/ ha/ year has been reported in Northern part of the country (Magunda *et al.*, 1999; Masanja, 2009). Study done by Mganilwa *et al.* (2007) at Magu district in the Lake Victoria Basin revealed that the pure maize stand with no cover crop had the highest mean soil loss yield of 15.2 ton/ha per year in the first season. Similar soil erosion studies in Lake Victoria basin by Kimaro *et al.*

(2005) showed that in Magu Tanzania the sediment generation from maize and cassava fields were 15.6 and 7.9 ton/ha/year respectively. Hatibu *et al.* (1995), and Guzha (1997) have done researches on land degradation at central part of Tanzania and they found that there are significant losses of soil sediments. Guzha (1997) for example studied soil losses caused by tillage systems at Hombolo village in Dodoma region, and found that no tillage system produced highest runoff yields on average in most of the rainfall events compared to other systems. In Morogoro region research done by Kimaro *et al.* (2006) on traditional tillage on Mount Uluguru revealed significant losses. He quantified soil losses caused by manual hoeing on the slopes of Mount Uluguru and found that the sedimentation losses were up to 77 kg m^{-1} per tillage pass.

Literature reveals that since the advent of tractors use, soil tillage has been on the increase with farmers believe that the more you till the soil, the more yields you get (FAO, 2004). Intensification of agriculture and expanding settlements coupled with inappropriate land conservation practices have largely contributed to soil losses and land degradation leading to adverse effects on the natural habits, reduction of crop yield and loss of biodiversity, thus threatening people's livelihoods (Majaliwa, 1998).

It is reported by many authors that conservation tillage can combat and reduce tillage erosion (FAO, 2004; Shetto *et al.*, 2007; Mganilwa *et al.*, 2007). In the year 2006, a tillage project was introduced in Morogoro with objective of conserving the soil (Shetto *et al.*, 2007). Cover crops and no tillage equipment were used as part of conservation agriculture techniques for filtering sediment loss and improving soil fertility. The results were quantitatively good because the farmers obtained bumper harvest compared to farmers using conventional tillage practices. However, at the end of project, almost all the farmers resented to the conventional tillage practices. Many reasons were been put forward as to why rate of adoption is slow for new technologies. This might be due to technologies being very expensive or are not relevant to farmers (Tenge *et al.*, 2007), or may be the range of technologies available are limited or rare data available related to their environmental conditions or may be farmers were not involved right from the planning stage (Sokoni and Shechambo, 2005). It was further revealed by Kimaro *et al.* (2006) that data on tillage erosion for various agro-ecological zones are limited in Tanzania and should be given required priority. Study of tillage systems and their impact to land degradation ought to be given priority for sustainable land use and effective agricultural production. Hence the need of this studies on different tillage systems in the eastern agro economical zones.

1.2 Problem Statement

Parts of Morogoro region is characterized by low, erratic and highly variable rainfall (Msanya *et al.*, 2001). According to Mesfine *et al.* (2005), these types of climate are easily affected by land degradation. The region has enough land for agriculture about 70,799 km^2 (Regional Commissioner Document, 2006). Unreliable climatic conditions make agricultural production as a risk business at this area.

It is revealed that tillage activities produced significant soil losses and land degradation as observed by many searchers (Lal, 1997; Makungu, 1991; Hatibu *et al.*, 1995; Kimaro *et al.*, 2006; Mganilwa, *et al.*, 2005). According to Lal (1997), soil losses incur substantial loss to productivity. The average loss in crop yields due to tillage erosion for Sub Saharan Africa is estimated at 6 per cent, and in 1989, 3.6 million tons for cereals, 6.5 million tons for roots and tubers, and 0.36 million tons for pulses were lost by erosion (Lal, 1997). If this erosion level continues, yield loss by the year 2020 would be 14.4 per cent (Lin *et al.*, 1996). Hence the need of preservation of land from degradation by using the right tillage system which will utilise well, the available rainfall and get profit in agriculture (Six *et al.*, 2002), this will be revealed through the increase in crop yield, soil improvement and protection of water resources.

1.3 Justification

In many countries in the World research on comparison of different tillage systems has received considerable attention, including some in European countries (Cannell, 1985), United States of America (Lal *et al.*, 1997), Canada (Coote and Ramsey, 1983; Beyaert *et al.*, 2002), Australia (Hamblin, 1980), China (Xu and Mermoud, 2001) and India (Rao and Dao, 1992). Studies undertaken included evaluation of the impact of tillage systems on land degradation, soil physical property and yields. Examples under semi-arid conditions in India Rao and Dao (1992) studied tillage systems and found that conventional tillage is superior to no tillage, reduced tillage or mulching with a number of crops - sun hemp (Crotalaria juncea), barley (Hordeum vulgare), mustard (Brassica juncea) and chickpea (Cicer arietinum) grown in the dry season. In West African semi-arid regions, Lal (1997) obtained data which showed soil inversion and deep ploughing superior to no tillage in increasing plant-available water and crop yields. But in United States conservation tillage was superior and a more cost effective farming practice than conventional tillage erosion for Sub Saharan Africa is estimated at 6 per cent, and in 1989, 3.6 million tons for cereals, 6.5 million tons for roots and tubers, and 0.36 million tons for pulses were lost by erosion (Lal, 1997). If this erosion level continues, yield loss by the year 2020 would be 14.4 per cent (Lin *et al.*, 1996). Hence the need of preservation of land from degradation by using the right tillage system which will utilise well, the available rainfall and get profit in agriculture (Six *et al.*, 2002), this will be revealed through the increase in crop yield, soil improvement and protection of water resources.

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No developing country has installed a system for monitoring soil quality at a national scale (Afolayan *et al.*, 2004). The existing assessments are based on consultation with experts, extrapolation from case studies, field experiments and other micro studies or inferences from land use pattern. While little is known about current status, even less is known about trends and to what extent the degradation processes are induced (Hussain *et al.*, 1999). In addition, even if the data is available from other parts, but still the tillage effects are environmentally dependent that different results have been reported under different types of soil and climate (Dick, 1983; Limousin, 2007).

Hence a need arises to conduct a research on effects of tillage systems on land degradation in Morogoro Rural district at Mkambalani village. Five tillage systems were studied including conventional tillage, strip tillage, tied ridges, basin tillage and no tillage, where the experimental plots were planted with maize crop.

1.4 Main Objective

The main objective was to study the different tillage systems and their impacts on land degradation in Morogoro District which is under Eastern Agro-Ecological Zone - Tanzania.

1.4.1 Specific objectives

a) Determine the socio – economic characteristics of the study area

b) Determine the effect of five tillage systems on soil erosion and sedimentation

c) Evaluate the influence of tillage systems on soil characteristics in the study area

d) Assess the influence of tillage systems on maize crop growth and yield

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Overview of Soil Tillage Systems

Soil tillage is one of the fundamental agro technical operations in agriculture because of its influence on soil properties, environment and crop production (Acharya and Sharma, 1994). To ensure normal plant growth, the soil must be in such a condition that roots can have enough air, water, nutrients and penetrate easily the soil. Structure of the Ap horizon is largely influenced by soil tillage system and the implements used for tillage (Sidiras and Kendristakis, 1995; Beyene *et al.*, 2006). Tillage is identified as one of major process of soil erosion within sloping arable fields in many agro environments (Van Muysen *et al.*, 2002; Kimaro *et al.*, 2006). However tillage is required for seedbed preparation to optimize soil and environmental conditions for seed germination, seedling establishment and crop growth.

There are various forms of tillage practiced throughout the world ranging from the use of simple stick or jab to the sophisticated equipment. Whatever equipment used, tillage can be broadly classified into no tillage, minimum tillage and conventional tillage.

2.1.1 No tillage system

No tillage (NT) or zero-tillage is the practice of planting seeds into the stubble of the previous crop without any tillage or soil disturbance. Weed control relies heavily on herbicides. In this management practice, which forms part of conservation agriculture, the soil is never tilled and the last year's crop residue is left on the field. It is widely used all over the world to control erosion and maintain soil water content. Peters *et al.* (2003) itemized benefits of no tillage which include reduced farm power energy requirements for seedbed preparation, maintenance of higher soil organic matter levels, and prevention of soil erosion due to the stabilizing effect of plant debris in the topmost soil horizons. No-tillage management minimizes the impact of erosion since the soil surface is protected from the physical impact of rain detaching soil particles (Freebairn *et al.*, 1986). The effectiveness of no-tillage systems in reducing soil erosion is usually attributed to the energy effects of mulch cover and the maintenance of rapid infiltration rates. High infiltration rates for no tillage systems are typically found in soils with intense earthworm (*Lumbricus terrestris*) activity (Edwards *et al.*, 1988; Zachmann *et al.*, 1987).

No Tillage has considerable potential for stabilizing production in semiarid zones, but can have contrasting consequences on water conservation and yield. Lal *et al.* (1994) and Mganilwa *et al.* (2007) demonstrated positive effects on yields, where as (Kosutici *et al.*, 2005; Al-Issa and Samarah, 2007) found negative effects. No Tillage systems are characterized by high levels of previous crop residues on soil surface. The presence of residues can conserve soil moisture and decrease evaporation. But sometimes residues hinder correct seed placement and appropriate row closure in NT. The presence of residue may delay plant emergence and reduce crop yield mainly because of cooler soil temperatures. Delayed crop emergence and reduced plant population are problems sometimes associated with durum wheat under NT. Poor crop establishment, low plant populations, and delayed early plant growth due to higher mechanical resistance of soil were the primary cause of low durum wheat yields on NT in Mediterranean climate (Khaledian *et al.*, 2006). NT has been widely used in the last decades as an attractive alternative to Conventional Tillage (CT) because of their potential to reduce production costs. Besides lower operation costs, NT can save significantly the time with seedbed preparation compared with CT. However, yield variably with NT still remains a major concern among farmers. Yield responses to tillage systems can differ widely with respect to soil type, crop species, precipitation, and region climatic condition (El Titi, 2003).

2.1.2 Minimum tillage system - Strip tillage

Strip Tillage (ST) is a system combining the benefits of no-till and full-width tillage. Strip tillage is usually performed in the fall following soybeans or wheat to prepare the ground for corn planting (Mesfine *et al.*, 2005). Tillage is usually confined to narrow strips where seeds will be planted. The loosened soil in the strip creates a ridge of 6 to 10 cm high, which improves soil drainage and warming. By spring, it usually settles down to 2 to 5 cm high, and after planting the field is flat (Lessiter *et al.*, 1999). Row middles are untilled and covered with undisturbed crop residue. Fertilizer can also be applied during strip tillage. Land is prepared with implements which do not invert the soil and which cause little compaction, resulting in a good cover of residues on the surface in excess of 30%. The 30% is the conservation tillage definition in which 30% of the surface covered with crop residue (Cassel, 1982). Equipment used includes chisel plough, vibro-cultivator and draught animal ripper. Usually the strips of 5 - 20 cm wide are prepared to receive the seed and the intervening bands are not disturbed (FAO, 2004).

Introduction of conservation tillage practices using appropriate equipment can help farmers improve soil quality for sustainable agriculture (Freitas, 2000; Hoogmoed *et al.*, 2004). However, reduced tillage without soil cover results in reduced infiltration and lower grain yields (Akinyemi *et al.*, 2003; Guzha, 2004). Such problems are inevitable in areas where lack of off season rainfall and dry season feed shortage make it difficult to cover the soil either with crop residues or cover crops. This is typically the case in semi-arid Ethiopia and central part of Tanzania, and this situation calls for an alternative approach. A strip tillage system may offer a solution. Strip tillage systems where planting lines are cultivated while the inter-row space is left undisturbed have been found to have the benefits of both no tillage and conventional tillage (Licht and Al-Kaisi, 2005). Moreover, strip tillage systems allow the farmer to plough only in one direction, along the contour, so as to prevent surface runoff. Tillage time is reduced thus enabling farmers to complete land preparation in time and to reduce the oxen time required, which can be particularly beneficial to resource poor farmers who own only one or no oxen at all (Temesgen *et al.*, 2007).

Introduction of minimum tillage often necessitates higher N fertilization to maintain crop grain yields, especially during the first few years until a gradual build up of organic N pool could compensate for sustainable production (Phillips, 1969; Rice *et al.*, 1986). Several researchers reported lower yields under minimum than conventional tillage with low rates of N application and the reverse with high rates of N application (Kitur *et al.*, 1984; Meisinger *et al.*, 1985; Tolessa *et al.*, 2007). However, other researchers reported higher yields from minimum than conventional tillage at all N levels used in their experiments (Moschler *et al.* 1972; Sharratt *et al.* 2006). This emphasizes that successful crop production is a combination of many factors including proper management of inputs and a thorough understanding of the soil resources and how they respond to production practices (Uri, 1999). Hence the reduced tillage practices can increase moisture retention, reduce erosion, decrease fuel consumption, and increase soil C storage (Six *et al.*, 2002).

2.1.3 Conventional tillage system

Conventional tillage (CT), which is most commonly practiced in the country, involves the use of hand hoes, ox drawn mould board ploughs, tractor drawn disc ploughs and harrows combined with straw collection and burning during land preparation. During the operation the soils are cut, inverted and pulverized burying most of the residues underneath. The practice frequently causes soil compaction, affects soil physical properties, provokes biological degradation and results in declined crop yields. With fine dust on the surface and compaction below, a lot of soil is washed away with the first rains. Soil losses 30 tons/ha/year has been reported in Kilimanjaro region in conventional flat cultivated fields at a slope of 5% (Kaihura *et al.*, 1998). Soil losses up to 100 tons/ha/year have been reported for different land use systems (Magunda *et al.* 1999) in Lake Victoria basin. However as Murillo *et al.* (2004) and Vanda *et al.* (2009) pointed out, the global experience with minimum tillage, or direct drilling, results in equal, and even slightly smaller, harvests than traditional tillage (by using mould board ploughing or conventional tillage). According to these authors, conservation tillage only produces profitable yields with correct management.

2.1.4 Tied ridges (TR)

Ploughing is a necessary process of land preparation for the planting of crops, but in Sub-Saharan Africa, due to environmental conditions, the process can often ultimately lead to soil degradation and problems of erosion. In Ethiopia, a system of 'tied ridging' has been introduced (Mesfine *et al.*, 2005) as a means of minimising soil damage, and at the same time optimising the use of available water for the crops which are grown. The practice involves either planting the crop in small furrows on the flat and making ridges during crop development, or planting the crop on prepared ridges, and then blocking the furrows at regular intervals. These ties act as mini-dams, which collect the rainwater and minimise the flow of water off the field. They are effective in both a wet and dry season. In a wet season, the crop is elevated on the ridge and suffers less from water-logging. In a dry season, the trapping of rainfall and conserving it in the field enhances the yield. In Tanzania farming systems, ridges are widely used in the Southern Highlands (Iringa, Ruvuma and Rukwa) on slopes of 4-20% to grow maize, wheat, groundnuts, round and sweet potatoes. These ridges control soil erosion and retain some moisture as they are usually constructed on the contour (BACAS, 1993). Tied ridges (TR) which are parallel ridges with earthen bunds constructed at right angles to them, at intervals of 1- 4m, are used in growing maize and other grain crops in Mwanza and Shinyanga although their popularity has considerably declined in recent years due to the amount of labour required under hand-hoe cultivation. The tied ridges, nevertheless, create a series of individual basins that increase the surface retention capacity, decreasing runoff, and increasing crop growth and yields (Prentice, 1946; Kayombo, 1993).

2.1.5 Basin tillage (BT)

Floodwater harvesting (FWH) is used to support paddy production on "mbuga" soils which are vertic, black-grey cracking clays around Dodoma, Singida, Tabora, Shinyanga and Mwanza. Farmers in these regions have developed an elaborate system of retaining the seasonal flood in bunded basins called *majaruba*. Records show that the development of this system started in the early 1940's (Allnutt, 1942). It is estimated that 32% of rice in Tanzania is produced under the *majaruba* system (Kanyeka *et al.*, 1994). In Shinyanga and Tabora Regions for example, valley fields are subdivided by bunds of 25-100 cm height to form cultivated reservoirs or *majaruba* which are transplanted with rice crop (Mwakalila and Hatibu, 1992). The importance of this runoff farming is illustrated by the biggest increase in rice production in Tanzania over a 15 year period occurring in the semi-arid marginal areas (MoA, 1993). Yields are, however, still low compared to those of well-managed irrigation projects which produces 6t/ha (Hatibu *et al.*, 1997).

2.2 Effects of Tillage on Land Degradation

The magnitude of tillage erosion depends on the erosivity of the tillage operation and erodibility of the landscape, as described by Lobb and Kachanoski (1999). Tillage erosivity is determined by the design of the tillage implement that is types of equipment, the arrangement, geometry of cutting tools and how the tillage is operated (Sheng *et al.*, 2006). Critical parameters are the frequency of pass, tillage speed and depth, the match between the tractor and implement and behaviour of the operator. Landscape erodibility is determined by the topographic properties of the landscape and properties of soil. Numerous studies from different parts of the world have shown that slope gradient is dominant property in influencing tillage translocation and tillage erosion (Linstrom *et al.*, 1990; Govers *et al.*, 1999). However the variability in tillage translocation which causes tillage erosion can not be explained by slope gradient alone. The effects of other factors such as tillage depth and speed, tillage direction, soil properties have been stressed by researchers (Lobb *et al.*, 1999; Van Muysen *et al.*, 2002).

2.3 Effects of Tillage on Topography

Soil movement by tillage can be a dominant force in redistributing soil within the profile and throughout the landscape. Soil erosion by tillage results in the removal of soil from convex slope positions and soil accumulation in concave slope positions (Govers *et al.*, 1999; Lobb *et al.*, 1999; Sheng *et al.*, 2006). Net down slope soil flux by tillage erosion is a function of slope gradient, while soil translocation by water erosion is a function of slope steepness and length (Papiernik *et al.*, 2006). Thus, areas with high soil loss resulting from tillage erosion do not always correspond to those with severe water erosion, but tillage and water erosion operate to redistribute soil in the landscape in predictable patterns. Tillage erosion rates are usually highest in crest, shoulder and upper back slope positions while soil movement by water erosion is greatest in the mid to lower back slope region. Tillage erosion is especially evident in hilly landscapes. Soil morphological effects of tillage erosion include truncated soil profiles at convex slope positions, deep topsoil accumulation in concave slope positions and inverted soil profiles, where subsoil material is deposited over original surface horizons (De Alba *et al.*, 2004; Heckrath *et al.*, 2005).

Few studies have specifically reported the impact of tillage-induced changes in soil properties on crop production, but these studies consistently report higher grain yields or biomass production in areas of soil accumulation by tillage compared to areas of soil removal by tillage (Heckrath *et al.*, 2005; Papiernik *et al.*, 2006). An investigation conducted at the site used in the present studies indicated that low wheat (*Triticum aestivum*) yields (averaged 50% of the maximum measured yield in each of 3 years) were observed in areas affected by high soil loss by erosion, predominately due to tillage erosion on convex slope positions (Papiernik *et al.*, 2006). Considerable research has been conducted to define relationships between topographic parameters and soil properties (Gregorich *et al.*, 1998). Some of the findings indicate Organic carbon (OC) is correlated with slope gradient and distance from summit positions (Walker and Ruhe, 1968; Kleiss, 1970). In terms of slope position, Norton *et al.* (2003) indicated that total carbon (C) concentrations were greatest on back slopes and lowest on summits and toe slopes due to localized accumulations of nutrients from surface run on contributions, whose concentrations gradually decreased down slope. Other researchers (Gregorich and Anderson, 1985) found lower concentrations of soil organic matter (SOM) in the upper slope positions where erosion was at a maximum, with greater concentrations occurring in depositional areas on lower slope positions. Woods and Schuman (1988) concluded that active SOM concentrations differed less between slope positions than between land-uses or soils. Bertol *et al.* (2007) reported that greater SOM concentrations were found on slopes with north facing aspects.

2.4 Water Runoff

Water loss in the form of surface runoff is one way in which water from the cultivated field is lost. Water runoff is severe during heavy rainfall and other factors such as soil type, soil cover and topography. The better understanding of the effects of tillage on the amount of runoff will help to make appropriate recommendations on selection of the right tillage system. Soil compaction in the surface layer can increase runoff, thus increasing soil and water losses. However, when the compacted layer is tilled with a mouldboard or chisel plough, the resulting rough, cloddy surface can decrease runoff and erosion. While it sounds contradictory, both effects are possible, depending on the soil and soil conditions encountered.

Several studies have shown less runoff with conservation tillage rather than convention one (Onstad, 1984; Rusu *et al.*, 2005). Rusu *et al.* (2005) compared convention tillage with strip tillage on runoff and soil erosion and found that strip tillage decreased runoff by 2.5 fold and erosion by 3.5 fold. Generally tillage treatment that increases the surface roughness will reduce the volume of surface runoff as most of the water will be trapped in the depressions and infiltrate into the soil with time (Mwendera, 1992). Differences in runoff volumes among tillage treatments have attributed to the varying effects of tillage on surface conditions and residue cover (Blevins *et al.*, 1971). A tillage treatment that increases the surface roughness will reduce the volume of surface runoff as most of water will be trapped in the surface depressions and will be infiltrated into the soil with time (Guzha, 1997). Smoother surfaces will cause higher amounts of surface runoff. The same is true on conservation tillage which involving minimum tillage with no crop residues on the surface of soil will generate a large amount of runoff. Research done by Hatibu *et al.* (1995) showed that tied ridging produced the least amount of surface runoff as expected while the zero tillage plots and strip cultivated plots produced the highest runoff yields on average in all rainfall events. There was also a high correlation between rainfall characteristics and runoff. The rainfall amount, intensity, distribution, energy load and it's seasonally and variability can cause severe runoff and erosion (Blevins *et al.*, 1971). The amount of rainfall governs the overall water balance and the relative proportion that becomes runoff. Intensity distribution affects runoff by altering the amount and rate of overland flow. Storms with peak intensity in the beginning usually generate less runoff because the water storage capacities of soils are still unutilized and the relatively dry soils still have high infiltration capacities (Lal, 1997). High rainfall intensities are related both to relatively large size and high number of drops falling per unit area per unit time.

Blevins *et al.* (1971) noticed also the effect of tillage on volume of runoff was dependent on the antecedent soil moisture level and time of runoff event. When soil moisture content was high runoff was higher from the no tillage plots than from the conventional tilled plots. The reverse was true when the last rainfall was more than seven days before a runoff event. The rainfall pattern and initial soil moisture were found to have significant influence on cumulative runoff yield.

2.5 Effect of different tillage on sedimentation

Sedimentation is the process of movement of soil particles from one point and deposited to other point caused by water or wind. Different soils have different susceptibility to soil erosion and hence sedimentation. Soil properties which affecting susceptibility to erosion including soil texture, structure, water retention and transmission properties, unconfined compressive and shear strength. Researchers (Mesfine *et al.*, 2005; Papiernik *et al.*, 2006) mentioned the binding materials which stabilized the soils include organic matter, clay and its mineralogy, iron and aluminium oxides and antecedent soil moisture. Relative amounts of binding materials in the soil strongly influence soil structural stability. Soils with high amounts of organic matter are less susceptible to erosion as the organic matter prevents slaking of aggregates, limits the degree of crust formation and improves soils water retention properties (Lal, 1997). Clay particles which are small have effect of cohesion, stickiness, plasticity (ability of being moulded without breaking when at certain degree of wetness) are highly susceptible to erodibility rather than sand soils. Some of the soil properties affecting erodibility are inherent like the soil texture, clay and mineralogy. Other properties are dynamic and temporal like structural and soil water content while other properties are induced by man like structural modification due to tillage. Hence soil erodibility varies with time.

Recent estimates of tillage erosion and deposition rates based on radionuclide (Cs) tracer studies, which integrated soil redistribution over a period of approximately 40 years, frequently exceeded 10 Mg ha $^{-1}$ annually at eroding and aggrading sites of intensively cultivated land (Govers *et al.*, 1999; Van Oost *et al.*, 2003). Controlled tillage experiments employing modern tillage practices with a combination of several tillage operations showed even higher tillage erosivities (Lobb *et al.*, 1999; Gerontidis *et al.*, 2001). Typically, the mouldboard plough was the most erosive implement (Van Muysen *et al.*, 2002). Therefore, tillage has the capacity to alter soil profile height by several millimetres annually at both eroding and aggrading sites and is a major contributor to the distributions of colluvial soils on arable land.

Soil tillage systems are important factors in the conservation of soil physical, chemical, and biological properties since they are able to control, or even reduce, erosion and losses by runoff (Bertol *et al*., 2007). Conventional tillage favours water erosion and sedimentation processes because it promotes an excessive mobilization of topsoil. On the contrary, conservation managements reduce the mobilization of the soil and, therefore, maintain vegetal residues on the topsoil improving the environment for plant growth (Masanja, 2009). Conversely, a number of authors (Dickey *et al*., 1984; Salako *et al*., 2007) have emphasized the benefits that crop covers provide to the soil when remaining on soil surface. These coverage decrease water and soil losses mainly because of the protection they provide against the detachment caused by raindrops; moreover, they constitute a physical barrier to runoff. In addition, vegetal residues incorporated or not to soil surface, contribute to control invasive plants since they exert a suppressive effect on the growth of these plants. An appropriate cover can prevent erosion, maintain the organic matter content and allow culture sustainability.

2.6 Soil Characteristics

Soil characteristics are the measure of soil quality. Soil quality has been defined as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health (Doran and Parkin, 1995). Agricultural production can reduce soil quality. Tillage for instance initiates processes that may damage the natural soil ecosystem. It alters many of the soil physical properties including, bulk density, pore space, pore size distribution, water holding capacity, soil water content. infiltration and aggregation (Spedding *et al*., 2004). Soil quality relates to the chemical, physical and biological properties of the soil, and how these are distributed throughout the soil profile.

Scientists use an array of indicators to describe soil quality such as pH, organic matter content, plant-available nutrients, porosity, grain size distribution, water permeability and retention capacity, topsoil depth and presence of chemicals toxic to plants or plant consumers (Mulengera *et al.*, 1999; Lindert, 2000; Kajiru *et al.*, 2001). These properties vary vertically within the soil profile and horizontally from site to site and also interact. Therefore, soil quality cannot easily be described by one variable or an index. Crop yields alone are not a good proxy as they depend on water, fertilizer, seed variety, and crop management practices in addition to soil quality. However, measuring yield trends while controlling for other inputs and management can provide an observable and credible measure of trends in soil quality (Coxhead *et al.*, 2006).

2.6.1 Soil physical properties

The physical properties of a soil are those characteristics which can be seen with the eye or felt between the thumb and fingers. They are the result of soil parent materials being acted upon by climatic factors (such as rainfall and temperature), and affected by topography (slope and direction, or aspect) and life forms (kind and amount, such as forest, grass, or soil animals) over a period of time. A change in any one of these influences usually results in a difference in the type of soil formed. Important physical properties of a soil are colour, texture, structure, drainage, depth, and surface features (stoniness, slope, and erosion). The physical properties and chemical composition largely determine the suitability of a soil for its planned use and the management requirements to keep it most productive. To a limited extent, the fertility of a soil determines its possible uses, and to a larger extent, its yields.

However, fertility level alone is not indicative of its productive capacity, since soil physical properties usually control the suitability of the soil as growth medium. Physical property parameters of soil can be measured includes bulk density, total porosity, infiltration, water holding capacity, air capacity and soil moisture content. These parameters are important for normal plant growth and agricultural production.

Many authors examined influence of different tillage systems on the soil physical properties (Kovac and Zak, 1999; Gilandeh *et al*., 2009; Husnjak *et al*., 2002). Kovac and Zak, (1999) did experiments and found that changes in soil physical properties were induced by different tillage treatments, but the changes were small and insignificant. Contrary to this Gilandeh *et al*., (2009) and Husnjak *et al*., (2002) found that there were changes in soil physical properties, especially when similar tillage system has been practiced for longer period. According to the Gilandeh *et al*., (2009), the influence of tillage system on the soil physical properties was greater in humid climate and loamy soils in comparison to the arid climate and sandy soils. They found out that the soil physical changes affected by different soil tillage treatments could influence yield level of grown crops. Since tillage strongly influences the physical properties of soil, it is important to apply that type of technology that will make it possible to sustain physical properties at a level suitable for normal growth of agricultural crops. Physical properties represent a group of properties having a substantial impact on the different physical-chemical and biological processes in soil and hence they should be kept optimal (Lal, 1997). For this reason, it is essential to know the soil physical properties not only during the growing season but also after the harvest of agricultural crops as noticed by Husnjak *et al.* (2002). They did research in Northern Slovenia, and found that by comparing different tillage systems on soil physical properties of bulk density, total porosity, and infiltration, water holding capacity and air capacity were not significant in winter wheat seasons but significant impacts were recorded in summer soybeans cultivation seasons.

2.6.2 Bulk density

Many farmers have the belief that, undisturbed soil is harder and more resistant to root penetration than tilled soil. In fact, high soil strength has been proved to reduce and even stop root growth (Sidiras and Kendristakis, 1995). The most common variables used to access soil strength in tillage studies are bulk density (ρ_b) and penetrometer resistance. Both they are interrelated and the use of only one of these variables may lead to misleading results (Campbell *et al.*, 1996). Bulk density is inversely related to total porosity (Papiernik *et al.*, 2005), which provides a measure of the porous space left in the soil for air and water movement. The optimal bulk density for plant growth is different for each soil. In general, low bulk density or high porosity leads to poor soil-root contact and high bulk density or low porosity reduces aeration and increases penetration resistance hence limiting root growth (Cassel, 1982). Bulk density is related to natural soil characteristics such as soil texture, organic matter, soil structure (Cassell, 1982; Chen *et al.*, 1998) and gravel content (Husnjak *et al.*, 2002). But it varies over year due to the action of several processes such as freezing and thawing (Unger, 1991), settling by desiccation and kinetic energy of rainfall (Cassel, 1982), and loosening by root action and animal activities. Crop operations, especially tillage may also alter bulk density. However this changes of bulk density due to the tillage is temporal one, the soil rapidly settle recovering its former bulk density (Husnjak *et al.*, 2002). In sandy soils, ρ_b can be as high as 1.6, whereas in aggregated loams and in clay soils, it can be as low as 1.1 g/cm^3 (Chen *et al.*, 1998). The bulk density is affected by the structure of the soil, i.e. its looseness or degree of compaction, as well as its swelling and shrinkage characteristics, which are dependent upon the wetness. Bulk density is also known as 'volume weight' or 'apparent density'.

Anken *et al.* (2004) found that tillage did not affect soil bulk density 14 years after establishing tillage treatments in Switzerland. Arshad *et al.* (1999) found no change in soil bulk density, but did find enhanced aggregate stability with 12 years of no tillage versus conventional tillage in northern British Columbia. Mahboubi *et al.* (1993) observed an increase in soil bulk density, penetration resistance, and aggregation with 28 years of no tillage versus conventional tillage in Ohio. Hill (1990) also found an increase in soil density and strength with 12 years of no tillage versus conventional tillage in Maryland. In the sub arctic, Sharratt *et al.* (2006) found that a silt loam was more stable and wetter at the time of sowing in spring with 7 years of no tillage compared with intensive tillage. Generally bulk density is not affected much by tillage systems.

2.6.3 Porosity

Porosity of a soil is the volume of all the open spaces (pores) between the solid grains of soil and it defines the volume of water that can be held in a given volume of the soil. Soil permeability is the property of the soil pore system that allows fluid to flow. Soils need large pores and channels for adequate aeration and good drainage. Large pores that can be seen by the human eye are known as macro pores. Meso pores and micro pores are too small to be seen by the human eye and are respectively responsible for storing plant available water and holding the water that is unavailable to plant roots. Measurements of pore characteristics are becoming more and more used to characterize soil structure since they influence numerous functions in soils (Lipiec *et al.*, 2005). One of important function of soil they mentioned is transmission of water, which directly affects plant productivity and the environment. Infiltration of water increases water storage for plants and groundwater recharge and reduces erosion. The rate of infiltration is controlled by the pore size distribution and the continuity of pores or pathways (Kutilek, 2004). The role of macro pores in rapid infiltration under pounded conditions (preferential flow) was stressed in numerous papers (Lin *et al.*, 1996; Lipiec *et al.*, 2005; Masanja, 2009). Lin *et al.* (1996) reported that 10% of macro-pores (>0.5 mm) and meso-pores (0.06–0.5 mm) contributed about 89% of the total water flux. As shown by Lipiec *et al.* (2005), the maximum infiltration of conducting channels in untilled soil was more than 1 mm/min, although the volume of these channels amounted to only 0.2% by vol. The preferential flow has also been observed in an unsaturated soil under non-pounded conditions (Arshad *et al.*, 1999). Therefore, this flow has been increasingly recognised as a major component of water movement in many soils, particularly clays (Lin *et al.*, 1996). The structure and functions of macro-pores can be an effective measure of soil 'quality' as they are relatively resistant to vertical compression (Lin *et al.*, (1996) proposed to incorporate macro-porosity as a criterion of soil structure in the soil morphological system.

Tillage largely influences pore size distribution. Soils under conventional tillage (CT) generally have lower bulk density and associated higher total porosity within the plough layer than under no tillage (NT). The changes in total porosity are related with alterations in pore size distribution. This relation can be different depending on soil type. Heenan, *et al.* (2004) reported that under the same site conditions, NT compared to CT resulted in lower volume of macro-pores (>30 mm) on sandy soil and silt loam, whereas the opposite effect was found on sandy loam. Lin *et al.* (1996) reported in their review that converting from CT to NT generally results in an increased volume fraction of pores 100–500 mm and a decreased volume of pores 30–100 mm. The effect of soil tillage and management on transmission properties is not uniform. The results showed that untilled compared to tilled soil had greater (Arshad *et al.*, 1999), similar (Lipiec and Hatano, 2005) or lower infiltration rates (Heenan, *et al.*, 2004). The inconsistencies can be associated with pore functioning. In NT soils, greater infiltration was attributed to greater contribution of flow-active macro-pores made by soil fauna or by roots of preceding crops as noticed by Lipiec *et al.* (2006), whereas in tilled soils with stable structure - to preferential flow through inter aggregate pores (Lin *et al.*, 1996).

2.6.4 Infiltration

Infiltration is the term applied to the process of water movement into the soil. The factors that influence infiltration are varied and dynamic. Some of the factors include soil texture, soil structure, surface roughness, total porosity, pore continuity, pore size distribution and initial soil moisture (Burwell *et al.*, 1963). Understanding the characteristics of water movement through root zones may provide critical information to develop and implement improved management practices and refine estimates of watershed hydrology. Water is one of the most important factor impacting crop yield and transport of nutrients and chemicals in the soil profile (Summer and Miller, 1996). Soil properties related to water infiltration, including hydraulic conductivity, soil organic matter, soil bulk density, soil water content, and soil texture, impact plant-available water stored in the root zone, evaporation from the soil, and plant transpiration (Gilandeh *et al.*, 2009). Both natural soil variation and management factors, such as tillage, crop type, and crop management techniques, cause water infiltration differences (Zachmann *et al.*, 1987).

Tillage may increase or decrease the infiltration rate depending on the degree of soil compaction. Allmaras *et al.* (1977) measured unsaturated hydraulic conductivity (K) values that were increased at least fourfold by chiselling 0.43 m deep compared with an untilled check. Burch *et al.* (1986) measured enhanced infiltration of simulated rain when the level of tillage disturbance was reduced and suggested that the increase may have been caused by changes in the surface seal. Lal *et al.* (1994) measured infiltration rates of 480 mm h^{-1} for no-till and 150 mm h^{-1} for the ploughed treatment after a field had been planted in maize (*Zea mays L.*) for 5 years. They found that surface residues prevented surface seal in the no-till treatments. The manner in which recently tilled soil is settled may affect infiltration rate. Meek *et al.* (1989) measured a 17% increase in infiltration rate in the field when soil was packed lightly before the first flood irrigation compared with no packing. Tillage disturbs natural channels that have formed in soil. The increase in porosity when soil is tilled may not result in an increase in infiltration rate because of disruption of the vertical continuity of the pores (Burch *et al.*, 1986). Plant roots are important in forming new channels (Parker and Jenny, 1945). Root growth initially may decrease infiltration rates (Barley, 1954), but later decomposition of roots leaves channels that result in increased infiltration rates. Meek *et al.* (1989) measured increases in infiltration rate that were related to decreases in stand density under alfalfa. Disparte (1987) measured a positive correlation between increases in infiltration caused by the type of crop and size of tap root. It is generally the pore sizes and their connectivity that determines whether a soil has high or low infiltration rate (permeability). Water will flow easily through soil with large pores with good connectivity between them. Small pores with the same degree of connectivity would have lower infiltration rate, because water would flow through the soil more slowly. It is possible to have zero permeability (no flow) in a high porosity soil if the pores are isolated not connected. It is also to have zero permeability if the pores are very small, such as in clay soils. Porosity and infiltration can be affected by the use of different tillage systems.

2.6.5 Water holding capacity

Available water capacity or available water content (AWC) is the range of available water that can be stored in soil and be available for growing crops (Burch *et al.*, 1986). The concept, put forward by Veihmeyer and Hendrickson (1927), who assumed that the water readily available to plants (S_a) is the difference between water content at field capacity (θfc) and permanent wilting point (θwp):

$$S_a = 10(\theta_{FC} - \theta_{WP}) \qquad \text{[mm (water)/m (soil depth)]} \;\ldots\ldots \qquad (1)$$

Hill (1990) criticised that the terms field capacity (FC) and permanent wilting point (PWP) were never clearly defined, and lack physical basis, and that soil water is never equally available within this range. He further suggested that a useful concept should concurrently consider the properties of plant, soil and meteorological conditions.

Richards (1928) remarked that the concept of availability is oversimplified. He viewed that: the term availability involves two notions: (a) the ability of plant root to absorb and use the water with which it is in contact and (b) the readiness or velocity with which the soil water moves in to replace that which has been used by the plant. The magnitude of S_a for any soil is very important. It shows the capacity of the soil to supply water to the crop over time. A low value of S_a indicates early wilting of crops and a high frequency of irrigation will be required to keep soil moisture at acceptable levels. The magnitude of S_a is a function of soil texture and structure. Coarse textured soils (sandy soils) have lower S_a than fine textured clays, while loams are intermediate. This is because the finer the particle size the larger is the surface area for water adsorption. Therefore, soils with fine particles will have higher water contents at both field capacity and wilting point than soils with coarser particles.

2.6.6 Moisture content

The relationships between crop yield, soil moisture and tillage are not completely understood. The common approach to determining effect of tillage has been to evaluate tillage using crop yield or soil moisture content. While most researchers agree changes in soil moisture can influence crop growth depending on soil properties and environmental conditions (Blevins *et al.*, 1971; Larson, 1964; Lindwall and Erbach, 1983) no general conclusions have been made (Belvins *et al.*, 1971; Van Doren *et al.*, 1976). Experiments done by Lindwall and Erbach (1983) indicated changes in soil moisture content due to tillage are not of the magnitude to influence crop production. General conclusions about tillage and crop yield are impractical because of the many combinations of soil properties, climate and crops. This was restated by Larson (1964) in an experiment on evaluation of tillage requirements for corn production. Larson (1964) concluded to define a set of parameters which could be used to evaluate tillage practices over wide areas is not practical because of limited knowledge and the many combinations of soil, crop and climate. Even when specific soil property changes on crop yield and soil moisture were understood, the tillage required to achieve those changes may not be possible or known (Ojeniyi and Dexter, 1979).

Soil moisture content (SMC) is a very important parameter for cutting and tilling the soil by mouldboard plough. With low soil moisture content the cohesion force between particles of soil is very strong and a lot of energy is needed during tillage and with the higher soil moisture content, tillage equipment cannot be used in the field due to the slippage and sunk of implement (Ahmadi and Mollazade, 2009).

The ploughing depth is also a very important and effective parameter which is affected by not only weight of implement but also moisture content of soil. Increasing the ploughing depth raise the clod mean weight diameter (MWD) (Yassen *et al.*, 1992). The raised clod means weight diameter can increase costs on secondary tillage due to many passes tilling in order to get optimal clod mean weight diameter for normal plant growth (Ahmadi and Mollazade, 2009). At higher moisture contents of soil, degree of sheering and shattering of clods is reduced leading to a lower impact force (Thomas and Sigh, 2002). This is in agreement with the findings of Sigh *et al.* (1979) that when moisture contents exceed the plastic limit value, the draught per unit area decreases. Plastic limit is the water content at which hand-rolled soil breaks at a diameter of approximately 3 mm. The draught requirement decreased with increasing water content, while the finest tilt was produced at intermediate water content on the clay soil on the clay soil.

2.6.7 Soil structure and texture

Soil structure is generally defined as the mutual arrangement, orientation, and organization of the particles in the soil. Structure is strictly a field term descriptive of the gross, overall aggregation or arrangement of the primary soil separates. Soil structure is highly dynamic and may change greatly from time to time in response to changes in natural conditions, biological activity, and soil management practices. Soil structure can be of decisive importance in determining soil productivity since it greatly affects the water, air, and heat regimes in the field. Soil structure also influences the mechanical properties of the soil, which may in turn affect seed germination, seedling establishment, and root growth. Moreover, soil structure can affect the performance of agricultural operations such as tillage, irrigation drainage, and planting.

Soil texture is concerned with the size of mineral particles. Specifically it refers to the relative proportion of particles of various sizes in a given soil. The texture of a soil cannot be altered and thus is considered a basic property of that soil. The determination of the particle size distribution is referred to as 'mechanical analysis' and the various groups into which the mineral particles are separated are spoken of as separates (textural fractions). There are a number of different classifications based on size ranges, i.e. separates - sand, silt and clay.

Soil aggregation is one of the main factors controlling the chemical, physical, and biological processes that contribute to soil productivity and agricultural sustainability. Several studies showed that conservation tillage improved soil aggregation even within short-term application (Coppens *et al.*, 2006; D'haene *et al.*, 2008). The interaction of clay colloids with organic compounds and inorganic cementing materials creates soil aggregates by forming organo-mineral complexes (Shrestha *et al.*, 2006). This explains that soil aggregate formation is dependent on soil texture. A review of available literature indicates that different soil types and management practices have a strong effect on soil properties, like aggregation (Shrestha *et al.*, 2006). Several methods exist to express soil aggregation; however, dry sieving provides the naturally existing situation of aggregates unlike wet sieving where most information about naturally occurring peds is lost (Coppens *et al.*, 2006). Therefore dry aggregate size distribution could be considered to represent the actual state of soil aggregation and soil structure. Coppens *et al.* (2006) found out that differences in size of these aggregates have been associated with the effect of different tillage practices.

2.6.8 Soil chemical properties

Change in frequency and intensity of tillage practices alters soil properties, distribution of nutrients and soil organic matter in the soil profile. These changes become stable with time and could affect availability of nutrients for plant growth, crop production, and soil productivity. Long-term NT systems accumulate nutrients in the soil surface, whereas Mouldboard plough (MP) distributes nutrients relatively uniformly through the tillage depth. Stratification of nutrients has been observed in two long-term tillage studies under NT, whereas soil mixing promotes uniform distribution of nutrients in MP and Chisel plough (CP) as observed by Karlen *et al.* (1994) and Sidiras and Kendristakis (1995). In contrast, Franzluebbers *et al.* (1995) observed differences in nutrients distributions due to tillage system.

2.6.9 Soil pH

Soil acidity is caused by hydrogen (H+) and aluminium (Al+++) ions in the soil solution. The activity of this acidity is expressed by the familiar measurement of "soil pH" in soil tests. A pH measurement of 7 is neutral, pH less than 7 is acid, and pH greater than 7 is basic. The optimum pH range for agronomic crop production is 6 to 7. Soil pH is critical for many reasons. It has a major influence on the availability of elements, including essential nutrients like nitrogen, phosphorus, and potassium, as well as secondary nutrients, micronutrients, and potentially toxic elements like aluminium. One of the main reasons for managing soil pH by liming is to reduce the toxic effects of aluminium on plant roots. At low pH, high aluminium availability can severely restrict root growth and thus uptake of water and nutrients. Most soil microbes are sensitive to soil pH, which has an influence on nutrient availability (especially nitrogen), soil organic matter, and general soil health. Also, many pesticides are sensitive to soil pH. Extremes in soil pH can reduce the efficacy or increase the activity of pesticides, which can result in crop injury. Several factors can cause soil acidity, including decay of crop residues, acid precipitation, leaching of basic ions (leaving behind the more tightly bound aluminium), and the acidifying effect of ammonium sources of nitrogen. Ammonium nitrogen usually is the largest single source of acidity in farmed soils. Any source of ammonium nitrogen will increase soil acidity. For example, the most commonly used N fertilizer materials, including manure N, urea, urea-ammonium nitrate solution (UAN), ammonium nitrate, anhydrous ammonia, and ammonium sulphate, all will increase soil acidity.

The increased use of no-till (NT) systems in crop production systems has raised questions on how acid soils should be managed under these conditions. Increases in organic carbon (OC) in the surface of 5 to 7.5 cm from NT soils have been well documented. Dick (1983) observed an increase of OC in the surface 7.5 cm of soil with NT corn when compared with intensive tillage (mouldboard plough). Karlen *et al.* (1994) reported that OC was significantly higher in the surface 5 cm of soil in NT soils when compared with ploughed soils after 20 years of continuous corn. Many researchers have hypothesized that the surface 5 cm of soil in NT systems will be less sensitive to decreases in pH caused by surface application of N fertilizers because of increased OC (Blevins *et al.*, 1983; Arif *et al.*, 2007). As early as the 1930s, scientists were studying the nature of soils in relation to Al toxicity and recognized that plants growing in soils high in organic matter (OM) did not exhibit symptoms of Al toxicity compared with soils with similar pH but less OM content (Larson, 1964). Abundant work on reactions of Al with soil OM has underscored the importance of OM in controlling Al equilibrium (Arif *et al.*, 2007; Berggren and Mulder, 1995). Results from these studies show that Al forms relatively stable complexes with soil OM by interaction with carboxyl groups and, to a lesser extent, with phenolic hydroxyl groups (Arif *et al.*, 2007). The amount of complexed Al is dependent on pH and Al concentration in soil solution.

2.6.10 Soil CEC

Change in organic C contents due to tillage can affect soil cation-exchange capacity (CEC) of soil (Hussain, 1997). In higher organic C, no-till resulted in a significant increase in CEC in the 0- to 15-cm sandy clay loam layer compared with Chisel Plough and Mould board Plough after 28 years of cultivation as noticed by Mahboubi *et al.*, (1993). After 12 years of a tillage study, Karlen *et al.* (1994) found that no differences in CEC due to tillage system. Organic matter plays an important role in nutrient availability and soil aggregate stability. Soil productivity decreases when soil organic matter (SOM) declines (Chad *et al.*, 2007).

Phosphorus (P) is among the important nutrient in the soil for plant growth. Overland flow is believed to be the primary origin of P losses from agricultural soils as found by Stevens *et al.* (1999). As readily desorbable P accumulates in topsoil, its concentration decreases with increasing depth as noted by Stamm *et al.* (1998) but also P is transported in solution or associated with eroded particles (Kronvang, 1992). In general, P associated with eroded particles (mainly adsorbed or precipitated P) accounts for most P in overland flow from cultivated agricultural lands (Bundy *et al.*, 2001; Saavedra and Delgado, 2006). Thus, an immediate way of decreasing P movement is by minimizing particulate erosion and transport as mentioned by Andraski *et al.* (2003).

2.6.11 Soil Organic Carbon (SOC)

Studies conducted in semiarid dry land production systems have compared the effects of NT and CT on soil chemical properties. Tillage has been found to decrease SOC compared with NT (Follett and Peterson, 1988). Converting from the traditional wheat fallow (WF) rotation to more intense cropping systems such as a wheat corn fallow (WCF) rotation with NT in the Great Plains can increase SOC in surface soils (Bowman *et al.*, 1999; Sherrod *et al.*, 2003). The higher SOC under NT was attributed to reducing the amount of tillage and increasing soil water storage, which increases the amount of plant biomass returned to the soil surface. However, in an established WCF rotation in Nebraska, Wicks *et al.* (1988) found that there were no differences in surface SOC between NT and CT treatments over a 15 years period. While Dick *et al.* (1998) found little change after only 2 to 3 years in Ohio, a number of studies have documented significant changes in some chemical properties over longer time periods. For example, significant increases in SOC were reported for the topsoil layer, after 4 to 28 years of conversion to NT (Lal *et al.*, 1994; Ismail *et al.*, 1994). The amount of precipitation in a given area will greatly influence the time it takes to notice changes in soil properties.

Soil organic matter (SOM). is a key factor in semiarid agro ecosystem productivity. Soils of semiarid regions are characterized by low SOC content, low water and nutrient retention, and thus low inherent soil fertility (Lal, 1997). In these regions, low and erratic rainfall together with high evapotranspiration rates leads to a low crop biomass production and thus to a limited residue input into the soil. Hussain (1997) quantified the contribution of SOM to productivity and observed that 1 Mg

ha^{-1} of SOM increased wheat (Triticum aestivum L.) grain yield up to nearly 16 kg ha^{-1}. He concluded that a loss of fertility explained the loss of productivity due to a depletion of SOM.

2.6.12 Soil N, P, K

Plants need relatively large amount of nitrogen (N), phosphorus (P) and potassium (K) for normal growth and development. These nutrients are referred to as primary nutrients and are the ones most frequently supplied to plants in fertilizers. N is very dynamic and is constantly shifting between inorganic and organic forms. Hence N can be easily lost through leaching, runoff or evaporation caused by improper tillage systems.

Overland flow is believed to be the primary origin of P losses from agricultural soils (Stevens *et al.*, 1999). As readily desorbable P accumulates in topsoil, its concentration decreases with increasing depth (Saavedra and Delgado, 2006) and P is transported in solution or associated with eroded particles (Dick *et al.*, 1998). In general, P associated with eroded particles (mainly adsorbed or precipitated P) accounts for most P in overland flow from cultivated agricultural lands (Saavedra and Delgado, 2006). Thus, an immediate way of decreasing P movement is by minimizing particulate erosion and transport (Andraski *et al.*, 2003). Hence the benefits of long-term NT over CT include higher infiltration rates and reduced soil erosion, which helps to reduce P loss from soils (Dick *et al.*, 1998).

Implementation of no-tillage practices for cotton has prompted questions regarding the application of fertilizer K due to its limited-mobility in soil (Varco, 2000).

Fertilizer K is commonly broadcast and incorporated into the soil with tillage. Surface placement without incorporation in no-till and reduced-till conditions may lower the effectiveness of K fertilization due to soil K stratification in the shallow surface soil.

2.7 Tillage Systems and Yields

Influence of soil tillage systems on yields is hard to predict. The results depend one hand on the soil characteristics and microclimate and on the other hand, on the association of different practices, such as: the rank of soil preparation, the sowing dates, the equipment used, the cultures rotation, the species or the hybrid used, the way in which it is fertilized (the time and the way it is applied), the weed control (Rusu *et al.*, 2005). The relation between the production – its profit and the systems of soil tillage is mostly influenced by the previous management of the soil and by the weather. Consequently, the applying of the new systems of soil tillage must be done together with the managerial input, with the results acquired by research and the creation of new species and hybrids.

The alternative systems look for the sustainability of the agricultural system, to increase the actual soil fertility and ensure – as research proves - productions close in number to those obtained by classical ploughing. Another fact that must be specified is that the equal productions or the reductions up to 90 – 95% in the case of unconventional systems of soil tillage in opposition to the classic systems are considered more profitable. This is explained by the reduction of the expenditures when eliminating the ploughing in case of new systems of soil tillage and by the increasing of optimum tilled and traffic ability as result of the improving the soil characteristics.

The production differences between the alternative systems and the classic one can be the result of a variant choice that can be used in certain climate conditions (Horn *et al.* 2000; Rusu *et al.* 2005). The efficiency of the alternative systems is ensured only in the case of a crop rotation, case in which cultures rotation alternates with the systems of tillage. Cochran *et al.* (1982), Jessop and Stewart (1983), they found that wheat yields are reduced when seeds are sown in heavy surface residues as compared with conventionally tilled seedbeds. Reduced grain yield was more often associated with cool wet weather, especially during crop establishment in higher rainfall areas (Cook and Haguland, 1991). Factors contributing to yield depression include poor seed-soil contact (Cochran *et al.*, 1982), suboptimal temperatures, inconsistent seedbed quality and soil pathogens (Cook and Haguland, 1991), high crown set, low fertility, immobilization of N (Jessop and Stewart, 1983) and phytotoxicity from decomposing surface residues. Continuous wheat cropping, especially under conventional tillage, favours root diseases (Cook and Haguland, 1991) and promotes establishment of annual grass weeds (Dao, 1998). Crop rotation is an important practice for weed management because different herbicides and tillage systems can be used to control weeds that otherwise are not controlled in monoculture crops (Cook and Haguland, 1991).

2.8 Tillage Treatments and Weeds Control

Weeds have always been one of the greatest resource-consuming operations in crop production. In addition to requiring effective control measures, weeds rob crop plants of nutrients and water, often serve as hosts to insects and other pests, and create problems in harvesting and processing (Abu-Hamdeh, 2003).

Tillage treatments can increase or decrease weeds and can become a limiting factor in crop production (Buhler, 1992). Changes in tillage practices can affect weed population dynamics, including weed seed distribution and abundance in the soil seed bank (Buhler and Mester, 1991; Mulugeta and Stoltenberg, 1997). Soil tillage reduces weed numbers and species diversity but may increase germination of annual weed seed in the soil seedbank (Cardina *et al.*, 1991; Wrucke and Arnold, 1985). No-till systems typically have high populations of small-seeded annual weeds that remain on or near the soil surface (Clements *et al.*, 1996; Wrucke and Arnold, 1985). No-till systems have been reported to alter the composition and abundance of weed species that emerge and remain in the soil (Buhler and Daniel, 1988; Yenish *et al.*, 1992). Buhler and Daniel (1988) reported that conventional tillage had greater velvetleaf (*Abutilon theophrasti Medikus*) densities than no-till, and no-till had greater giant foxtail (*Setaria faberi Herrm.*) densities than conventional tillage. Giant foxtail and redroot pigweed (*Amaranthus retroflexus L.*) became more difficult to control when tillage was reduced, while velvetleaf became less of a problem (Buhler and Daniel, 1988). Wrucke and Arnold (1985) also reported increased densities of grass species with reduction of tillage, while density of common cocklebur (*Xanthium strumarium L.*) increased with tillage.

2.9 Weeds and Crop Yields

Tillage is considered the most effective farm activity for the purpose of developing a desired soil structure. It improves the physical conditions of soil and favours the rooting characteristics of plants, which lead to an enhanced nutrient uptake and better yield of crops (Arif *et al.*, 2007). Tillage constitutes a fundamental component in the weed management strategies. It not only kills weeds, but also disturbs the soil (Mohler and Galford, 1997). Although herbicides have improved the capability of farmers and helped to control weed but it is a potential ecological hazard (Lança Rodrígues *et al.*, 2009).

Weed control is a limiting factor in crop production (Buhler and Daniel, 1988). Weeds are probably the most ever-present class of crop pests and on the odd occasion cause massive crop failures over vast areas. They reduce the crop yield and deteriorate the quality of produce and hence reduce the market value of the turn out (Arif *et al.*, 2006). They use the soil fertility, available moisture and nutrients compete for space and light with crop plants, which result in yield reduction (Khan *et al.*, 2004). If left uncontrolled, the weeds in many fields are capable of reducing yields by more than 80% (Karlen *et al.*, 2002). The composition of weed communities is greatly affected by tillage systems. Weed control is a problem in reduced tillage (RT) which often favours annual grasses and discourages annual dicotyledonous species (Gill and Arshad, 1995). However, generalizations are limited, because the effect of tillage on annual weeds is species-specific (Buhler and Daniel, 1988), and the same species may respond differently when soil properties and other site characteristics vary. Derksen *et al.* (1993) reported that weed communities were greatly affected by location and year as compared to tillage systems. Increased soil disturbance decreased the number of weed species and species diversity in maize cropping (Cardina *et al.*, 1991). The relative contributions to the size and diversity of weed flora were greater by common species under conventional tillage (CT) and by rare species in less intensive tillage systems in spring crops (Gill and Arshad, 1995).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Location, soil and weather

The research was conducted at Mkambalani village, in Mkambalani ward, Mikese division in Morogoro Rural District. Morogoro Rural district is located at North East of Morogoro Region and is situated between 6° 00’ and 8° 00’ Latitudes South of Equator and between 36° 00’ and 38° 00’ Longitudes East of Greenwich (Morogoro District Profile, 2008). The field is located at 20 km East of Morogoro Municipal adjacent to the Dar es Salaam - Morogoro road. It is situated at the coordinates of 37° 56’ 8.5” E / 6° 45’ 33.8” S (Msanya *et al.*, 1998). The altitude is 404 m above sea level. Figure 1 is a map showing the location of the study area in Mkambalani ward.

3.1.1 Geology

Morogoro region is part of the Mozambique rock belt which is a poly-orogenic complex (Muhongo, 1994). The area constitutes rocks of Preterozoic, Archean and Early Palaeozoic ages (Sampson and Wright, 1964). This rock complex is divided into five sub units but the two namely Hornblende and Muscovite are dominant to the area (Msanya *et al.*, 2001). The landform consists of peneplains situated at an altitude range of 400 - 800 m. The peneplain units consist of ridges crests and ridge slopes. Most of the peneplain ridge crests are almost flat to gently undulating while ridges slopes are undulated. They form the most extensive land unit in the district (Msanya *et al.*, 2001). Few isolated hills are present in the peneplain. Besides these peneplains the district has landforms of Mountainous, Piedmonts and Valleys. The site at the study area has peneplain which is gently undulating land portion, characterised by a pervasive repetition of low hills, rounded and elongated with summits of similar height of 400 - 600 m.

3.1.2 Soil

Landform patterns and geology have had profound influence on type and distribution of soils in the district. The district has different types of soils as described by Msanya *et al.* (2001). The soils described including Lixisols, Luvisols and Cambisols at the mountains and valleys, Lixisols and Acrisols on the piedmonts and Acrisols and Lixisols on the peneplains.

According to the soil profile described by Msanya *et al.* (1998), dominant soils on the glacis and peneplains are very deep, well drained, brown friable sandy clays and red friable clays classifiyng as Acrisols and Lixisols. Soil profile described by Msanya *et al.* (1998) is shown at Appendix 1.

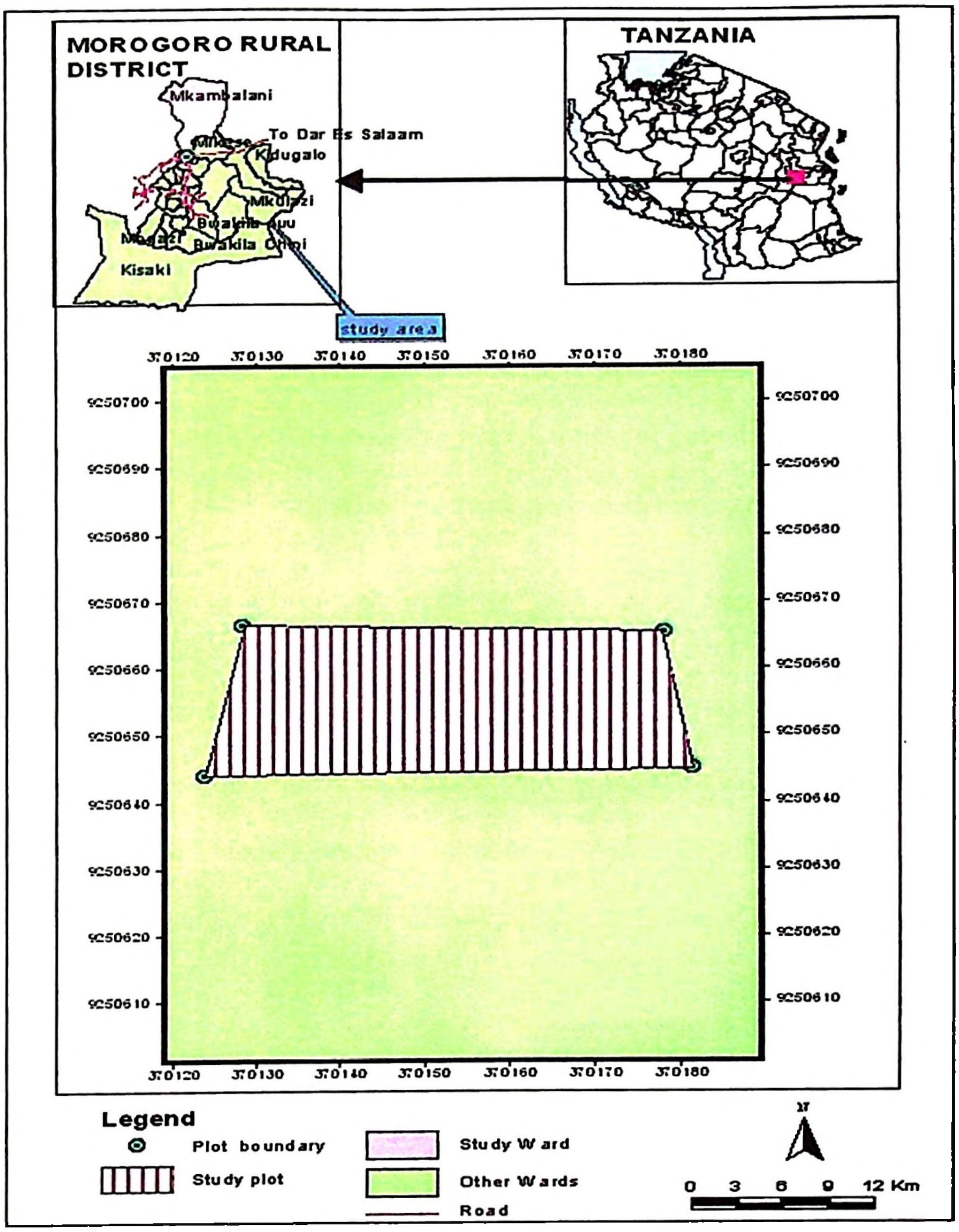

Figure 1: Location of research site at Mkambalani village

3.1.3 Climate

The annual total and distribution of rainfall is the basis of the classification of climates from humid to arid. Climatic classification is a method of arranging various data of climatic parameters to demarcate country or region into homogenous zones i.e., places having similar conditions. Agroclimates well understood and wisely integrated into agroclimatic regions are becoming valuable and handy tools for the practical execution of plans for harnessing the potentials of climates for agricultural production. Rainfall effectively stored in the soil is used for evapotranspiration of crops. Any shortage of rainfall will result in stress and reduced crop production.

The relief and slope aspect have a great influence on climate of the Morogoro district. Areas higher in altitude such as Uluguru Mountains are cooler than the plains. The trend of rainfall reveals a similar influence of altitude on rainfall. Rainfall is higher in areas of high altitude and tends to be low at low altitude areas.

3.1.3.1 Rainfall

Morogoro District falls within two distinct agro-ecological zones (AEZ) according to De Pauw (1984). The zones are tropical lowland termed E4 and tropical highlands E14. Onset dates for rainfall is unreliable, but main rain season starts from March to May with peak rainfall in the month of April. Generally daily temperatures are higher than 20°C throughout the year. Wind speed is relatively constant except for the months of November to December, which have relatively high wind speeds during the year (Msanya *et al.*, 2001). Hence the study area has a bimodal type of rainfall. The short rains, which start in October and end in December and the long rain starts in March and end in June. These rains are separated by a dry spell, which is between January and February and July and September. Table 1 and Figure 2 shows general trend of average monthly rainfall distributions at Mkambalani ward. The data shows that rainfall distribution is not enough. Total annual amount of rainfall were found to be unpredictable and few average of 670 mm per year. Figure 2 indicates that, the months of June, July, August, September and October received rainfall amount below 50 mm per month. Normally rainfall of 50 mm per month is often considered as the threshold value above which grass growth occurs (Richards, 1928). Figure 3 shows the influence of altitude on rainfall. Rainfall is higher at high altitudes and tends to be lower at low altitudes. Areas on the leeward side of the Uluguru Mountains receive relatively lower rainfall than those on the windward side. Climatic data of the district reveal a gradual decrease in rainfall from the east towards the west and northwest. In the Tungi areas a rather dry condition prevails, while at SUA where rainfall for Morogoro station kept receives relatively more rainfall and Morningside station at the top of Uluguru Mountains receives the most (Msanya *et al.*, 2001). This trend can be attributed to the rain shadow effect of the Uluguru Mountains. Figure 4 shows unpredictable trend of rainfall pattern where January and February in the year 2010 received enough amount of rainfall.

Table 1: Average Monthly Rainfall at Kingolwira Meteorological Station for Period of 2005 – 2009

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain (mm)	56.4	74.1	124.7	77.9	58.9	21.8	23.4	9.9	7.5	48.0	66.8	101.4

(Source: Kingolwira MET. Station, Morogoro)

3.2 Hydrology

Hydrology is the study of the movement, distribution, and quality of water throughout the earth, including the hydrologic cycle (i.e. the science of surface water) and ground water.

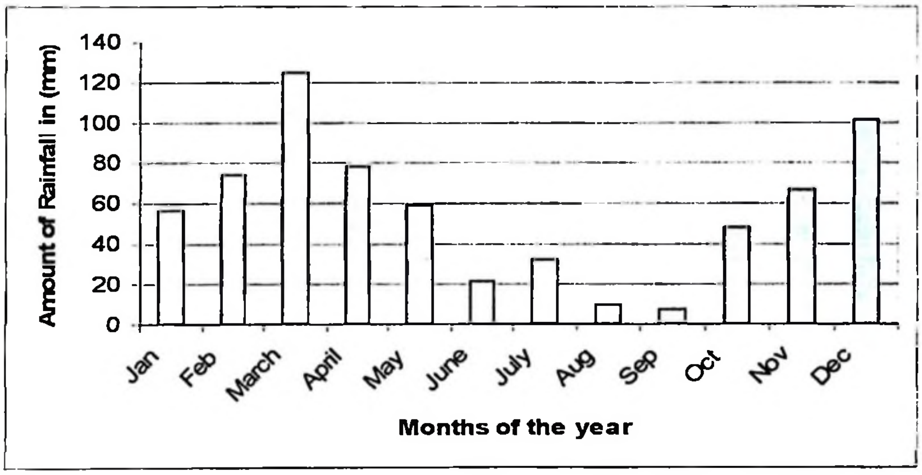

Figure 2: Average Rainfall from year 2005 to 2009 at Kingolwira Sisal Estate

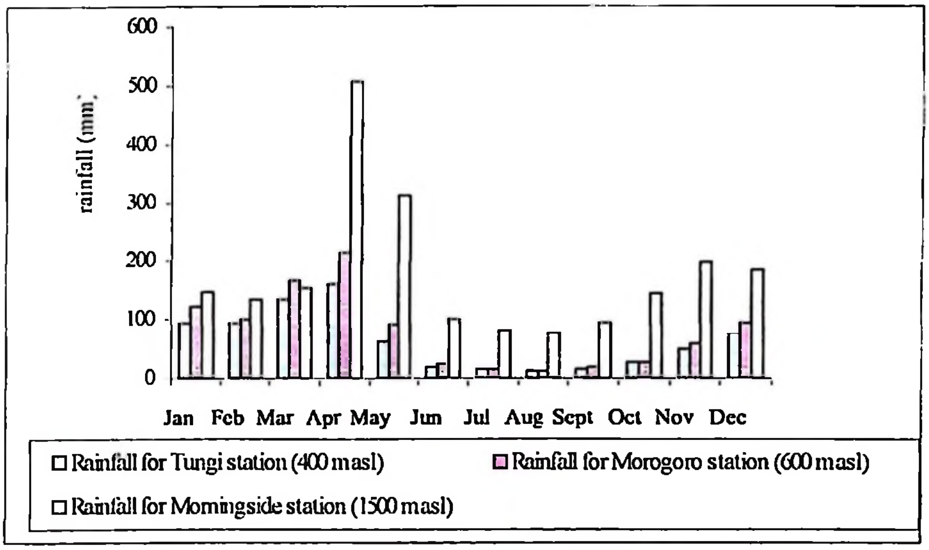

Figure 3: Average rainfalls at Morogoro Municipal. Source: Msanya *et al.*, 2001

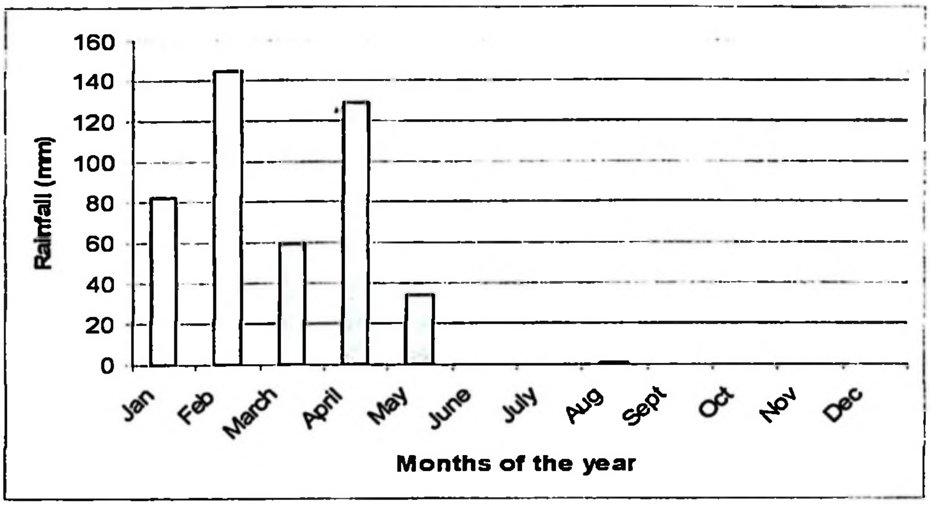

Figure 4: Rainfall in the year 2010 at Kingolwira MET Station, Morogoro

3.2.1 Drainage

Morogoro district belongs to the internal drainages and has many external runoffs hydrological. The district drains to the Indian Ocean. However the northern part of the district particularly the Mkambalani ward has only one river called Ngerengere which crosses the ward at northern part with narrow valley. Hence large part of the ward is semi arid peneplain which depends much on ground water sources.

3.2.2 Runoff

Surface runoff and soil erosion caused by tillage operation in Tanzania have been reported by many researchers (Hatibu *et al.*, 1995; Kimaro *et al.*, 2006; Mganilwa *et al.*, 2007; Masanja, 2009). It has been noticed that the soil loss can reach up to 77 kg m^{-1} per tillage pass depending on land topography, soil characteristics, climatic condition and land management (Kimaro *et al.*, 2001).

3.3 Pre Field Work

During this phase the following activities were carried out:

3.3.1 Collection of materials

The materials for this research was obtained and collected from different sources as outlined below:

- Global Positioning Systems (GPS) instrument
- 30 m measuring tapes, meter ruler and digital camera
- Modified Gerlarch troughs for runoff and sediment collection and iron plates labels for marking the treatments
- Buckets, plastics bags, sisal rope, hammer and hand hoe and
- Double ring infiltrometer, sampling cores

3.3.2 Preparation of Questionnaires

Semi-structured questionnaires were prepared for gathering information on land use, knowledge of land degradation and socio-economic information of the farmers at the study area.

3.4 Field Work

The following activities were carried out in the field.

3.4.1 Gathering social-economic data

A study conducted to assess farmers' social economic status, their knowledge and opinion on land degradation and acceptability and economic benefits of using conservation agricultural technology in improving soil erosion and land degradation. Questionnaire surveys that targeted issues of social economic and cover the main fields of interest were designed (Appendix 9) and included to gather the following data:

- Biographical data, including demographic data on households, social and geographical background of households/individuals.
- Social economic data, including land ownership, land tenure and main economic activities such as farming, trading or mixed activities.
- Respondent knowledge and attitudes towards land degradation and conservation agriculture and the problems faced by the living community at village concerning shortage of rainfall, climate change and general trend of declining crop harvests.

A total of 53 households were used for interview and were randomly selected as done by Kimaro *et al.* (2005) to avoid biasness in information gathering during interviewing the farmers. The information gathered was analysed using SPSS software and Microsoft excel package.

3.4.2 Experimental design layout

A one acre land was acquired from farmers for setting up experiments to determine the effectiveness of different tillage systems on prevention of runoff and sedimentation. On farm experiments were established under farmer management conditions with researcher working hand in hand with the farmers.

In facilitating the statistical analysis and interpretations of data collected a completely randomized experimental block design (CRBD) was used. There were five tillage treatments of No tillage (NT), Conventional Tillage (CT), Strip Tillage (ST), Tied Ridges (TR) and Basin Tillage (BT). The five tillage systems were replicated in three times. The totals of 15 field plots in the three blocks were obtained. Each plot has size of 20 m length and the width of 1.8 m. The length of all the plots were situated parallel to the direction of the slope and the general slope average was 6%. The plots were separated by pathways of 1m apart. The schematic plan layout is shown in Figure 5.

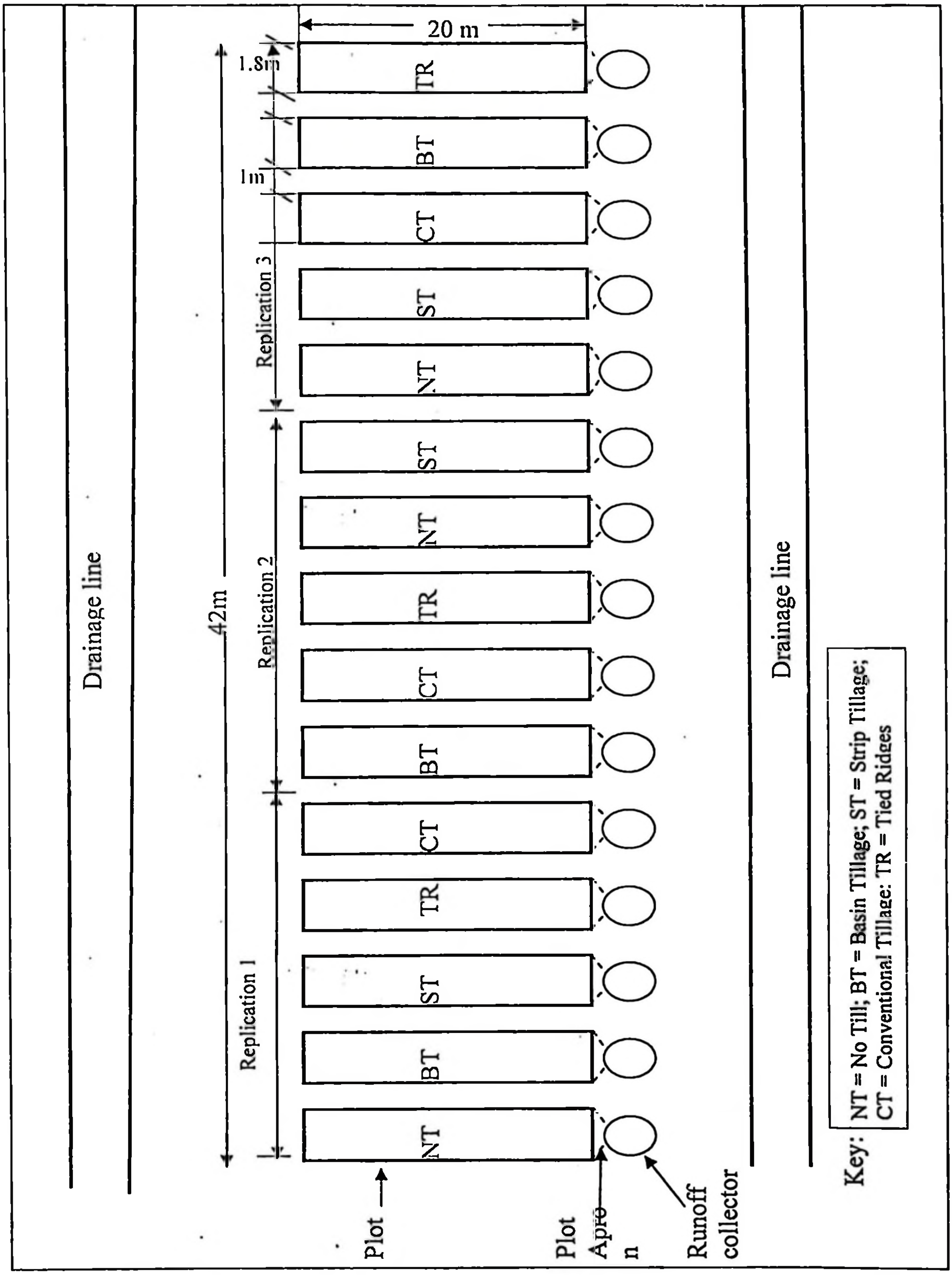

Figure 5: Experimental plot layout

3.4.3 Tillage Treatments

Tillage equipment used for five treatments made is commonly used by most of Tanzania farmers particular to the study area at Mkambalani village. Majority of the farmers use hand hoe and the study was based on that situation.

3.4.3.1 No Tillage (NT)

The site selected was seasonally planted with crops. Hence there were not enough residues left. Soil at this NT plot was not disturbed through out the season. The only disturbance was during planting when jab planter was used to dig the hole for the seeds. Herbicide (*glyphosate*) was used to kill the weeds. It was applied five days before planting. Weeds were not much due to the use of herbicide. The emerged weeds were manually uprooted. The uprooted weeds were spread to the plot as soil cover.

3.4.3.2 Strip Tillage (ST)

Strip or minimum tillage treatment (ST) involved the preparation and management of the plot with minimum soil disturbances. It involved digging to 10 cm depth with a pick mattock (Swahili is known as sururu). The pick mattock with a width of 80 mm was used to strip the line on the plot; the dug line later was used to plant maize seeds. However at the beginning herbicide round-up (*glyphosate*) was used to kill weeds to the ST plots. The few emerged weeds were uprooted by hand during weeding and spread to the plot as soil cover. Jab planter was used to plant maize seeds.

3.4.3.3 Convention Tillage (CT)

This method of land preparation by using hand hoe is very common to this area. It is flat cultivation with a hand hoe. Involved digging across the slope to a depth of 10 cm. It produced uniform sized clots and a relatively rough surface configuration. Hand hoe was used to plant maize seeds to CT plots. Weeding was done two times by using hand hoe after two weeks of planting then after a month later. The thinning and fertilizer application was done uniformly with other plots of the treatments.

3.4.3.4 Basin Tillage (BT)

A hand hoe was used to make the basin. The plot of 20 m long and 1.8 m wide was subdivided by three bunds of 15-20 cm height to form cultivated reservoirs (basin) or *majaruba*. Each basin with the length of 6 m and width of 1.8 m was bounded with edged soil. The basin was then planted with maize crop. Weeding was done by using hand hoe. Application of fertilizer was done at the same rate as to other plots. To provide nitrogen urea fertilizer was used. Nitrogen application was at split, 50% of the total requirement was applied at early stage of plant growth (14 days after planting) and the remaining N fertilizer was applied when maize was a meter high or on second weeding. Rate of 20 kg N/ha (2.5 g/hole of urea fertilizer) was applied as have been done and recommended by Nkonya *et al.* (1998). The application of Phosphorus (P_2O_5) to promote root growth, strong stems, and good grain was done during planting. The rate of 20 kg/ha of Phosphorus (2.5 g/hole of DAP fertilizer) was applied as recommended by Katinila *et al.* (1998). Fertilizer is normally placed 5 cm below the depth of the seed and about 5 cm to the side. This was accomplished by digging a single hole beside each seed and placing fertilizer in the hole and covering it with soil.

3.4.3.5 Tied Ridges (TR)

The tied ridge is the practice that involves planting the crop on the prepared ridges, and then blocking the furrows at regular intervals. These ties act as mini-dams, which collect the rainwater and minimises the flow of water off the field. They are effective in both during a wet and dry season. In a wet season, the crop is elevated on the ridge and suffers less from water-logging. In a dry season, the trapping of rainfall and conserving it in the field enhances crop development and the yield. Hand hoe was used to make ridges at the plot of size 20 m to 1.8 m. The ridges of 30 cm high with 30 cm width were made. Maize seeds were planted on the width of the ridges at the spacing of 25 cm within the row.

3.5 Planting

Maize seeds (*Zea mays var TMVI*) was used and planted at a spacing of 0.9 m between the rows and 0.25 m within the rows. This spacing brings the population of 45,000 plants per hectare as recommended for good crop growth and yield (Nkonya *et al.*, 1998).

3.6 Instrumentation and Measurements

3.6.1 Meteorological data records

The meteorological data records which was obtained in the field was rainfall recorded at Tanzania Meteorological Agency at Kingolwira Sisal Estate. The data obtained was for only six years from 2005 up to 2010. These measurements were obtained daily from the meteorological station nearby the study area. The study area and the station is within two km apart. The rainfall was measured by using standard rain gauge only. The most common and the non-recording gauge called a Standard Rain Gauge (SRG) was used. Recording of rainfall using SRG is general done manually. Typically the SRG is a metal cylinder with a funnel shaped collector on top and a plastic measuring tube in the middle. According to the Spokane National Weather Service office, these tubes are usually 8 inches (20 cm) and have been in use for more than a century. The diameter of the collector is 10 times that of the tube; thus, the rain gauge works by magnifying the liquid by a factor of 10. Magnifying the rain in this way allows precise measurements down to one-hundredth of cm. Amounts that exceed the tube capacity are caught in the outer shell of the gauge, allowing the recorder to pour out the liquid in the tube and fill it back up if needed (Figure 23 in Appendix 10).

3.6.2 Measurement of soil bulk density and porosity

The samples for measuring bulk density of soil were taken at the beginning of planting season and at the end of harvesting. Undisturbed soil samples were taken in each plot at depth of 0 - 10 cm, 10 - 20 cm and 20 - 30 cm using sampling cores. For the 15 treatments available, 45 samples were collected. The samples were oven dried at 105 °C for 24 hours and weighed. Bulk density was then calculated as ratio of the dry mass of the soil to the core volume as shown in equation 2.

$$\rho_b = \frac{M_s}{V_t} = \frac{M_s}{V_s + V_a + V_w} \quad \text{..................} \quad (2)$$

Where:

V_t = unit volume of soil (cm^3)

V_a = volume of air (cm^3)

V_w = volume of water (cm^3)

V_s = unit volume of dry soil (cm^3)

ρ_b = bulk density (g/cm^3)

M_s = mass of solids (g)

3.6.3 Porosity

The total porosity was calculated from the bulk density and the particle density of the soil as follows:

$$f = 1 - \left(\frac{\rho_b}{\rho_s}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where f = Total Porosity

ρ_b = Bulk density (g/cm^3)

ρ_s = Particle density (g/cm^3)

3.6.4 Soil moisture content

The samples for measuring moisture content of soil were taken at the beginning of planting season and then at the end of the season during harvesting time. Undisturbed soil samples were taken in each plot at the depths of 0 - 10 cm, 10 - 20 cm and 20 - 30 cm using sampling cores. For the 15 treatments available at the research site, 45 samples were collected. The samples were oven dried at 105°C for 24 hours and weighed. The moisture content (MC %) of each sample was calculated on a percent of dry weight basis by using equation 4 as done by Gilandeh *et al.* (2009) :

$$MC\,(\%) \approx \frac{W_{wet} - W_{dry}}{W_{dry}}\, x\, 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where:

$MC\,(\%)$ = Moisture content (%)

W_{wet} = the weight of the wet soil sample (g)

W_{dry} = The weight of the dry soil sample (g)

3.6.5 Soil texture

Soil samples were taken randomly at different plots at 5 cm to 10 cm depth increments.

Soils were then separated into size grades by sieving through a series of standardized wire mesh sieves arranged from the coarse called gravel down to the finest clay. The sieve is a wire fabric with the size of the opening that designates the number of wires per millimetre and size of opening ranges from 4.75 for gravel soil to 0.075 mm for clay soil. The cumulative amount of soil retained on each sieve was weighed and classified. The percentages of sand, silt and clay were determined and the soil texture triangle (Figure 6) was used to determine the texture of soil as per USDA system (Heckrath *et al.*, 2005).

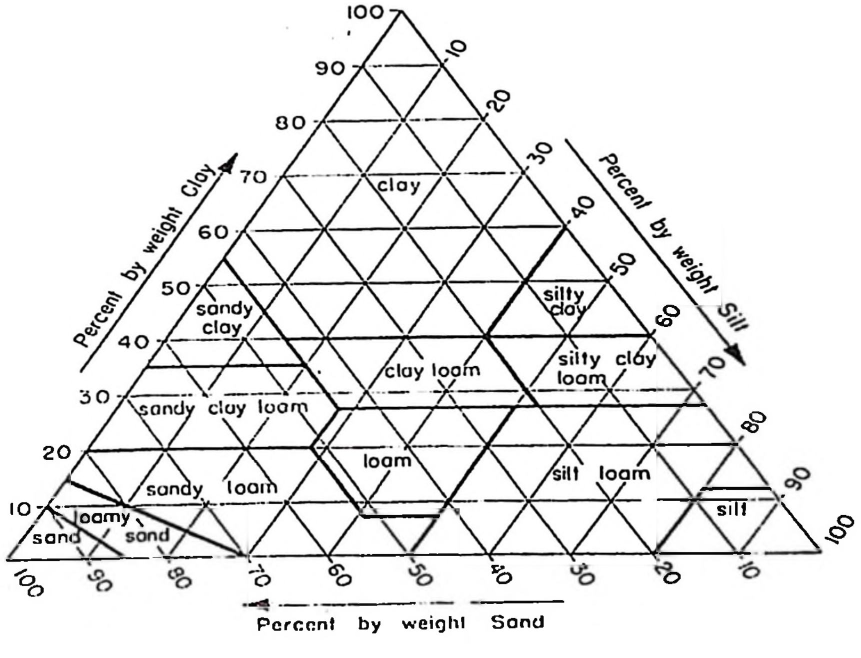

Figure 6: Textural triangle, showing the percentages of clay (below 0.002 mm), silt (0.002 – 0.05mm), and sand (0.05 – 2.0 mm) in the basic soil textural classes

Source: Heckrath *et al.* (2005)

3.6.6 Measurement of infiltration

Infiltration was measured by using a double ring infiltrometer which consists of inner ring of size 27.8 cm diameter surrounded by an outer ring of 54.5 cm diameter as shown in Figure 21 in Appendix 10. The infiltration measurements were done during harvesting time. Double ring infiltrometer was used as have been done by Matula and Kozakova (1997) by inserting into the soil and pouring water steadily in the rings. The time was taken by measuring the rate of immersing water in the soil by stop watch and ruler. The results of the infiltration experiments were presented as cumulative infiltration (I) versus time (t) in selected time steps.

3.6.7 Measurement of chemical properties of soil

Measurements of soil for pH, N, P, K, CEC and organic matter were taken at the beginning and during harvesting time. Soil samples were taken at depth increments of 0 to 5, 10 to 20 and 20 to 30 cm in each plot and from all replicate plots. Soil samples were air-dried and ground to pass through a 2-mm sieve before analysis. They were analyzed for pH (1:1 soil:water), percentage SOC using the Walkley–Black method (Nelson and Sommers, 1982), basic cations extracted by 1 M ammonium acetate (Knudsen *et al.*, 1982), CEC using the Base replacement method (Sumner and Miller, 1996), and Bray-P (Bray and Kurtz, 1945). Base saturation was calculated by dividing the sum of all bases (cmol kg21) by the CEC (cmol kg21) and then multiplying by 100 (Tarkalson *et al.*, 2006).

3.6.8 Measurement of runoff and sedimentation

Sediments and runoff water were collected every day at around 9.00 am (if it rained in the previous 24 hours). The volume of runoff from each plot was determined by immersing a 100 cm plastic meter rule into the trough and then was estimated by multiplying height of its level in the Modified Gerlarch trough with the cross-sectional area of the trough (Figure 14 in Appendix 10). Daily soil loss was determined by 5 litres sub-sample of a thoroughly stirred runoff collected in the Modified Gerlarch troughs. Where the volume of runoff was less than five litres, the entire volume was taken as a sample. Each sample was left to settle and the sediments were obtained by decanting followed by sun drying. The sediments were then oven dried and weighed and the cumulative weights was expressed on the basis of oven dry weight in kilograms/tons per hectare per year as done by Mganilwa *et al.* (2007). At the end of farming season soil fertility and soil loss were determined.

3.6.9 Measurement of crop growth

Plant growth was monitored by measuring plant height of 3 randomly selected plants in 1 m^2 areas in each of the cropped plots as done by Guzha (1997). The meter ruler was used to measure plant height. Maize plant strengthened its leaf to get full height and then ruler was placed adjacent to take the height. The measurements were taken at 30, 50 and 70 days after emergence. This was done in order to compare the differences if any in the crop growth possibly due to the differences in soil characteristics brought by application of difference tillage treatments. Other factors of soil fertility and slope were kept constant because application of chemical fertilizers was the same at all the plots and the application of complete randomized design was aimed to control this problem. At the end of the season the final crop yield in terms of grains for each treatment were determined and compared.

3.6.10 Crop yield

Maize cobs were harvested at the randomly selected area of 1 m^2 in each of the cropped plots. The cobs were carefully removed and shelled by hand and sun dried. Moisture content of the grain was carefully determined by drying in an oven at 70° C for 24 hr and grain yield were adjusted to a moisture content of 15.5% (Temesgen *et al.*, 2007) and then weighed. Statistical analysis on the data was carried out by using the Genstat software and Microsoft excel package.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the experimental results and discussion in the form of tables, graphs and expression in words.

4.2 Socio-Economic Characteristics

The results in Table 2 summarises the family characteristics of households at Mkambalani village in the Mkambalani ward, Mikese division in Morogoro Rural district. Most of respondents were middle aged active group (65.3%), and less active group were (34.7%). Average level of formal education 69.6% attended primary education level, 18.5% reached to secondary school and while 11.9% had informal education. Primary occupation of majority depends on agriculture (70%), agriculture and trading (22%) and agriculture and other activities like employee as teachers and soldiers (8%).

The study area is characterised by high ethnic diversity with the indigenous group of Luguru (30%) comprising the majority but not as expected, followed by Zigua (17.1%), Makonde (16.2%), Kwele (14.2%), Ngoni (12.5%) and Pare and Chagga (10%). The village surrounded by institutions of Pangawe army, Mkono wa Mara prison and Kingulwira sisal estate. People who worked at these areas after retiring from work they were staying and joining in the village hence the complexity of mixing formed. In addition after village got tape water from nearby Kiroka village the numbers of people joining the village were increased of difference ethnic groups.

4.2.1 Land tenure and agricultural characteristics

According to the respondents, most farm holdings are small, ranging from 0.1 to 5 ha and majority have below 2 ha. This village is surrounded by large farm of Kingulwira Sisal Estate. The estate usually allow temporally nearby villagers to grow maize while the estate owner planting permanent crop sisal seedling. Most respondents (95.2%), owned farms and others (4.8%) hired farms. However no one has land title deeds. The average household size was found to be with 4 members. Main crops grown in this village are maize, sunflowers, cassava and sim sim. Most of farmers use hand hoe (92.5%) for agricultural operations while few (7.5%) use tractors. Tractors for hiring are available however they are very expensive for village farmers to use (Table 2).

4.2.2 Tillage practise and knowledge of land degradation

The village practised conventional agriculture that is characterised by straw burning and intensive tillage using hand hoe and disc plough for tractor in land preparations. Majority of farmers (91.6%) have the knowledge of land degradation and soil erosion but few people (8.4%) were not sure that the process of soil erosion is going on to their farms. Farmers know soil erosion and accept the temporary soil erosion measures like ridging across slopes, the reduced tillage methods, and the use of cover crops to protect soil from running water and the application of vegetated buffer zones at the edges of fields; however they are not practising to their farms with arguments that the exercise is tough and expensive. Average harvest they got at the village generally is very low but worse in the season of 2009/10. The farmers who harvested highest in this season were few obtained 1.5 ton/ha were only 9%, majority 65% have 0.5 ton/ha -- 1.4 ton /ha and those below 0.5 ton/ha were 26%.

Table 2 : Social - Economic Characteristics of Farmers in Mkambalani Village – Morogoro Tanzania

S/n	Characteristics	Percent response (%) (n=53)
1	**Age**	
	Active adult (18 - 50)	65.3
	Less active adult (> 50 years)	34.7
2	**Educational Level**	
	Informal Education	11.9
	Primary school education	69.6
	Secondary school education	18.5
	High schools and Institutions	0
3	**Family size**	
	Average	4
4	**Primary Occupation**	
	Farming	70
	Farming and trading	22
	Farming and livestock keeping	4
	Farming and employee	4
5	**Ethnicity**	
	Luguru	30
	Zigua	17.1
	Makonde	16.2
	Kwele	14.2
	Ngoni	12.5
	Others - Pare and Chaga	10
6	**Farm Ownership**	
	Family owned farm	95.2
	Hired farm	4.8
7	**Farm size**	
	< 5 ha	100
	> 5 ha	0
8	**Machinery use in land preparation**	
	Hand hoe	92.5
	Tractors	7.5
9	**Knowledge of land degradation**	
	Farmers with knowledge	91.6
	Farmers unaware of land degradation	8.4
10	**Average harvest in the year 2009/10**	
	Above 1.5 ton/Ha	9
	1.4 /ton/Ha - 0.5 ton/Ha	65
	Below 0.5 Ton//Ha	26
11	**Fertilizer use**	
	Use fertilizer	12.3
	Not use fertilizer	87.7

They knew that they got low yield due to bad weather resulting from low rainfall during the season. The use of fertilizer to increase production is not common at the village. Data obtained show that farmers using fertilizer were only 12.3% and not using fertilizers were 87.7%. The reasons of not using fertilizer were (65.1%) said expensive, (30.7%) said fertilizers destroy the soil at their farms, (2.3%) the farms have enough soil fertility, no need to add and last (1.9%) they were not sure because they have not got enough knowledge on fertilizer use.

4.3 Effects of Tillage on Bulk Density

At the commencement of the trial in March 2010, no significant differences in bulk density were found between the plots or within the plots. The similarly measurement were done during harvesting time the same results were found. However there is a general increase in bulk density with depth as shown in Table 3. Normally, bulk density tends to increase with soil depth mostly as a result of low organic matter (OM), less aggregation and root penetration as well as pressure exerted by overlying layers (Lin *et al.*, 1996). There was also decreasing in bulk density between the seasons at the depth of 0 - 5 cm within tillage systems except to CT. The complete inversion and structural breakdown is the cause of low bulk density (Guzha, 1997) however the exception was probably due to soil heterogeneity caused by land form at that area and perhaps due to slight textural differences that were not eliminated by blocking. Generally it was found that tillage decrease soil bulk density and BT treatment had the lowest bulk density after tillage. Comparisons of bulk density among different tillage systems have produced conflicting results in different studies. Results obtained here are consistent with those presented by some researchers who studied the influences of different tillage systems on soil bulk density (Guzha, 1997; Salinas-Garcia *et al.*, 1997; Tapela and Colvin, 2002). Guzha (1997) investigated influence of tillage system, namely No Tillage, Tied ridging, Hand Hoe, Disc Plough and Strip Tillage on soil bulk density on Central part of Tanzania under dry land sorghum. He found that tillage decreased soil bulk density and Disc plough treatment had the lowest bulk density after tillage. Salinas-Garcia *et al.* (1997) investigated on conventional bending, mouldboard, chisel, minimum tillage and no tillage on soil bulk density of an Alfisol under dryland corn (*Z. mays L.*). They indicated no tillage is highest (5 – 19%) and mouldboard plough resulted in the lowest bulk density (7 – 21%) compared to other tillage treatments. Similar result was given by Tapela and Colvin (2002).

Table 3: Tillage against Bulk Density (g/cm^3) and Porosity (%) at the Start and End of Experiment within Tillage System

Tillage Type	Depth (cm)	Bulk Density (g/cm^3)		Porosity (%)	
		Start	End	Start	End
NT	0 – 5	1.30	1.27	0.51	0.52
	10 - 20	1.27	1.38	0.52	0.48
	20 - 30	1.30	1.34	0.52	0.50
BT	0 - 5	1.27	1.11	0.52	0.59
	10 - 20	1.40	1.29	0.47	0.51
	20 - 30	1.23	1.33	0.54	0.50
ST	0 – 5	1.33	1.25	0.49	0.53
	10 - 20	1.30	1.34	0.53	0.49
	20 - 30	1.33	1.42	0.50	0.46
TR	0 – 5	1.37	1.32	0.48	0.50
	10 - 20	1.37	1.32	0.48	0.50
	20 - 30	1.37	1.37	0.49	0.48
CT	0 – 5	1.27	1.35	0.53	0.52
	10 - 20	1.37	1.41	0.48	0.47
	20 - 30	1.37	1.33	0.49	0.50

They compared the influence of NT, chisel and mouldboard plough on soil condition index and corn growth. Soil condition index can be used to select the type of implement required to obtain a good seedbed with minimum energy input. The lower the soil condition index the more optimum soil physical conditions would be. Tapela and Colvin (2002) indicated that the mean soil condition index for the no tillage, chisel and mouldboard treatments were 0.86, 0.76 and 0.73 respectively. However, Lal *et al.* (1994) did not find significant differences in bulk density of no tillage and chisel after 28 years of cultivation. This could be due to some self-working properties of some clay soil that would benefit under no tillage.

4.4 Influence of Tillage on Soil Porosity

Total porosity for the all research plots and depth per particular tillage systems varied from 46.4% of ST to 58.5% of BT. Total porosity below 45% on medium heavy soils had a negative effect on plant growth (Lindstrom and Onstad, 1984). Tables 3 and 4 show that mean values of porosity decreased with depth at 10 - 20 cm and then started to increase again on the depth of 30 cm. This might be from the frequent use of conventional tillage which may create soil hard pan. Generally total porosity of the soil increased with tillage. Table 3 shows that total porosity at the beginning of experiment was different to the ones obtained at the end of experiment. According to the data obtained it means that the significance of tillage is to increase the porosity. Similar results were revealed by Guzha (1997) at the Central part of Tanzania, from ferruginous sandy loam soil of Botswana (Willcocks, 1981) and Kikuyu red loam soils of East Africa (Hosegood, 1964). However these results are contrary to those obtained by Armon (1980) and Lal (1997). They found that no tillage system was superior to other tillage systems in maintaining porosity in the soil. This disparity could be due to differences in initial soil conditions. soil type, climate conditions, machinery used in tillage as well as the cropping history of the area prior to the experiment (Guzha, 1997).

Table 4: Tillage against Bulk Density (g/cm^3) and Porosity (%) on varying Depth at Start and End of Experiment in different Tillage Systems

Tillage Type	Depth (cm)	Bulk Density (g/cm^3)		Porosity (%)	
		Start	End	Start	End
NT	0 - 5	1.3a	1.27ab	051a	0.52ab
BT		1.27a	1.11b	0.52a	0.59a
ST		1.33a	1.25ab	0.49a	0.53ab
TR		1.37a	1.32a	0.48a	0.50b
CT		1.27a	1.35a	0.53a	0.52ab
LSD		**0.19**	**0.17**	**0.06**	**0.08**
NT	10 - 20.	1.27b	1.38a	0.52a	0.48a
BT		1.4a	1.29a	0.47b	0.51a
ST		1.3ab	1.34a	0.53a	0.49a
TR		1.37ab	1.32a	0.48b	0.50a
CT		1.37ab	1.4a	0.48b	0.47a
LSD		**0.1**	**0.16**	**0.03**	**0.07**
NT	20 – 30.	1.3ab	1.34a	0.52ab	0.50a
BT		1.23b	1.33a	0.54a	0.50a
ST		1.33ab	1.42a	0.50ab	0.46a
TR		1.37a	1.37a	0.49b	0.48a
CT		1.37a	1.33a	0.49b	0.50a
LSD		**0.12**	**0.09**	**0.04**	**0.03**

Means with the same letters on the same column are not significantly different at the 5% level of the Duncan's Multiple Range test

4.5 Influence of Tillage on Soil Moisture Content

The average soil moisture contents (MC) at the beginning of research were higher than at the end of farming (Table 5). High values of MC were observed at the top layer on TR (16.4%), ST (14.5%), CT (13.9%) and BT (12.9%) as expected due to the ability of the ridges to catch and hold flowing water but at the end of season the values dropped to ST (8.9%), CT (8.6%), TR (8.4%) and NT (7.9%). This could be the drought condition brought by uneven distribution of rainfall in the season of 2009/2010. Within the systems moisture contents in TR is found to be higher (16.4%) but NT was the least with only (12.13%). This could be explained by little residues were available in the first year of NT farming. These results are similar to Bonari *et al.* (1994) and Bhatt *et al.* (2004) who reported that soil moisture contents are substantially higher with chisel ploughing than shallow, disk or no ploughing in the maize field. Based on the differences in average moisture content values of all depths among particular tillage systems recorded, significance differences were not observed. These results were similar to those obtained by Merril *et al.* (1996) who reported no significant differences in soil water content among conventional, minimum and no tillage systems. The similarity could be due to lack of infiltration from high rainfall events or from reduced storage capacity (Barzegar *et al.*, 2003). This area experienced drought condition in the months of the end of April, May and June whereby even for the maize crops, water stress was observed. Contrary results were reported by Rao *et al.* (1986) who observed soil moisture contents were significantly high for plots under conservation and conventional tillage systems than on no tillage plots. This could be the effect of tillage regime on soil moisture content that depended on the time of sampling, soil depth and crops as reported by Franzluebbers *et al.* (1995).

Table 5: Moisture Content at Different Depths

System	Beginning of Season			End of season		
	Depth			Depth		
	0 – 5 cm	**10–20 cm**	**20-30 cm**	**0 – 5 cm**	**10–20 cm**	**20-30 cm**
TR	16.4a	17.9a	18.07a	8.43a	12.4a	10.03a
ST	14.5a	19.6a	16.86a	8.9a	10.23a	9.1a
CT	13.93a	18.5a	21a	8.6a	10.67a	12.7a
BT	12.93a	16.2a	16.26a	7.83a	9.23a	11.5a
NT	12.13a	16.9a	18.1a	7.96a	9.63a	10a
LSD (0.05)	**8.39**	**4.49**	**5.12**	**2.23**	**6.12**	**3.07**

Means with the same letters on the same column are not significantly different at the 5% level of the Duncan's Multiple Range test

4.6 Influence of Tillage on Runoff

NT produced higher amount of runoff on average in most of rainfall events while TR was the least as expected due to its ability to trap and hold flowing water (Table 6 and Figure 6). Among the different tillage systems the significance differences were observed between NT and CT, BT and TR but not with ST (Table 6). NT and ST started with bare soil cover at the beginning of experiment. Vegetative residues on the surface of no tillage soils are important in slowing water movement and allowing greater infiltration (Locke *et al.*, 2008), but the vegetative cover in the no tillage plots at the study area were weak and not enough probably due to drought. These results are similar to the results obtained through research done at central Tanzania by Guzha (1997). He reported that tied ridging produced the least runoff while NT treatment produced the highest runoff yield on average in most of the rainfall events. However these results are contrary to the observation done by Mazzoncini *et al.* (2008) and Locke *et al.* (2008). Mazzoncini *et al.* (2008) reported that in first year of their experiment they observed that no differences in runoff volumes from two tillage systems of no tillage and conventional tillage but Locke *et* *al.* (2008) found that total runoff from no tillage plots was less than that of the conventional tillage plots. These contradicting results could be probably due to combination of vegetative coverage and initial soil moisture conditions which would influence the slowing water movement and improve soil infiltration.

4.7 Influence of Tillage on Sedimentation

NT plots collected more sediment in first rainfall during the experiment while TR collected the least amount (Figures 7 and 8). These results could be probably due to no tillage plots had bare soils without vegetative cover for prevention of runoff, with the loosen soil above made easy for running water to carry sediment but tied ridges have the edge structures for holding water movement. However in the later rainfall events the CT became the big collector of more sediment. This could be due to weeding practiced done by hand hoe as means of weeds control and sealing effect of pores caused by energy from rain drops. Statistically significant differences were observed between CT - NT and CT - TR (Table 6). CT produced highest amount of sediment on average in most of rainfall events while TR was less collected as expected due to its ability to trap and hold flowing water.

Table 6: Means Runoff and Sediment Collected During Farming Season

Tillage system	Runoff collected	Sediment collected
NT	64.93 a	4.98 b
ST	60.4 ab	5.69 ab
CT	45.8 bc	7.74 a
BT	32.23 cd	6.09 ab
TR	30.23 d	4.79 b
LSD 0.05	**14.91**	**2.57**

Means with the same letters on the same column are not significantly different at the 5% level of the Duncan's Multiple Range test

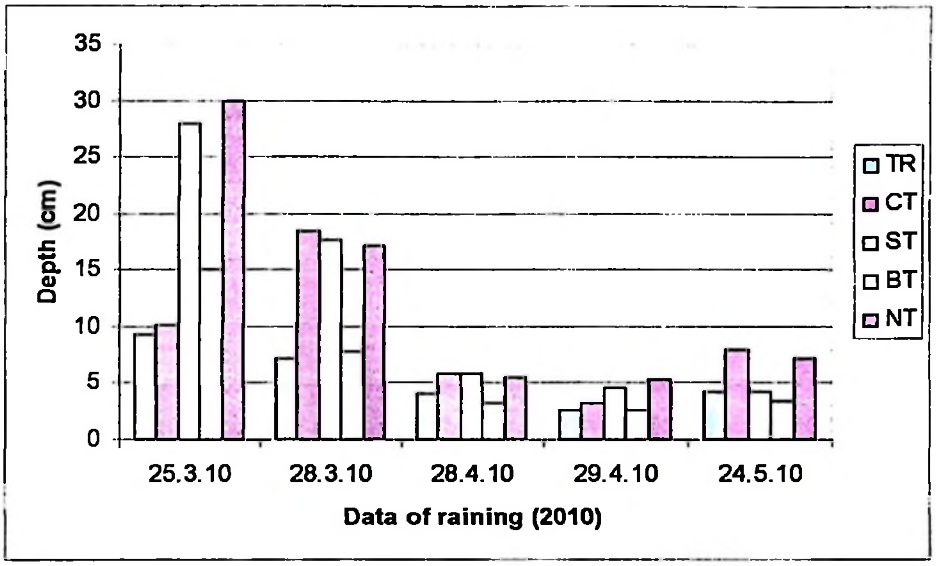

Figure 7: Effects of tillage on water flow

CT produced amount of sediment 23.2 ton/ha/season followed by BT (18.3 ton/ha/season), ST (17.1 ton/ha/season), NT (14.9 ton/ha/season) and TR produced least sediment (14.4 ton/ha/season) as shown in Figure 8. These results were similarly to the previous researchers studies (Hatibu *et al.*, 1995; Hussein *et al.*, 2007; Locke *et al.*, 2008). Study done by Locke *et al.* (2008) revealed that sediment loss from the no tillage plots was less than one fourth of the conventional tillage plots. Results obtained by Hatibu *et al.* (1995) at central Tanzania show that tied ridging produced the least amount of sediment while the conventional tillage plots produced the highest yields on average in all rainfall events. These studies demonstrated that the benefit of reduced tillage in reducing sediment loss and the important of tied ridges in minimising soil damage and its ability to hold water.

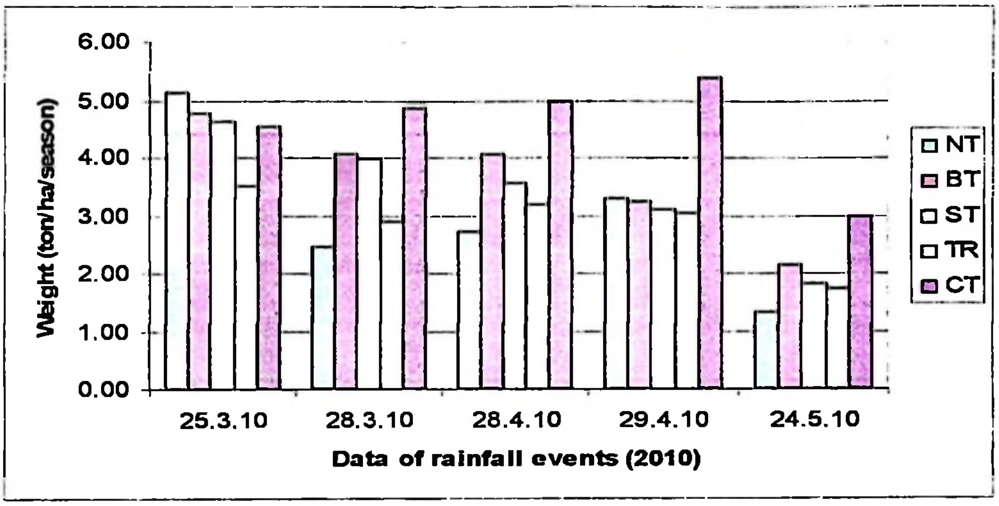

Figure 8: Sediment collected during rainfall events

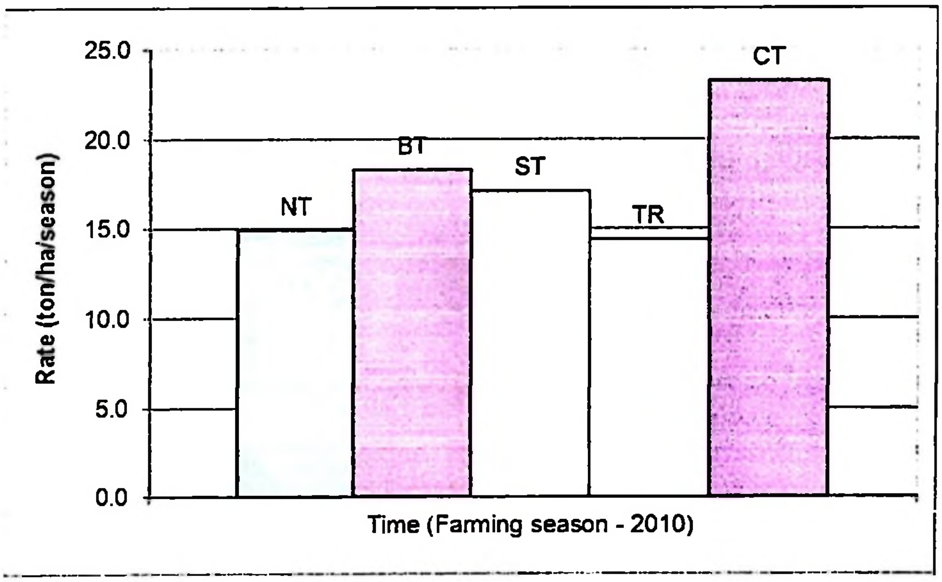

Figure 9: Total amount of sediment collected in the farming season

4.8 Influence of Tillage on Infiltration

The influence of tillage on infiltration rate for the different tillage systems is shown in Figure 9. It was found that NT was the least and CT infiltration rates were higher compared to other tillage systems. The higher infiltration rate in CT treatment was probably due to the higher random roughness caused by initial land preparation. The same reason can be applied to the BT but TR plots which have high ridges expected to have higher infiltration rate. However lower values shown in Figure 9 of TR infiltration rate is probably due to infiltration tests were taken in the furrows where the soil was scooped to form the ridges thus exposing the less porous sub soil strata. The lower values in NT and ST were probably due to less vegetation cover on the top soil and less random roughness which could help in slowing runoff or could be the soil type. Soil texture determines the rate at which water infiltrates through a saturated soil; water moves more freely through sandy soils than it does through clay soils. This result is consistent to the observation done by Guzha (1997), who found that tilling the soil increases enhancement in infiltration rate hence infiltration rate was higher in conventional tillage compared to minimum and no tillage. The contrasting results were obtained by Moheialdeen *et al.* (2007) and Barber *et al.* (1996). Moheialdeen *et al.* (2007) found that there was similarly value of basic infiltration rate in both study sites. They tested conventional tillage, conservation tillage and no tillage systems under sorghum crop farming in Sudan. Barber *et al.* (1996) tested four tillage systems of Disc plough, Chisel plough, tines tillage and no tillage in Santa Cruz, Bolivia and found that no differences in the 30 min and 60 min infiltration capacities nor in equilibrium infiltration rate in 1989 or in 1993. They concluded that the lower infiltration capacities and equilibrium infiltration rates in 1993 compared to 1989 could be a result of soil degradation.

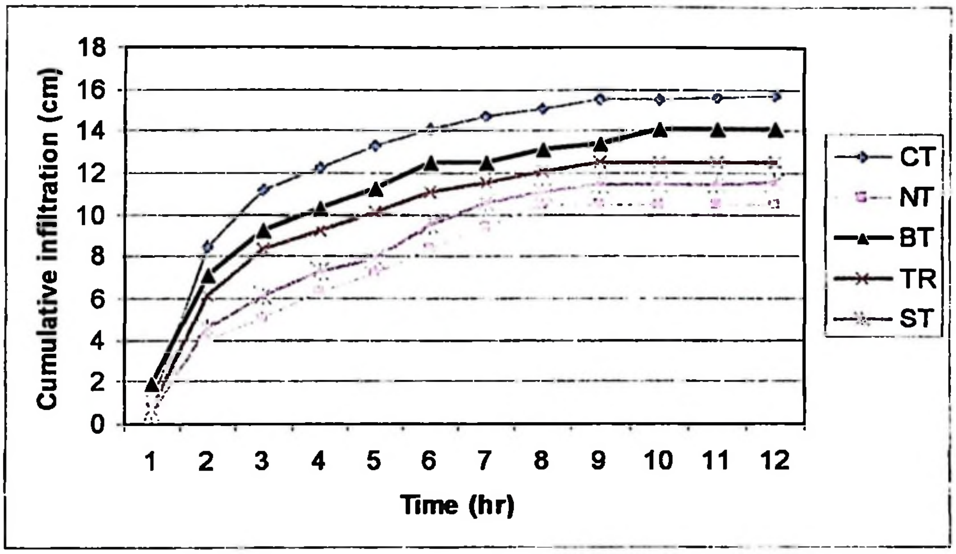

Figure 10: Two hour cumulative infiltration for the five tillage treatments

4.9 Influence of Tillage on Soil Texture

Tables 7 and 8 show soil texture mean values caused by different tillage systems. Statistically it was found that there were no significant differences between different tillage systems and also there were no significant differences in soil textures at the beginning and at the end of experiment within the treatments. This result was consistent with the result obtained by Afolayan *et al.* (2004) of Nigeria and Temesgen *et al.* (2007) of Ethiopia. Afolayan *et al.* (2004), in Nigeria tested treatments of NT, ploughing, ploughing plus harrowing and ploughing plus harrowing plus bedding and they found that there were no significant differences in their first year of experiment.

Table 7: Effect of Tillage on Soil Texture Properties at the End of Season

Tillage system	Clay	Silt	Sand
NT	53a	5.3a	41.7a
BT	50.3a	6.7a	43a
ST	55.67a	6a	38.3a
TR	52.3a	6a	41.7a
CT	51.7a	6a	42.3a
LSD (0.05)	**7.47**	**2.12**	**7.32**

Means with the same letters on the same column are not significantly different at the 5% level of the Duncan's Multiple Range test

Temesgen *et al.* (2007) evaluated traditional and improved tillage systems on soil physical and chemical properties. They found that tillage treatment did not significantly alter soil and chemical properties after a period of three years.

4.10 Effects of Tillage on Soil pH

Statistically significant differences were found for soil pH between tilled soil and conservation tillage. All tilled systems of BT, CT and TR found with higher means of pH with the means of 6.96, 6.85 and 6.81 respectively while ST and NT revealed low pH means of 6.64 and 6.39 (Table 9). The lowering of soil pH in the conservation tillage also was reported by Blevins *et al.* (1983) and Dick (1983). They argued probably due to the results of nitrification of N fertilizer, mineralization of N in plant residues and accumulation in the soil surface. These results were contrasting to the report revealed by Hussain *et al.* (1999). They tested tillage effect on soil chemical properties during the 1995 and 1996 using NT, Chisel plough (CP) and mouldboard plough (MP) and found that soil pH was higher in NT than in MP and CP during both years in the 0 – 5 cm layer. The higher soil pH in NT than MP in the top soil layer was a result of slower reaction of OC in NT compared with MP, probably due to lack of mixing. The lack of vegetative cover at the site could be reason of lowered in soil pH conservation treatments.

Table 8: Soil Chemical Properties at the Beginning of Experiment

Soil texture	Clay	Silt	Sand	Texture class
Beginning (%)	47	8	45	Clay
pH H20 1:2.5	6.48			
Organic C (%)	1.52			
Total N (%)	0.15			
Avail. P Bray mg/kg	0.16			
CEC soil cmol(+)/kg	13.2			
K cmol(+)/kg	0.8			
Na cmol(+)/kg	0.19			
Ca cmol(+)/kg	23.33			
OC (%)	1.52			

4.11 Effects of Tillage on Soil N, P, K

There were no significant differences in N value between the treatments. However the mean value of N in NT treatment is higher than in other treatments (Table 9). These results were similar to the findings by Campbell *et al.* (1996) who found that the amounts of organic C and total N in the 0 - to 7.5 cm depth were higher under NT than under tilled systems. These results contrasting with other findings for a Hatton fine sandy loam located in Canada where neither tillage nor rotation influenced organic matter concentration or total N (Campbell *et al.,* 1996). These contrasts may be a reflection of the frequent occasions when the crop was lost (thus minimal residues produced) due to drought.

Available P was found higher in the NT treatment compared to other treatment (Table 9), however statistically were found that no significant differences among the treatments. These results were similar to the results reported by Hussain *et al.* (1999), who reported that soil tillage had a significant effect on the organic matter and P concentrations of the soil surface (0 to 5 cm layer), after 21 years of experiments. No significant differences were found among tillage system influencing the presence of K. However the BT treatment on average was found to have higher value of K compared to other systems.

4.12 Effect of Tillage on CEC

In the study by Tarkalson *et al.* (2006), they found that the NT treatment had a 20% higher CEC in the 0 -- 5 cm depth compared with CT. Other research has shown increases in CEC in the surface soils of NT systems compared with CT due to increased SOC (Jaiyeoba, 2003; Ciotta *et al.*, 2003) but in this study at Mkambalani village it was found that ST treatment had higher value of CEC (13.53), however no significant differences on different tillage systems observed. ST treatment showed higher in OC (1.49) than other treatment (Table 9). The highest OC values are found in minimum tillage treatment, suggesting improved soil fertility. This may reflect the effect of crop residues left on the surface, good soil intervention and low soil disturbance by the reduced tillage system used (Camacho-Tamayo *et al.*, 2008). However there were no significant differences between the treatments. Similar results were reported by Wicks *et al.* (1988) and Lipiec and Hatano (2005).

Table 9: Influence of Tillage on Soil Chemical Properties

Tillage	pH	CEC	Org. C	N	Ava. P	Ca	K	Na
NT	6.39c	13.2a	1.23a	0.39a	1.33a	21.23a	0.76a	0.18a
BT	6.96a	13.4a	1.47a	0.17a	1.32a	24.43a	0.86a	0.18a
ST	6.64bc	13.53a	1.49a	0.14a	0.84a	20.77a	0.72a	0.17a
TR	6.81ab	12.4a	1.24a	0.15a	0.93a	20.86a	0.69a	0.18a
CT	6.85ab	13.33a	1.32a	0.16a	0.87a	23.25a	0.73a	0.21a
LSD	**0.323**	**3.655**	**0.539**	**0.371**	**0.66**	**4.266**	**0.228**	**0.058**

Means with the same letters on the same column are not significantly different at the 5% level of the Duncan's Multiple Range test

4.13 Effect of Tillage on Organic Carbon (OC)

Wicks *et al.* (1988), found no significant differences in conventional and minimum tillage for first year of study and Lipiec and Hatano (2005), found that no significant increase in SOC contents during 14 yr under DT (disc tillage) treatment. This implies that the SOC pool in the 0 - 5 cm deep soil layer was at a steady-state phase of equilibrium. This was contrary to past research results, which show significantly higher SOC levels in NT compared with CT (Dick, 1983; Hussain *et al.*, 1999). Hussain *et al.* (1999) found that the organic matter concentration in the surface layer (0 – 5 cm) was significantly different among tillage systems and decreased in the following sequence, NT > mouldboard plough (MT) > Chisel plough (CT). Increased organic matter contents in the soil surface layers under NT are a common finding (Blevins *et al.*, 1983; Dick *et al.*, 1998; Dao, 1998) and may be due to increased accumulation through decreased soil mixing, and from a decreased decomposition rate as a result of less soil residue contact with soil, lower aeration, and a lower soil temperature (Hussain *et al.*, 1999). Temesgen (2007) from the study done in Ethiopia found that tillage treatment did not alter physical and chemical properties after a period of three years. According to some literature, the SOC and total nitrogen (TN) contents of soils take longer up to 5 years to respond to reduced tillage (West and Post, 2002: Heenan *et al.*, 2004) while others reported significant changes in short periods of two to three years (Su *et al.*, 2004; Ozpinar and Cay, 2006). Although statistically there was no significant difference, there is a tendency for improvement in SOC and TN. The increase in the SOC and TN in the less ploughed soils could be due to the decreased mineralization rate of the organic matter (Ozpinar and Cay, 2006).

4.14 Effect of Tillage on Crop Growth

Total growth of maize crop increased with time and rainfall distribution (Figure 10). In the first 30 days significant differences were observed on NT and TR tillage systems (Table 10). During this time rainfall distribution was good and average growth height of maize were 108.8 cm in NT plots and lowest were 95.9 cm in TR plots. In the 50 days of crop growth stages no significant differences were noted. At this stage maize height were the highest 181.1 cm in NT plots and the shortest 171.3 cm in BT plots. Similar results of no significant difference was obtained in the 70 days of crop growth when maize height were highest 201.4 cm in the plots of CT and BT and shortest 185.8 cm in the TR plots. High ridges in the tied ridges improves rate of soil infiltration. It was expected the ridges to hold water and improve plant growth. Inadequate rainfall during growing period caused high ridges to be drier due to the improved infiltration rate which enhancing the passage of water, this ultimately reduced growing rate of maize crop in tied ridges. The prolonged drought could equally reduce level of moisture contents to all tillage treatments hence there was no significant differences in growth height among the treatments in the late stage of crop growth. However the BT and CT in the late stage of crop growth showed higher value of growth height probably due to their ability to hold moisture level to the tilled soils. Similarly results reported by Guzha (1997), who observed no significant differences, between the plant height for minimum tillage, hand hoe and disc plough in late stage of sorghum growth. In contrast, Al-Issa and Samarah (2007) in Jordan, reported plant height was significant higher in plots tilled with a disk plough followed by plots tilled with a chisel plough. This results supported by previous reports, show that conservation and conventional tillage systems improve early establishment and plant growth, resulting in taller plants compared to no tilled plots probable cause mentioned is the lowering of temperature in no till plots. No tilled plots with surface residues decrease soil water evaporation, thus furnishing a moist and cooler environment (Rao and Dao, 1992).

Table 10: Means Crop Growth and Yield of Maize

Systems	**Growth stage days**			**Yield**
	30	50	70	Ton/ha
NT	108.85a	181.1a	187.57a	3.08a
BT	98.87ab	171.3a	201.44a	2.24a
ST	106.17ab	174.47a	195.57a	2.92a
TR	95.98b	173.8a	185.87a	2.53a
CT	100.1ab	179.63a	201.44a	2.72a
LSD (0.05)	**8.8**	**37.6**	**24.6**	**0.9**

Means with the same letters on the same column are not significantly different at the 5% level of the Duncan's Multiple Range test

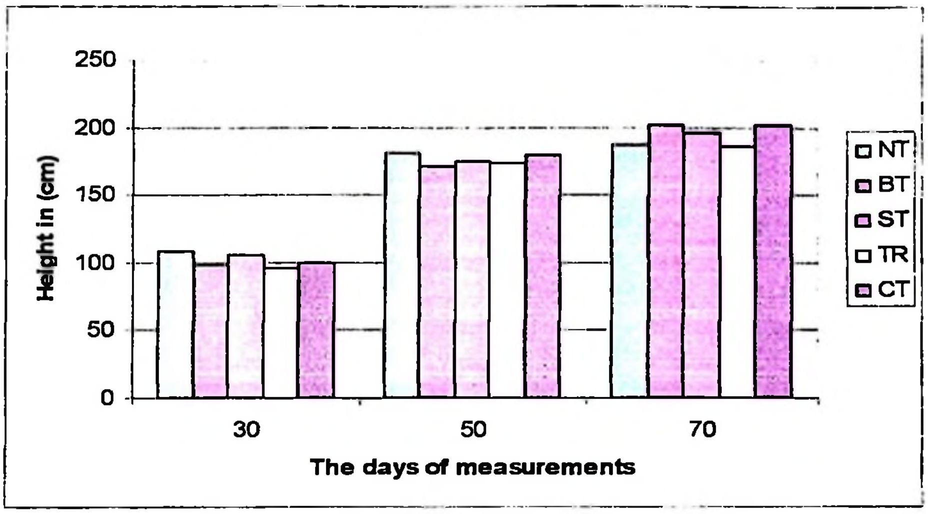

Figure 11: Crop growth measurement stages

4.15 Effects of Tillage on Crop Yield

No significant differences were observed among different tillage systems on maize yield as shown in Table 10. However the highest yield was observed on no tilled plots (Figure 11). No significant trend for different tillage systems on yields were observed by many researchers during first years of experiments (Barzegar *et al.*, 2003; Dick *et al.*, 1998; Tolessa *et al.*, 2007). Barzegar *et al.* (2003) tested conventional, conservation tillage and no tillage under chickpea in Iran and found that there was no significant trend on yield but higher yield was observed on conservation tillage. They argued that lack of differences among chickpea yield due to tillage treatments may be attributed to inadequate rainfalls distribution during growing stages.

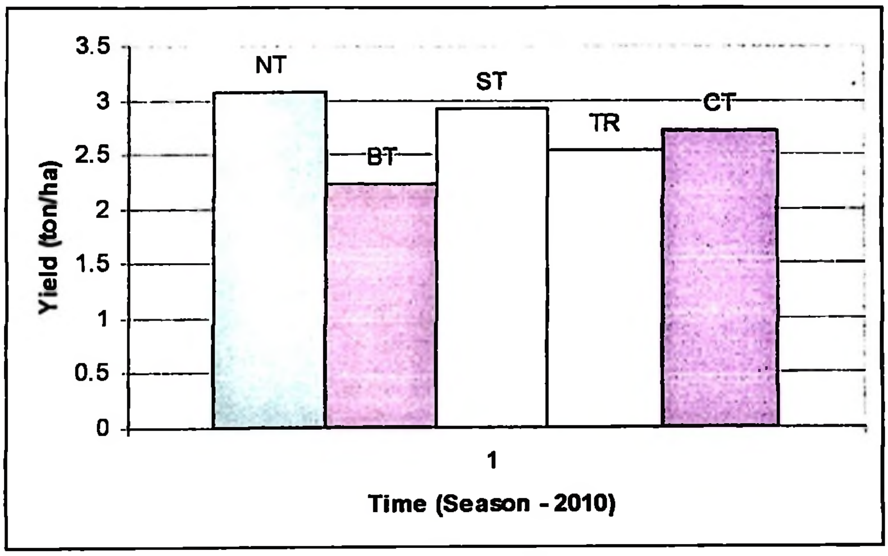

Figure 12: Influence of tillage on crop yield

Tolessa *et al.* (2007) tested conventional and conservation tillage under maize yield in Ethiopia and found no significant difference on yield in the first two years of experiments, but higher yields were seen on conservation plots. This trend they argue may be tillage treatments to respond to the yield depend on the gradual build up of soil fertility and may take up to three years adverse effects become evident. These results contrasting with other researches (Kosutici *et al.*, 2005; Guzha, 1997; Mahoo *et al.*, 1995; Al-Issa and Samarah, 2007) who reported significant differences on crop yields during first year of experiment and got lowest yield in NT plots. The lowest yield was experienced from zero-tillage plot by Kosutici *et al.* (2005) when tested with conventional tillage. This result is in agreement with Al-Issa and Samarah (2007) where zero-tillage has also been found to give lower yield, which are subject to restricted root growth. From existing literature, there is considerable evidence existing for unlikely poor performance of the zero-tillage associated with the influence of climate, soil, management practices that zero-tillage performance in terms of enhancing yield could be limited, especially at the earlier few years where zero tillage persist. It was also clearly observed in many occasions that the zero-tillage did not increase yield when the precipitation is reasonably ample or increased (Al-Issa and Samarah, 2007). However according to the results at Mkambalani village where higher yield was obtained in the no tillage plots could be due to the effects of the previously year of crop grown at the site. The evident was clear even to the status of physical and chemical properties obtained from no tilled plots which showed highest N and enough organic C (Table 9). Guzha (1997) reported significant differences with tied ridges in the central Tanzania and had the highest yield most probably due to its high water retention ability. The same results obtained by Mahoo *et al.* (1995) working on the same soils in the same area. TMV1 is streak resistant maize crop, medium maturity, suitable to the low and medium zone and yield 4.25 t/ha, at the station but 3.5 t/ha at the farmer field conditions (Kaliba *et al.*, 1998). According to Figure 11, yield of NT treatment was closer to the recommendation by the breeders. Low yield revealed was the results of bad weather during the experiment.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMNDATIONS

5.1 Conclusions

No significant differences in bulk density were found between the plots in the first year of experiment however, it was found that tillage decrease soil bulk density. Total porosity of the soil increased with tillage. In the experiment at the Mkambalani village showed that total porosity at the beginning of experiment was lower than the ones obtained at the end of experiment. According to that data obtained it means that the significance of tillage is to increase the porosity. Optimum porosity is required for normal plant growth because porosity below 45% on medium heavy soils had a negative effect on plant growth.

MC increases with depth. Conservation tillage holds more moisture content than conventional tillage and NT. MC at the beginning of experiment were higher than at the end of experiment. This implied that MC depends on rainfall distribution because rainfall distribution at the beginning of the experiment was good compared at the end.

NT produced higher amount of runoff on average in most of rainfall events while TR was the least as expected due to its ability to trap and hold flowing water. This finding emphasis the importance of implementing soil conservation technology package, that is when applied no tillage can go together with the use of cover crops for covering soil.

CT treatment was the big collector of more sediment than other tillage treatments. The source of land degradation is the frequency use of practicing conventional tillage.

In Morogoro District which is under Eastern Agro-Ecological Zone – Tanzania, tillage increase enhancement in infiltration rate.

Statistical analysis revealed that there were no significant differences between different tillage systems and soil textures in first year of the experiment. This means that tillage did not alter soil textures in short run in Eastern Agro ecological zone.

Statistically significant differences were found for soil pH between tilled soil treatments and conservation tillage treatments. This means that importance of soil tillage is in mixing of crop residues which results in proper decomposition of OM hence keep the soil pH higher. No significant differences were found in the amount of N, P and K present due to different tillage treatments in first year of farming.

ST plots showed higher in OC than other plots during the experiment in the first year. The high OC values which were found in strip tillage system, suggesting the improvement of soil fertility and reflecting the dual advantage it has over NT and conventional tillage. But even though ST plots was found to have higher OC content statistically observed that there were no significant differences between the treatments.

In the first 30 days of plant growth significant differences were observed on NT and TR tillage systems when the rainfall distribution was good. However during the end of season with little rainfall no significant differences were observed among different tillage treatments on crop growth.

No significant differences in yields were observed among different tillage treatments, but observed the increase of yield in NT.

5.2 Recommendations

High amount of sediment produced under CT treatment of 23.2 ton/ha/season call the need to reduce frequencies of tilling the land or use conservation methods in land preparation and crop production.

High amount of water runoff collected in the NT treatment require the need of using NT with cover crops in crop productions.

There is a need to try all tillage treatments with cover crops to check effectiveness of controlling water runoff and sediment production.

First year trial was not good enough to draw appropriate conclusion, hence suggestion to have more research on tillage.

Under natural rainfall conditions rainfall amount, intensity and distribution differs which all affect soil properties and crop development, hence the one year trial is not enough. There are the need to extend study to another year and other places of different soil and climatic conditions.

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APPENDICES

Appendix 1: Profile description

Ah 0 - 18/33 cm: black (7.5YR2.5/1) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; moderate medium and coarse subangular blocks; many fine and very fine pores, few medium pores; few coarse and many fine roots; clear wavy boundary to

Bw 18/33 - 40/51 cm: dark brown (7.5YR3/2) moist; sandy clay loam; friable moist, sticky and plastic wet; weak fine and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; few coarse and fine roots; clear wavy boundary to

Ab 40/51 - 82/94 cm: very dark grey (7.5YR3/1) moist; sandy clay loam; friable moist, sticky and plastic wet; weak fine subangular blocks and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; fine and very few very fine roots; clear wavy boundary to

Bwb 82/94 - 150 cm: dark reddish brown (5YR3/2) moist; sandy clay; friable moist, sticky and plastic wet; moderate fine and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; few fine and very fine roots

Mineralogy: kaolinite (30%), smectite (40%); illite (20%), others (10%)

Analysis data for soil profile

Horizon	Ah	Bw	Ab	Bwb
Depth (cm)	0-18/33	18/33-40/51	40/51-82/94	82/94-150+
Clay %	25	29	32	42
Silt %	10	6	2	6
Sand %	65	65	66	52
Texture class	SCL	SCL	SCL	SC
pH H_20 1:2.5	6.6	6.2	6.1	6.3
pH KCl 1:2.5	5.5	4.8	4.8	4.9
EC mS/cm	0.08	0.04	0.03	0.05
Organic C %	3.04	2.83	1.41	1.13
Total N %	0.24	0.19	0.17	0.16
C/N	13	15	8	7
Avail. P Bray mg/kg	5.46	1.03	0.70	0.32
CEC soil cmol(+)/kg	7.22	8.31	10.38	13.35
Ca cmol(+)/kg	2.9	5.0	4.3	6.5
Mg cmol(+)/kg	2.3	2.8	2.9	3.7
K cmol(+)/kg	1.10	0.30	0.19	0.13
Na cmol(+)/kg	0.05	0.05	0.08	0.11
TEB cmol(+)/kg	6.35	8.15	7.49	10.44
Base sat. %	88	98	72	78
ECe mS/cm	0.31	0.16	0.13	0.19
CEC clay cmol(+)/kg	28.9	28.7	32.3	31.8

Source: Msanya *et al.* (1998).

Appendix 2: Data Analysis for Maize Yields

```
Source                       df Type III SS         MS             F     P
------------------- --------- ----------- ---------    ---------- -----
---
Blocks                        2 1.295121e11 6.4756e10   0.3000261 .7488
ns
Main Effects
  TREATMENT                   4 1.293734e12 3.2343e11   1.4985234 .2898
ns
Error                         8 1.726678e12 2.1583e11<-
------------------------- --------- ----------- ----------    ---------
----- ---
Total                              14 3.149924e12

Model                         6 1.423246e12 2.3721e11   1.0990243 .4378
ns

R^2 = SS model/SS total = 0.45183499602
Root MS error = sqrt(MS error) = 464580.214904
Mean Y = 2699048
Coefficient of Variation = (Root MSerror) / abs(Mean Y) * 100% =
17.212744%

Compare Means
Factor: 1) TREATMENT
Test: Duncan's
Significance Level: 0.05
Variance: 215834776080
Degrees of Freedom: 8
Keep If:

n Means = 5
LSD 0.05 = 874732.298723

 Rank Mean Name           Mean       n Non-significant ranges
----- --------- ---------- -------- ----------------------------------
-
    1 NT             3077712       3 a
    2 ST             2923712       3 a
    3 CT             2723072       3 a
    4 TR             2526832       3 a
    5 BT             2243912       3 a
```

Appendix 3: Data analysis for sediment collected

```
Source                  df Type III SS        MS              F     P
-------------  -------- -- ----------- ----------   -- ------- ----- ---
Blocks                   2 29.17733333 14.588667     0.348522 .7159 ns
Main Effects
  Treatments             4 57.71066667 14.427667    0.3446757 .8407 ns
Error                    8 334.8693333 41.858667<-
---------------------- ----------- ---------   --------- ----- ---
Total                   14 421.7573333

Model                    6      86.888 14.481333    0.3459578 .8936 ns

R^2 = SS model/SS total = 0.2060142009
Root MS error = sqrt(MS error) = 6.46982740625
Mean Y = 16.2866666667
Coefficient of Variation = (Root MSerror) / abs(Mean Y) * 100% =
39.724687%

Compare Means
Factor: 1) Treatments
Test: Duncan's
Significance Level: 0.05
Variance: 41.8586666667
Degrees of Freedom: 8
Keep If:

n Means = 5
LSD 0.05 = 12.181678896

 Rank Mean Name          Mean        n Non-significant ranges
----- ------------ -------- ----------------------------------------
    1 NT          18.4666666667      3 a
    2 BT          17.2666666667      3 a
    3 ST                   16.7      3 a
    4 CT          16.3666666667      3 a
    5 TR          12.6333333333      3 a
```

Appendix 4: Data Analysis for Soil Porosity

```
Source                     df Type III SS         MS             F      P
--------------- --------- ----------- ---------   ---------- ----- ---
Blocks                      2 0.005186958 0.0025935   1.6243113 .2558 ns
Main Effects
  Treatment.                4 0.012435477 0.0031089   1.9471032 .1960 ns
Error                       8 0.01277331 0.0015967<-
--------------- --------- ----------- ---------   ---------- ----- ---
Total                      14 0.030395745

Model                       6 0.017622435 0.0029371   1.8395059 .2083 ns

R^2 = SS model/SS total = 0.57976650273
Root MS error = sqrt (MS error) = 0.03995827555
Mean Y = 0.530245
Coefficient of Variation = (Root MS error) / abs(Mean Y) * 100% =
7.5358137%

Compare Means
Factor: 1) Treatment
Test: Duncan's
Significance Level: 0.05
Variance: 0.00159666378
Degrees of Freedom: 8
Keep If:

n Means = 5
LSD 0.05 = 0.07523521903

 Rank Mean Name              Mean        n Non-significant ranges
----- ----------------- ------- ----------------------------------
    1 BT                  0.585728       3 a
    2 ST             0.52540266667       3 ab
    3 CT             0.52094966667       3 ab
    4 NT             0.51672166667       3 ab
    5 TR                  0.502423       3 b
```

Appendix 5: Data Analysis for Moisture Content

```
Source                    df  Type III SS          MS              F      P
----------------- --------- ----------- ----------  --------- ----- ---
Blocks                     2       11.668       5.834  0.2936971 .7532 ns
Main Effects
  Treatment                4       31.904       7.976  0.4015304 .8027 ns
Error                      8      158.912     19.864<-
----------------- --------- ----------- ----------  --------- ----- ---
Total                     14      202.484

Model                      6       43.572       7.262   0.365586 .8816 ns

R^2 = SS model/SS total = 0.21518737283
Root MS error = sq rt(MS error) = 4.45690475555
Mean Y = 13.98
Coefficient of Variation = (Root MS error) / abs(Mean Y) * 100% =
31.880578%

Compare Means
Factor: 1) Treatment
Test: Duncan's
Significance Level: 0.05
Variance: 19.864
Degrees of Freedom: 8
Keep If:

n Means = 5
LSD 0.05 = 8.39165857034

 Rank Mean Name              Mean        n Non-significant ranges
----- ------------- ------- ----------------------------------------
    1 TR                     16.4        3 a
    2 ST                     14.5        3 a
    3 CT               13.9333333333     3 a
    4 BT               12.9333333333     3 a
    5 NT               12.1333333333     3 a
```

Appendix 6: Data Analysis for Crop Growth

```
Source                    df Type III SS         MS              F      P
---------------- -------- ----------- ----------    ---------- ----- ---
Blocks                     2 945.3243333 472.66217    12.72647 .0033 **
Main Effects
  TREATMENT                4 327.6293333 81.907333   2.2053621 .1585 ns
Error                      8 297.1206667 37.140083<
------------ -- -- ------ ----------- ----------    --------- ----- ---
Total                     14 1570.074333

Model                      6 1272.953667 212.15894   5.7123982 .0139 *

R^2 = SS model/SS total = 0.81076012749
Root MS error = sqrt(MS error) = 6.09426643111
Mean Y = 101.923333333
Coefficient of Variation = (Root MS error) / abs(Mean Y) * 100% =
5.9792652%

Compare Means
Factor: 1) TREATMENT
Test: Duncan's
Significance Level: 0.05
Variance: 37.1400833333
Degrees of Freedom: 8
Keep If:

n Means = 5
LSD 0.05 = 11.4745559826

 Rank Mean Name           Mean       n Non-significant ranges
----- ------------- ------- ---------------------------------------
    1 NT              108.5         3 a
    2 ST         106.166666667      3 ab
    3 CT              100.1         3 ab
    4 BT         98.8666666667      3 ab
    5 TR         95.9833333333      3 b
```

Appendix 7: Data Analysis for Effect of Tillage on Clay Soil

```
Source                        df Type III SS          MS              F      P

------------------ -------- ----------- ---------    --------- -----
---
Blocks                         2          4.8        2.4    0.1525424 .8610
ns
Main Effects
  Treatment                    4 46.93333333 11.733333   0.7457627 .5873
ns
Error                          8 125.8666667 15.733333<-
------------------ -------- ----------- ---------    --------- -----
---
Total                         14       177.6

Model                          6 51.73333333 8.6222222   0.5480226 .7603
ns

R^2 = SS model/SS total = 0.29129129129
Root MS error = sqrt(MS error) = 3.96652660817
Mean Y = 52.6
Coefficient of Variation = (Root MS error) / abs(Mean Y) * 100% =
7.5409251%

Compare Means
Factor: 1) Treatment
Test: LSD
Significance Level: 0.05
Variance: 15.7333333333
Degrees of Freedom: 8
Keep If:

n Means = 5
LSD 0.05 = 7.46835277656

 Rank Mean Name            Mean        n Non-significant ranges
----- ---------------- ------- -------------------------------------
---
    1 ST         55.6666666667       3 a
    2 NT                    53       3 a
    3 TR         52.3333333333       3 a
    4 CT         51.6666666667       3 a
    5 BT         50.3333333333       3 a
```

Appendix 8: Data Analysis for Effect of Tillage on Buck Density of Soil

```
Source                   df Type III SS        MS             F         P
-------------- ------ -------- ----------- ----------    --------- -----
---
Blocks                    2 0.002253333 0.0011267    0.4842407 .6331
ns
Main Effects
  Treatment               4 0.017306667 0.0043267    1.8595989 .2111
ns
Error                     8 0.018613333 0.0023267
------------------ ------ -------- ----------- ----------    --------- -----
---
Total                    14 0.038173333

Model                     6     0.01956   0.00326    1.4011461 .3208
ns

R^2 = SSmodel/SStotal = 0.51239958086
Root MSerror = sqrt(MSerror) = 0.04823553324
Mean Y = 1.35866666667
Coefficient of Variation = (Root MSerror) / abs(Mean Y) * 100% =
3.550211%

Compare Means
Factor: 1) Treatment
Test: Duncan's
Significance Level: 0.05
Variance: 0.00232666667
Degrees of Freedom: 8
Keep If:

n Means = 5
LSD 0.05 = 0.09082000807

 Rank Mean Name              Mean        n Non-significant ranges
----- ---------------- -------- ------------------------------------
---
    1 ST                  1.42        3 a
    2 TR                  1.37        3 a
    3 NT         1.34333333333        3 a
    4 BT                  1.33        3 a
    5 CT                  1.33        3 a
```

Appendix 9: Questionnaire

Socio economic questionnaire for farmers at Mkambalani village, Mkambalani ward, Morogoro Rural District, Tanzania.

Name of interviewer...

A. General Information

Date...............   District...............
Division............   Ward....................
Village................

B. Household characteristics

Sex: 1 Female ____________ 2. Male _________.
Age: ______________ Tribe: ______________ Size of household:

Household head:
Female headed; _________ Male headed _________ Grandparents headed:

Orphans headed;________.

C. Education

What is the highest level of education of the household head?
Informal education .... Primary level........... Secondary level ....
College level ....   University ....

D. Occupation

1) Agriculture....... 2) civil servant.......... 3) Trade..........
4) Others (Specify)............................

E. Marital status

1) Married......... 2) Single .... 3) Widower....... 4) Widow ....

F. Size of household

i). Number of children female .... ii) Number of children male ....

Age and education structure of household

Age group	Primary education	Secondary & above	Illiterate	Total
< 16 yrs				
17 - 55 yrs				
> 56 yrs				

G. Land tenure

What is the total area of land do you own/hire....................Ha

What are the main crops do you grow?

Food crops……………………………………………………………………………

Cash crops……………………………………………………………………………

If owned farm, did you have title deed of your farm?

Yes ( ). No ( ).

H. When did you get this farm?

……………………………………………………………

Explain yields trend you were obtained since you have started farming in this farm

Estimate	1970s harvest	1980s yield harvest	1990s yield harvest	2010s yield harvest
Low to high				

Why the cause of the above trend.

……………………………………………………………………………………

I. What methods do you use in land preparation?

Hand hoeing ………….. Ploughing ……….. Others (specify)…………………

Why you use the selected method? ……………………………………………

J. What do you know about the following?

Soil fertility……………………..

Soil erosion…………………………

Climate change …………………………..

What are the effects of the above mentioned if any in your farm?

Soil fertility – stagnate crop growth? Yes ( ), No ( ).

Normal crop growth, Yes ( ), No ( ).

Soil erosion - gully or rill erosion, Yes ( ), No sign ( ).

Climate change - Drought. Yes ( ). Normal climate ( ).

How do you normally do to reduce the mentioned above effects in your farm?

……………………………………………………………………………………

K. Fertilizer use

Did you apply any fertilizers/manures in your farm? Yes ( ). No ( ).

What type of fertilizer did you use if any?

Artificial fertilizers ( ). Manures ( ). Both ( ). Others (specify)……………

L. Crop yield harvested in this season 2009/10

S/n	Crops grown	Average harvest ton/ha	Farm size	Total harvest in tons

M. Other sources of income

i)................................ ii) ....iii)
....

N. Access of extension services: 1) Easily accessed ( ). 2) Not easily accessed ( ).

O. Do you consider gender balance in farming activities in your family?

Yes ( ). No ( ).
If yes why..
If no why ....

P. HIV/AIDS Effects

HIV/AIDS has any effect in the farm activities? Yes ( ). No ( ).
If yes explain the effect(s)..

Explain the measures have been taken to reduce the effects
....

Thank you for your cooperation

Appendix 10: Pictures

Figure 13: Land preparation

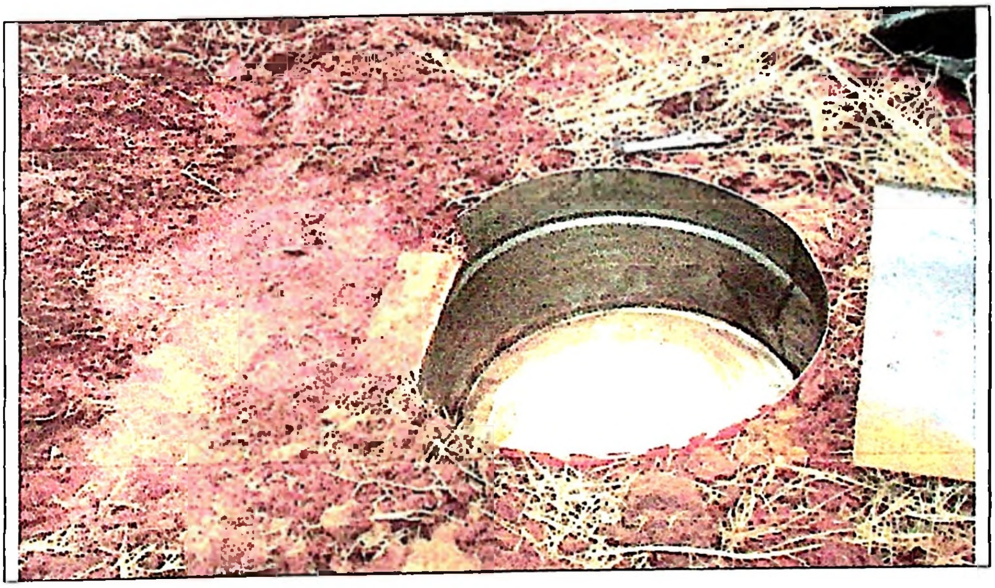

Figure 14: Installation of Modified Gerlarch Trough

Figure 15: Plots planted

Figure 16: Field soil samples collection

Figure 17: General view of study site after a month of maize growth

Figure 18: Strip tillage treatment

Figure 19: Maize at the tussling stage

Figure 20: Soil sample taking during harvesting

Figure 21: Double ring infiltrometer

Figure 22: Plots ready for harvest

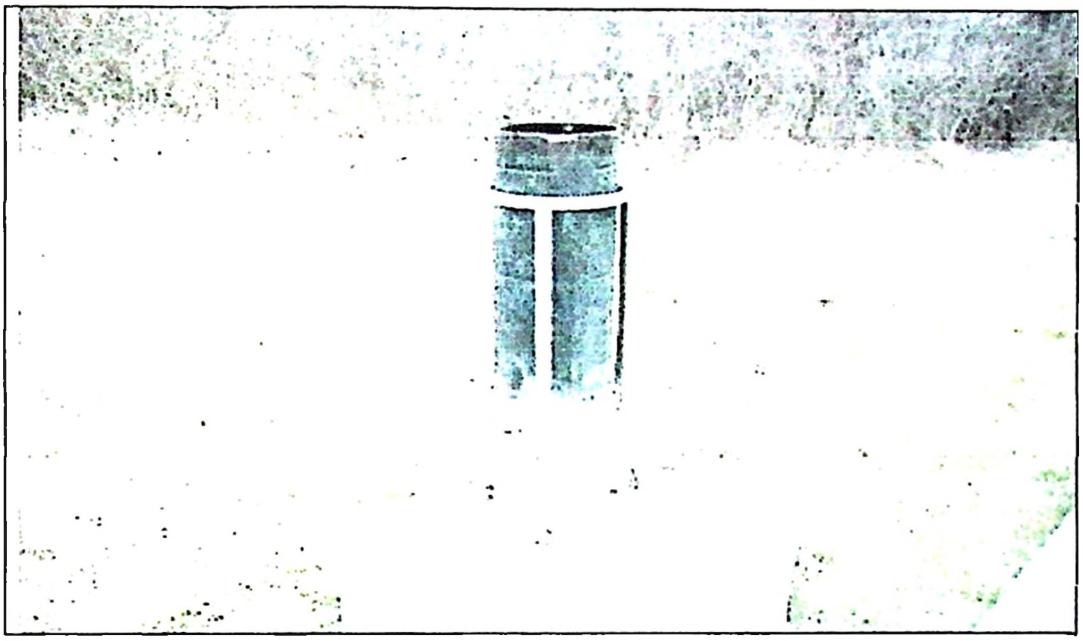

Figure 23: Standard rain gauge