EFFECT OF DRY WHEAT STRAW MULCHING AND COWPEA-MAIZE INTERCROPPING ON SOIL EROSION AND MAIZE YIELD IN ZAMBIA

By

Elizabeth Kabwe

A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy, Soil Science.

The University of Zambia

Lusaka

2019

COPYRIGHT

DECLARATION

I, Elizabeth Kabwe, hereby declare that all the work presented in this dissertation is my own and has not previously been submitted for a degree at this or any other university.

Signature...

Date...

APPROVAL

This dissertation of Elizabeth Kabwe is approved, fulfilling part of the requirements for the award of Master of Science degree in Agronomy-Soil Science from the University of Zambia.

Examiner 1………………………………Signature…………………Date…………..

Examiner 2………………………………Signature…………………Date…………..

Examiner 3………………………………Signature…………………Date…………..

Chairperson

Board of Examiners…………………….Signature………………….Date…………..

Supervisor………………………………..Signature………………….Date…………

DEDICATION

To my husband Emmanuel and children Temwani and Wongani whose patience, support and endurance gave me strength throughout my studies

ABSTRACT

Past and present-day erosion is a significant form of land degradation that has rendered vast areas of sloping land unproductive with respect to crop production. Thus, conservation tillage, along with complementary practices such as soil cover and crop diversity has become a better option to ensure sustainable food production and maintenance of environmental sustainability. A field study was conducted to evaluate the effect of dry wheat straw mulching and cowpea-maize intercropping practices on soil erosion and maize yield. The field experiment was conducted at the University of Zambia, Great East Road Campus Field Station, in Lusaka, which is managed by the School of Agricultural Sciences. The study aimed at assessing the effect of mulching and intercropping practices on soil erosion and runoff, water balance and components of the Universal Soil Loss Equation. The study was carried out in the 2016/2017 rainy season with maize as a test crop. A randomized complete block design was adopted with three replicates. Treatments were (i) dry wheat mulching, (ii) cowpea-maize intercropping and (iii) conventional practices. The results showed that the use of dry wheat straw mulch at the rate of 12 ton/ ha could reduce the amount of soil lost by 14 % as compared to the intercropping practice. The runoff was not significantly affected by the dry wheat mulch and cowpea-maize intercrop. The annual soil loss predicted from the Universal soil loss equation was significantly reduced by 58 % in the dry wheat mulch and 29 % in the cowpea-maize intercrop as compared to the conventional practice. The non-significance of the maize yield obtained would have been due to the infestation of Army worms during the maize tasselling stage.

Key words: soil loss, runoff, conservation tillage, crop diversity

ACKNOWLEDGMENTS

I thank my supervisors, Dr. Elijah Phiri and Dr. Lydia M. Chabala for the guidance rendered during this study and the entire staff of the Department of Soil Science for making my research possible. Special thanks go to Agricultural Productivity Programme for Southern Africa (APPSA) for funding my research.

Sincere thanks go to the Ministry of Agriculture for offering me the chance to study. My classmates are appreciated for all the encouragements and advice they provided during the write-up of this dissertation. To my amazing, loving and remarkable parents, in-laws and siblings who have encouraged and prayed for me, I say thank you.

Above all, I thank Yahweh, God Almighty for seeing me through this process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

ANOVA	Analysis of Varience
FC	Field capacity
FAO	Food and Agriculture Organization of the United Nations
HI	Harvest index
K	Potassium
N	Nitrogen
P	Phosphorus
Ca	Calcium
USLE	Universal soil loss equation
C.P	Conventional practice
I.P	Intercropping practice
M.P	Mulching practice
SLR	Soil loss ratio
RUSLE	Revised Universal Soil Loss Equation
WP	Wilting point

CHAPTER ONE: INTRODUCTION

1.1 Background

Soil erosion is a significant form of land degradation that has rendered vast cultivated agricultural lands unproductive concerning crop production (Rauschkolb, 1977; Eswaran et al., 2001). Soil and water erosion are critical environmental issues affecting the ecosystems. Globally, it is estimated that one-sixth of the world's lands are affected by water erosion. In Africa, 8.5% of the mean yield loss is associated with past water erosion (Eswaran et al., 2001) and the most extensive limitation on steep lands is severe soil erosion. Conservation tillage, along with complimentary land husbandry practices such as soil cover and intercropping practices are seen as promising options for maintaining sustainable food production and environmental stability. Tillage practices disturb soil structure, hydraulic properties, and soil stability to such an extent that they also directly affect plant growth and optimal attainable yields (Duplessis, 2003).

The two most significant and closely related soil characteristics influencing soil erodibility are infiltration capacity and structural stability (Millward and Mersey, 1999). The process of erosion consists of two closely related processes of detachment or breaking away of soil particles from a land surface by some erosive agent, most commonly water or wind, and sedimentation, or "subsequent transportation of the detached particles to another location" (Flanagan 2002). Water erosion is caused by raindrop impact and runoff of excess water, and as such, erosion and sedimentation control strategies must be based on covering the soil against raindrop impact, increasing water infiltration to reduce runoff generation and increased surface roughness to reduce overland flow velocity. Factors affecting soil erosion by water include;

Rainfall pattern: the more rainfall and the higher the "force" of the rain (called the Intensity, i.e., the amount of rain which falls per minute), the more erosion will occur.

Slope steepness: the steeper the field, the higher the erosion risk.

Slope length: erosion increases with slope length.

Soil type: clayey soils show in general more resistant to erosion than sandy soils.

Several approaches have been used to minimise the effects of soil erosion, and examples include mulching, intercropping and no-till. Mulch is a layer of different material placed on top of the soil surface. Different types of material such as residues from the previous crop, brought-in mulch including grass, perennial shrubs, farmyard manure, compost, by-products of agro-based industries, or inorganic materials and synthetic products can be used for mulching (Lal, 1990). Since crop residues on the soil surface decrease erosion, increase soil organic matter and improve soil quality (Lal et al., 1999), management of crop residues is seen as an integral part of many conservation tillage systems.

Intercropping is the growing of two or more crops at the same time on a single field. Intercropping has four general subcategories; mixed intercropping; no distinct row arrangement, row intercropping, strip intercropping; growing crops in strips wide enough to separate them, yet narrow enough to allow interaction between them; and relay intercropping, producing two or more crops during different parts of their life cycles. Whenever two crops are planted together, they will interact either or both in competition (for light, water, and nutrients) and facilitation (Vandermeer, 1992). Intercropping Maize with Cowpeas provides ground cover.

Recently, tillage practices are applied as an approach to control erosion. However, there is limited information available, and especially so in this part of the world (Zambia).

1.2 Statement of the problem

About 99.7% of the world food comes from the land and as such maintaining and securing the world food supply depends on the quality and productivity of all the soils. Soil erosion diminishes soil quality and reduces the productivity of natural agricultural and forest ecosystem. As much as similar research has been done elsewhere in the world, there is limited knowledge on the effect of mulching and intercropping on soil erosion and maize growth in this part of the world, particularly Zambia.

1.3 Objectives

The overall objective of the study was to evaluate the effect of dry wheat straw mulch and maize-cowpea intercrop practice on soil erosion and maize yield in Zambia.

Specific objectives were:

1. To characterise selected physical and chemical properties of the study site
2. To assess the effect of mulching and intercropping practices on soil loss and runoff
3. To assess the soil moisture components under the mulching and intercropping practices
4. To assess the elements of the Universal Soil Loss Equation (USLE) under mulching and intercropping practices
5. To assess the effect of mulching and intercropping practices on maize yield

1.4 Hypothesis.

Three hypotheses were tested:

1. Mulching and intercropping practices significantly reduce soil loss and runoff
2. Mulching and intercropping practices significantly increase soil moisture and affect the soil erodibility and crop management components of the Universal Soil Loss Equation
3. Mulching and intercropping practices significantly improve maize yield

1.4 Significance of the study

Due to the increasing population, more agricultural land is needed to meet the ever-increasing food requirements, and this will eventually lead to the use of marginal lands. As land increases in slope and climatic limitations, practices that go hand in hand with tillage methods are required to prevent land from degrading due to erosion. Therefore, there is a need to study the effect of mulching and intercropping practices on soil loss, runoff and maize growth of sloping land. Moreover, studies in soil erosion have received little attention in Zambia and scientific evidence of mulching and intercropping is limited.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Soil erosion occurs when the soil is removed through the action of wind and water at a higher rate than soil formation process. Factors that determine soil erosion include; slope, soil texture, vegetative cover, and land use. It can be minimized by; maintaining ground cover, increasing water infiltration into the soil, and minimum or no tillage.

2.2 Mulching

According to Junge et al., 2008, mulching, crop management, and conservation tillage are appropriate technologies for conserving sandy soils of high erosivity and low water-holding capacity. According to Gril et al. (1989), mulch serves as a barrier between falling rain and the soil, thereby reducing soil erosion and water runoff. Mulch protects soil from being hit directly by rain, reducing soil crusting and increasing the speed with which water soaks into the ground (Relf, 2015). Several investigations are done on the beneficial effects of mulch on the physical, chemical, and biological soil properties showed its influence on the soil's erodibility. Hulugalle et al. (1985, 1987) and Lal (2000) found that mulching decreases the bulk density and penetration resistance of the soil. Ogban et al. (2001) and Chiroma et al. (2004) investigated the influence of residue mulch has on the infiltration capacity and hydraulic conductivity of soils. Ogban et al., (2001) stated that the infiltration was five times higher and the transmissivity four times higher in plots with incorporated mulch compared with the surface or no mulch application. Mulch farming is not only useful for reducing soil and water loss but is also helpful in conserving soil moisture in the field. Thus, mulching can be used in higher rainfall period/region for decreasing soil and water loss and in low rainfall period/region for increasing soil moisture (Sharma and Singh, 2013). Straw mulch is known to improve soil moisture storage (Ji and Unger, 2001).

Barton et al. (2004) indicated that during intense rainfall, mulch effectiveness increased. According to Lal, (2007), beneficial effects of mulching arise from the protection of the soil surface against raindrop impact, decrease in flow velocity by imparting roughness on the soil surface and improved infiltration capacity. Planting more than one crop at a time and one place increases the canopy cover which in turn reduces the impact of the raindrops on the soil surface.

2.3 Intercropping

Use of cover crops together with the main crop or rotating them with the main crop can improve physical and chemical soil conditions as well as protect against rain-drop impact (Freitas et al., 2012) as well as against erosion (Dias et al., 2013). A cover crop is a close-growing crop raised mainly for protection and maintenance of soil. The effectiveness of the cover crop depends on close spacing and development of functional canopy for interception of rain-drops to expose minimum soil surface for erosion (Sharma and Singh, 2013). Cover crops enhance soil structure while increasing soil biota activity. They reduce soil compaction while increasing water percolation and retention. Cover crops enhance soil organic matter level. They also improve soil aggregation, infiltration and bulk density (Dale et al., 2003). According to Chaudhry and Shafiq (1986), crop management is the most natural and useful tool for soil conservation. This is done by combining crop selection, a method of sowing, mulching, crop cover, and fertilizer application. Efficiency in controlling soil erosion and their beneficial influence on the growth and yield of the main crop is the criteria used in the selection of an inter-crop for a particular cropping system.

An intercrop of Bananas and Pineapples reduced soil and runoff losses by 75% and 43% respectively (Almas and Jamal, 1999). Carvalho (2007) concluded that in dense coffee cultivation, where weeds are kept at an acceptable height by mowing, the soil was more efficiently protected against soil losses and water runoff when compared to manual weeding. Research has further shown that several other combinations of systems that employ maize with soil cover plants were more effective at controlling water erosion, reducing soil, water, and organic matter losses, as well as improving of soil physical parameters (Debarba and Amado, 1997; Gilles et al, 2009; Rossetti et al., 2012 and Dias et al, 2013). According to Kariaga (2004), there was 4.73 times more runoff under maize as a monocrop than under maize under maize intercropped with cowpeas.

2.4. Soil loss

Soil loss is displacement or removal of the upper layer of the soil. It leads to reduced crop productivity, and eventually permanently degraded land. Soil loss depends on rainfall erosivity and soil erodibility. The extent of washing away of soil particles depends on the soil characteristics, which lead to the concept of erodibility ((Singh and Khera, 2008). According to Araya et al., (2010), conservation agriculture (Permanent beds), reduced soil loss and runoff in the Ethiopian highlands and increased the yield of wheat. The amount of soil eroded from a given site during a season is highly variable and depends on prevailing conditions (FAO, 1998). Water runoff and the resulting soil loss are because of limitations in water infiltration, compacted subsoil, hardpans and reduced macropores (Lal, 1990).

2.5. Runoff

Runoff occurs when rain intensity exceeds the infiltration rate of sloped land that is independent of the stability of the soil surface. According to Lozano- Garcia et al. (2011), runoff is the portion of rain-water not infiltrated into the soil for crop uptake but removed out of reach by plants. Rainfall and runoff have the potential for detaching particles, but the transportation of particles is mainly through runoff (Unger, 1984). Wischmeier (1973) indicated that dispersed soil aggregates increased runoff, reduced surface roughness, enhanced surface sealing, and crusting and these factors result from raindrop impact. Straw mulch maintained topsoil structure and encouraged infiltration, thus decreasing runoff and erosion rates. According to Barton et al., (2003), runoff under conventional practice was high.

2.6 Soil Moisture

The response of soil moisture to rainfall was mainly in the 0- 20 cm layer and the 40 cm layer; the response was slow and occurred after a rainfall event (Zhao et al., 2014). According to Ugarte et al., (2014), cover cropping was a way to build soil organic matter and to increase the capacity of the soil to retain moisture.

Increasing organic matter led to high infiltration of water into the soil, return of water to the underground aquifer and increase in surface water. This was according to Brady and Weil (2002). There was a reduction in soil water evaporation in mulched plots in Nigeria, and soil moisture was higher in mulched plots than in un-mulched plots (Tian et al., 1993). To predicting average rate of soil erosion for various alternative combinations of crop systems, a soil loss equation was formulated by Wischmeier and Smith (1987).

2.7 Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) is used to compute sheet and rill erosion (Wischmeier and Smith, 1987) as a function of factors representing climate, soil, topography and land use. It is given by:

$$A = R * K * L * S * C * P \qquad \textbf{(Equation 1)}$$

where ***A*** is the average annual soil loss, ***R*** is the Rain Erosivity factor, ***K*** is the Soil Erodibility factor, ***L*** is Slope length, ***S*** is slope steepness, ***C*** is the cropping management factor, and ***P*** is supporting practice factor

All factors were determined empirically by statistical evaluation of the soil loss on the unit plots (22 m length and 9% slope) and on different parcels compared with the unit plots. The first two factors determine the actual soil loss on unit plots for defined soils and rainfall and are, therefore, expressed in physical units (ton.hr./MJ.mm and MJ.mm/ha.yr.). Other factors are dimensionless and represent the ratio between soil loss on a unit plot and other parameters of analysed parcels. This was according to Wischmeier and Smith, (1978).

2.8 Maize yield

Maize is a staple food, and widely grown in Zambia**.** According to Du Plessis (2003), it was essential that soil tillage was aimed at optimizing infiltration and minimization of evaporation. Crop yield increased when mulch was increased, and this was due to reduced temperature and increased soil moisture retention (Maurya and Lal, 1981). Tian et al., (1993) reported increased maize yield in legume intercropped plots as compared to control plots. Increased water storage as promoted by ground cover, leads to improved crop yields. Frye et al., (1982) observed a reduction in maize yield of between 12% and 36% attributed to a decrease in the moisture of about 5%. Cowpea is used as a cover crop grown together with maize to reduce erosion and according to Scot et al., (1987); this has been used by farmers to control soil erosion and declining levels of soil organic matter.

Based on the literature, mulching and intercropping practices are not new in erosion and other agricultural related studies. Soil loss and runoff can have devastating effects on agricultural productivity, and soil moisture retention is critical in crop growth. The USLE is an essential tool for prediction of annual soil loss. However, links are needed to provide information on how these practices can be used in the production of maize to reduce erosion. Moreover, very little research has been done in Southern Africa, particularly Zambia.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Site description

The study was conducted at the field station located at the University of Zambia (UNZA), Lusaka. The site is located at latitude 15.394 °S and longitude 28.337°E at an elevation of 1258 m above sea level.

Lusaka vegetation is characterized by Miombo woodland dominated by *Brachystegia, Julbernardia, and Isoberlinia* species It receives average annual rainfall of 800 m and the mean maximum and minimum temperatures of 31.1^{0}C and 10.1^{0}C respectively (Aregheore, 2009). Based on the representative soil profile (table 3), the study site has a surface texture of Sandy loam and a subsoil texture of Sandy clay loam. The soil was classified as a mixed Isohyperthermic Typic Paleustalf according to USDA classification (USDA, 1999). Quartz/quartzite dominate the mid-slope as the underlying geology.

3.2 Experimental design

The experiment was arranged in a Randomised Completely Block Design (RCBD) comprising three treatments which were replicated three times, thereby giving a total of 9 plots. The experiment was conducted on runoff plots and during one cropping season. The treatments were mulching, and intercropping evaluated against conventional treatment.

3.3 Analysis of soil samples

Soil sampling technique was according to Lim and Jackson (1998). Soil samples were collected from random points of each plot and after that composited. After drying, the samples were sieved through a 2-mm sieve. After that, the samples were analysed for selected elements (Ca, Na, K, P, N, Mg) and pH. Soil texture was determined by dispersion, then the Hydrometer method (Bouyoucos, 1962) and soil pH determined in 0.01 M calcium chloride extraction (ratio: 1:2.5) (McLean, 1982). Total organic carbon (C) determined by Walkey – Black wet oxidation using potassium dichromate and concentrated sulphuric acid. Total N determined by the micro–Kjeldahl procedure (Bremner and Mulvaney, 1982). Ammonium Acetate method was used to determine exchangeable bases at pH 7 (Thomas, 1982).

Available P determination was by Bray 1 method (Olsen and Sommer, 1982; and. Bulk density determined by the Core Ring Method (Blake and Bartge, 1986).

3.4 Planting

Maize (*Zea mays, L*, variety ZMS 602) a medium maturity variety\ was planted in the study. The legume used in the intercrop was cowpea (*Vigina inguiculata*), and the variety was BB10 -4- 2- 3. Tillage was done using a hand hoe to a depth of about 0.15m in all the plots. Two maize seeds were planted per station with a spacing of 0.5 m between maize rows and 0.3 m within the rows. The rows were made across the slope. Cowpea was planted three weeks after maize germination. This was done within the maize at a spacing of 0.5 m between the row and 0.15 m within the rows.

3.5 Cultural practices

Nitrogen, Potassium, and Phosphorus were split applied as Compound D fertilizer (10: 20: 10) at a rate of 300 kg/ha. This was the basal dressing application done at the time of planting. The top-dressing was done in a split application, two weeks apart from each application. This was done two weeks after emergence. Urea was used and split applied (two weeks apart) at the rate of 300 kg/ha.

Weeding was done whenever necessary to ensure clean fields throughout the growing season. Dry wheat straw was used for mulching and applied three weeks after emergence of maize at the rate of 12 ton/ha. Emergence, Tasselling, Silking, and Scoring for diseases and defects were done during the growth of the maize. Biomass, Stover and grain yield was recorded at harvest, and grain yield was calculated at 12.5% moisture content.

3.6 Data collection

3.6.1 Collection of runoff water and soil sediments

Runoff plots measuring 2 m wide by 20 m long were banded on three sides with concrete raised to 0.07 m. Each Block was separated by 2 m. At the end of each plot, a rectangular drainage pit lined with concrete was constructed (Figure 1) to hold about 0.2731 m^3 of water as well as soil sediments. To measure excess runoff from the collecting basins, mechanical water meters (Figure 2) were connected to the overflow.

Figure 1: Rectangular drainage basin runoff and soil loss collection

The depth of water in the drainage pits was measured every day, and water meters recorded any water flow (Figure 3). The runoff pits were emptied every after the measurements were taken.

The soil collected from the runoff pits after each rainfall event was oven dried at 105^{o} Celsius and weighed.

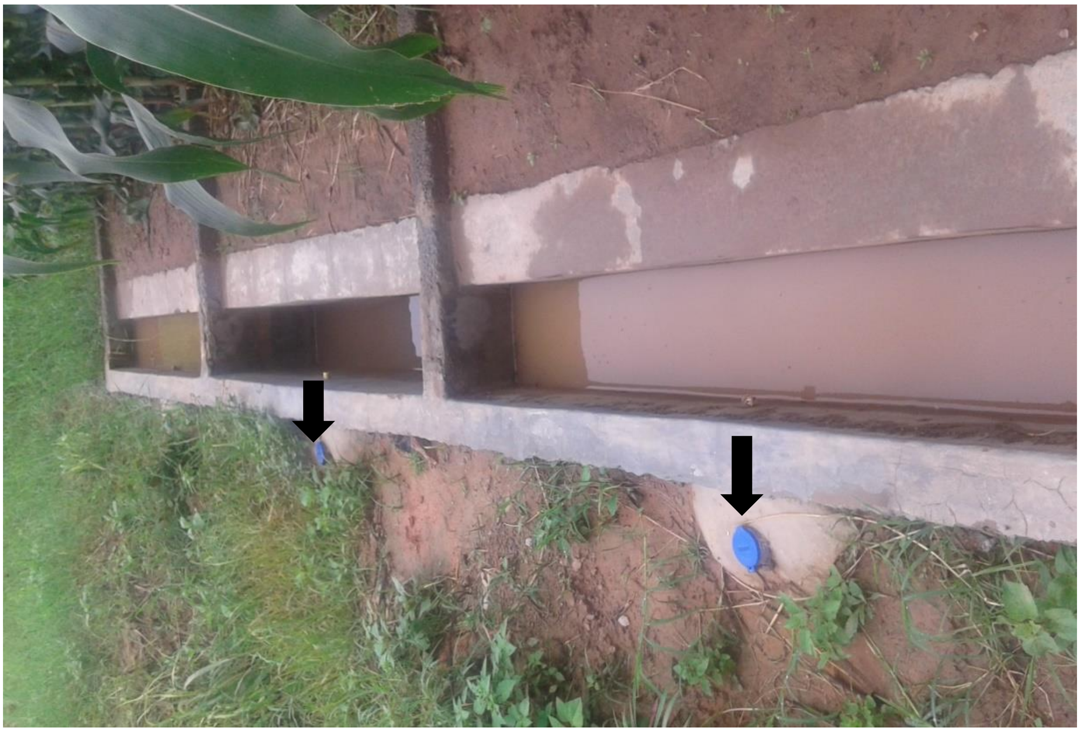

Figure 2: Drainage pits after a rainfall event

3.6.2 Measurement of soil moisture

PVC access tubes of diameter 0.063 m were vertically installed to a depth of 1.6 m for soil moisture monitoring using the Diviner 2000 probe (Sentek, 2009). Each plot had three access tubes installed in the lower, middle and upper slope positions of the plot (Figure 3). The access tubes were closed using a wooden stopper at the bottom to prevent water from entering from the bottom end. During installation, mud slurry was poured around the tube to get a perfect contact with the soil and avoid water pockets around the access tubes. The access tubes were covered on top with plastic caps to avoid rain-water collecting in the access tubes.

Figure 3: PVC access tubes installed in the plots

The Diviner 2000 probe used in the study is a portable soil moisture monitoring system. It comprises a data display unit and a portable probe (Figure 4). The portable probe measures soil moisture content at regular intervals of 10 cm down through the soil profile to the soil depth of 1.6 m. Data collected from a network of access tubes stored in the device was downloaded to a personal computer for analysis. The readings were recorded three days a week.

seedmech
BPA | Precision AG

Figure 4: Diviner 2000 moisture meter

3.6.3 Determination of Hydraulic conductivity

Undisturbed core ring samples were collected from the top 5cm soil surface for infiltration tests using the mini disk Infiltrometer as described by Zhang, (1997). The modified Horton equation was used to determine the hydraulic conductivity (Horton, 1933) by non-linear curve fitting techniques using R software (R Core Team, 2013).

3.6.4 Determination of Available water

Undistributed soil samples were collected from the top 5 cm of the soil surface using core rings (diameter=5 cm, height=5 cm) in replicates for soil moisture retention characterization. Pressure heads of -2.5 cm, -10 cm, -32 cm, -63 cm and -100 cm were measured on the sand bath apparatus (Di Bonito, 2005) The core samples were later cut into 2 cm slides and placed on initially saturated porous plates for moisture retention determination for using the pressure plate apparatus at -1019 cm and -7138 cm water suctions. The corresponding soil moisture contents and matric potentials from the Sand Bath and Pressure Plate apparatus were used to derive water retention curve parameters according to the van Genuchten equation (van Genuchten, 1980).

3.6.5 Estimation of Universal Soil Loss Equation parameters

Soil erodibility ***(K)*** was estimated using the formula published by Wischmeier and Smith (1978) given by;

$$K = 2.77 * 10^{-6} * M^{1.14} * (12 - OM) + 0.043(SC - 2) + 0.033(4 - PC)$$ **(Equation 2)**

$$M = (Si + S) * (100 - Cl)$$ **(Equation 3)**

where Cl = clay, *Si* = silt *(%), S* = sand (%), *O.M* = organic matter (%), SC = Structural class (-), *PC* = permeability class (-)

The structural class and permeability class used was according to Schwertmann et al (1987).

Rainfall erosivity ***(R)*** was calculated according to Wischmeier and Smith (1958) in which kinetic energy and maximum 30-minute intensity of a storm are determined. The kinetic energy of a storm was calculated using the formula;

$$E_{sj} = 210.3 + 89log_{10}I_j$$ **(Equation 4)**

where E_{sj} = the specific kinetic energy or the kinetic energy per unit of rainfall amount of pluviophase j (MJ/ha.mm), I_j = h_j/T_j = rainfall intensity of pluviophase j (mm/hr.), h_j = rainfall amount of pluviophase (mm), T_j = rain duration of pluviophase

The total kinetic energy of a storm was calculated using;

$$E = n\sum Epj$$ **(Equation**

5)

where, E = total kinetic energy (MJ/ha), Epj = kinetic energy of pluviophase of the storm (MJ/ha), n = number of pluviophase of the storm

The rainfall erosion index of a storm was obtained by;

$$EI = E * I_{30}$$ **(Equation 6)**

where EI = erosion index of the storm (MJ/ha/hr.), E = total kinetic energy of the storm (MJ/ha), I_{30} = maximum intensity during 30 minutes of the storm (mm/hr.)

To obtain ***R*,**

$$R = EI/100$$ **(Equation 7)**

where R = erosion index of the storm (MJ/ha.mm.hr.), EI = erosion index of a storm (MJ/ha/hr.)

The slope length factor ***L*** was estimated using an equation by Wischmeier and Smith (1958) given by;

$$L = (\frac{1}{22.13})^m$$ **(Equation 8)**

where L = slope length (m), 22.13m = length for standard plots for which L = 1, m = exponent of 0.3 since the slope was 3% or less

The slope steepness factor ***S*** was estimated using the equation by Wischmeier and Smith (1957) for natural runoff plots of slope 3-18% and was given by;

$$S = 0.00650s^2 + 0.045s + 0.050$$ **(Equation 9)**

where S = slope steepness factor, s = slope in %

The crop management factor **C** estimated according to literature from Nyakatawa et al. 2007; Shi et al. (2004).

The support practice factor ***P*** was equal to 1 since no support practices were employed.

3.7 Data analysis

The data collected were analyzed using R version 3.4.1 (R core team, 2013) at 95% confidence level to compute Analysis of Variance (ANOVA) of the effect of tillage practices on soil loss, runoff and maize growth.

CHAPTER FOUR:RESULTS AND DISCUSSION

4.1 Soil chemical and physical parameters of the study site

4.1.1 Chemical and physical properties of a composite soil sample

The results of the chemical and physical parameters of the study site are presented in Table 1. The texture was loamy sand with a high content of sand of 83.96%. The difference in the textural class contents between the measured and that in the representative soil profile is because of the influence of farming activities on the surface texture.

The pH is 5.33 which are moderately acid, and it is in the range of most mineral soils in humid regions and is optimal for maize production (FAO, 1984). Exchangeable Calcium (Ca), Magnesium (Mg) and potassium (K) were above the critical values as shown in Table 1. Therefore, deficiencies were not expected in this soil.

Table 1: Selected chemical and Physical characteristics of the soils

Parameter	Value	Critical value	Standard deviation
pH (0.01M $CaCl_2$)	5.33		0.37
N (mg/kg)	2.92	0.1	1.1
P (mg/kg)	43.15	10	27.44
K (cmol/kg)	1.74	0.1	0.24
Ca (cmol/kg)	14.24	0.1	4.48
Mg (cmol/kg)	4.01	0.1	0.62
Na (cmol/kg)	0.07	0.1	0.07
Org. C (%)	1.85	2	0.93
Bulk density (g/cm^3)	1.46		0.19
Sand (%)	83.96		
Silt (%)	14.47		
Clay (%)	1.57		
slope (%)	2.6		

The selected physical and chemical properties were done to establish baseline information on the soil fertility status of the study site.

4.1.2 Chemical Properties of the soil from a representative soil profile

According to the chemical properties, the organic matter is low and ranges from 1.6% to 0.12% in the subsoil (Table 2). The pH ($CaCl_2$) was between 5 and six which is similar to the pH obtained from the composite samples. The soil was classified as a mixed Isohyperthermic Typic Paleustalf according to USDA classification (USDA, 1999).

Table 2: Chemical properties from soil profile

Horizon	Depth (cm)	pH	OM (%)	N (%)	P (ppm)	K (-)	Ca (-)	Mg (-)	Na (-)
A	0-17	5.27	1.6	0.07	11.59	0.52	1.08	0.73	0.25
Bt	17-87	5.33	0.48	0.06	4.31	0.47	1.38	1.17	0.23
BCt	87-105	5.88	0.16	0.07	2.14	0.42	1.41	1.31	0.31
Btc	105-120+	5.92	0.12	0.07	1.86	0.4	1.4	1.21	0.26

OM = organic matter, pH in 0.1M $CaCl_2$, (-) = $cmolkg^{-1}$

4.1.3 Physical and hydraulic properties of the soil

The soil is deep, well drained and moderately weathered (Table 3 and Table 4). This can be seen from the depth, hydraulic conductivity and the parent material which is quartzite. There was more than 30 % clay and high bulk density of more than 1.5 g/cm^3. This may lead to compaction, clogging and poor workability. The hydraulic conductivity in Table 4 indicates that there is a high infiltration rate in the surface horizon and that it reduces as one goes deeper in the soil profile.

Table 3: Physical properties of the soil from a representative soil profile

Horizon	Depth cm	Bd g/cm3	TPV (%)	Texture Clay (%)	Silt (%)	Sand (%)	USDA (Textural class)
A	0-17	1.45	45.3	19.6	9.6	70.8	SL
Bt	17-87	1.58	40.4	33.6	5.6	60.8	SCL
BCt	87-105	1.6	39.6	31.6	3.6	64.8	SCL
Btc	105-120+	1.61	39.3	33.6	3.6	62.8	SCL

Bd= bulk density, TPV= total pore volume, SL= sandy loam, SCL= sandy clay loam

Table 4: Hydraulic properties of the soil for representative soil profile

Horizon		A	Bt	BCt	Btc
Depth	(cm)	0-17	17-87	87-105	105-120+
Θs	(cm3/cm3)	0.423	0.407	0.399	0.399
Θr	(cm3/cm3)	0.061	0.067	0.067	0.065
α	(1/cm)	0.04	0.025	0.029	0.026
N	(-)	1.329	1.219	1.229	1.215
Θfc	(%)	18.6	28.2	27.4	28.7
Θwp	(%)	13.8	21.7	20.6	21.7
Porosity	(%)	45.1	40.2	39.7	39.2
AWC	(mm/m)	14.6	81.8	15.8	13.7
Ks	(cm/day)	71.42	14.19	17.13	13.09

θfc=moisture content at field capacity, θwp=moisture content at wilting point, AWC=available water moisture content, Ks=saturated hydraulic conductivity

4.2 Rainfall patterns during the cropping season

The Long-term monthly rainfall and 2016/17 monthly rainfall for the study site is presented in table 5. The long-term annual rainfall varies from 753 to 969 mm with an average of 861mm with most of the rain received in December, January, and February. During the 2016/17 Season, the total annual rainfall received was 979 mm which was 13.7% more than what is expected for this site despite the delayed onset of the rainy season. The onset of the rain during the 2016/2017 season was one month later than the normal rainfall onset expected by mid-November. The months of January (+24.8%), February (+31.3%), and April (+20.6%) received rainfall amounts above-normal during the season. Noticeable deviations from the normal in monthly rainfall occurred in October (-16.2%) and March (-13.4%), however, the total rainfall received during the season was above expected normal rainfall. Comparison of rainfall received with the normal help understand the variability observed in soil erosion and maize yield and it also forms baseline information for similar research in the future.

Table 5: Comparisons of monthly rainfall received in the 2016/2017 season

Month	Monthly Rainfall (2016/17) (mm)	Monthly Normal Average Rainfall (mm)	Minimum Normal Rainfall (mm)	Maximum Normal Rainfall (mm)	Deviation from Normal (%)
Jun	0	0	0	0.1	0
Jul	0	0	0	0	0
Aug	0	0	0	0.4	0
Sept	0	2	1.6	2.4	-100
Oct	13.4	16	11.1	20.9	-16.2
Nov	102.2	86	61.2	110.8	18.8
Dec	213.4	219	200	238	-2.6
Jan	280.8	225	209.6	240.4	24.8
Feb	236.4	180	163.7	196.3	31.3
Mar	84	97	82.9	111.1	-13.4
Apr	38.6	32	20.9	43.1	20.6
May	10.2	4	2.1	5.9	155
	979	861	753	969.4	-13.7

The rainfall erosivity values (R) at 15 and 30 minutes maximum rainfall intensity (I_{15} and I_{30}) are presented in Table 6. I_{15} is the maximum15 minute's rainfall intensity of a storm and I_{30} is the maximum 30 minutes rainfall intensity of a storm. Each rainstorm is divided into successive increments of uniform rainfall intensities called pluviophases. The I_{15} and I_{30} are based on the steepness of the pluviophases.

Table 6: Rainfall erosivity at I_{15} and I_{30} rainfall intensities

	I_{15}			I_{30}		
Month	Mean (MJ mm/ha hr.)	Min (MJ mm/ha hr.)	Max (MJ mm/ha hr.)	Mean (MJ mm/ha hr.)	Min (MJ mm/ha hr.)	Max (MJ mm/ha hr.)
Oct	5.62	0.25	203.18	15.45	0.81	11.63
Nov	71.97	0.32	3388.43	75.22	0.35	441.67
Dec	1423.39	0.64	9941.36	101.13	0.81	869.28
Jan	1016.43	0.64	12039.20	105.27	0.69	925.41
Feb	1378.17	0.32	12785.00	98.69	0.35	641.21
Mar	381.41	0.32	3017.31	39.59	0.35	196.45
Apr	279.86	0.32	1059.86	42.51	0.35	166.69
May	327.45	72.47	582.43	23.45	10.69	36.21

4.3 Soil loss

4.3.1 Effects of cultural practices on predicted soil loss

The results from the predicted soil loss values based on the USLE are presented in Table 7

.

Table 7: Predicted K, C and A values of the USLE

	K (MJ.mm/ha.yr.)	C (-)	A (ton/ha/yr.)
Mulching	0.838	0.05	2.790[a]
Intercropping	0.824	0.38	20.847[b]
Conventional	0.965	0.62	39.820[c]
Mean	0.876	0.35	21.15

The highest annual soil loss predicted under the conventional practice (no surface cover by any material; maize planted alone) was 63% of the total annual soil loss. This indicated that soil erosion reduced by 29% and 58% under intercrop and mulch tillage respectively as compared to conventional practice. The cultural practices altered the soil erodibility (K) and crop management (C) components of the USLE, and the annual soil loss was significantly reduced in mulching and intercropping practices as compared to the conventional practices.

4.3.2 Effects of cultural practices on measured soil loss

Results of the effect of practices on soil loss are presented in (Figure 5). The amount of soil loss for rainfall events varied from 0.0006 to 0.139 ton/ha with an average value of 0.026 ton/ha. There were no significant differences in the soil loss during the growing season associated with erosive rainfall events. The highest annual soil loss occurred under conventional practice, followed by intercropping practice and the lowest was recorded in the mulching practice. The findings of Barton et al. (2004) showed that Mulching was very effective in decreasing runoff and erosion rates. Conventional practice recorded the highest total soil loss of 1.63 ton/ha amounting to 39 % of the total soil lost throughout the season.

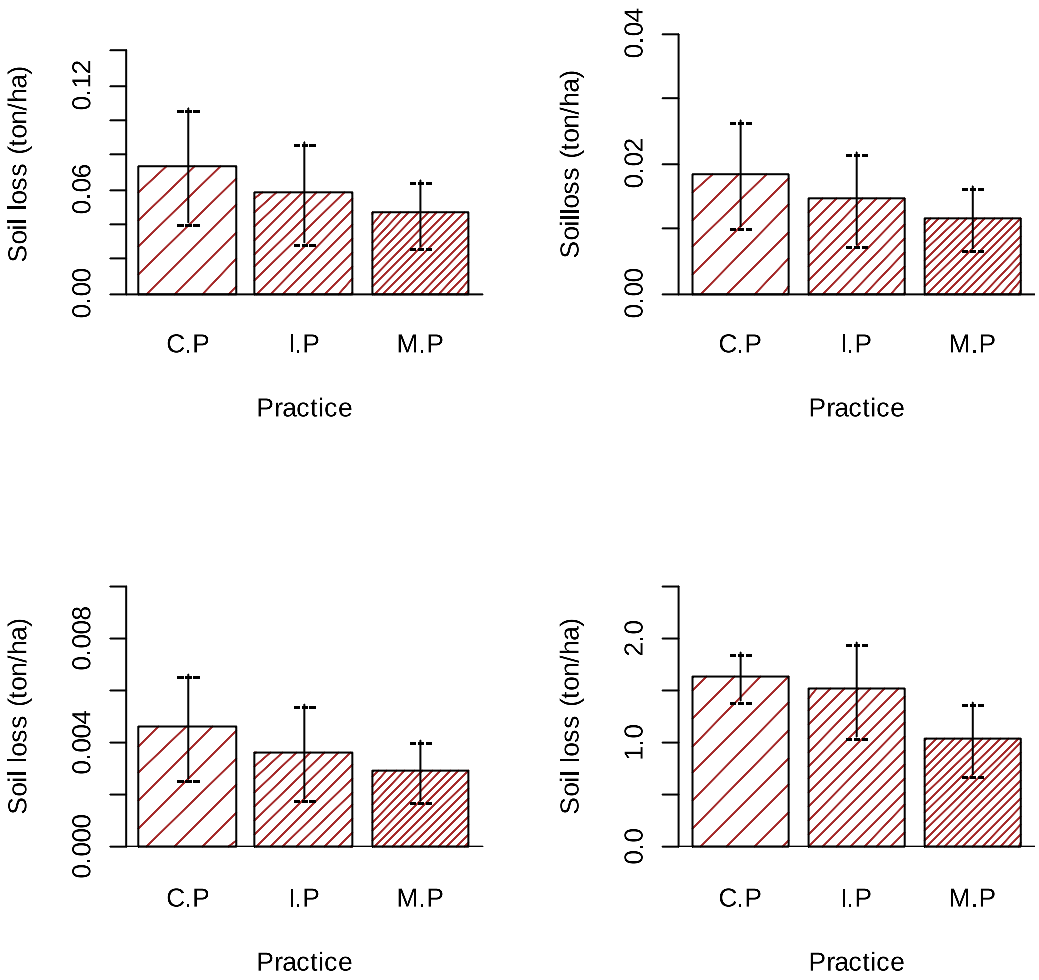

Figure 5: Soil loss in mulching, conventional and intercropping practices

The lowest observed soil loss was under mulch at 1.05 ton/ha, which was 25 % of the total soil loss. The differences between mulch and conventional practice practices were statistically significant ($p<0.05$).

4.3.3 Effect of cultural practices on the runoff

Results of runoff are presented in Figure 6. The amount of runoff from rainfall events varied from 0.59 to 6.15 mm with an average of 2.48 mm. The highest runoff in January was observed in conventional tillage at 5.05 mm and the lowest in mulch at 2.14 mm. It was observed that there was a statistical difference ($p<0.05$) between mulch and the other two treatments. This was similar to the event in February with the highest runoff recorded in conventional tillage at 0.95 mm and lowest in mulch at 0.66 mm. The other rainfall event in December indicated the highest runoff in mulch at 2.89 mm and the lowest in intercrop at

2.50 mm. The highest total runoff for the 2016/2017 season was observed under conventional tillage at 46.58 mm which was 36 % of the total runoff observed in the season. The lowest was under mulch tillage at 38.57 mm, and this is 29 % of the total runoff observed. However, there were no statistical differences (p>0.05) observed among the treatments. The non-significance of results obtained might have been due to high organic matter content and less surface compaction. This is because the experimental site had been fallow for over five years and this led to the accumulation of organic matter and improved soil structure due to no compaction.

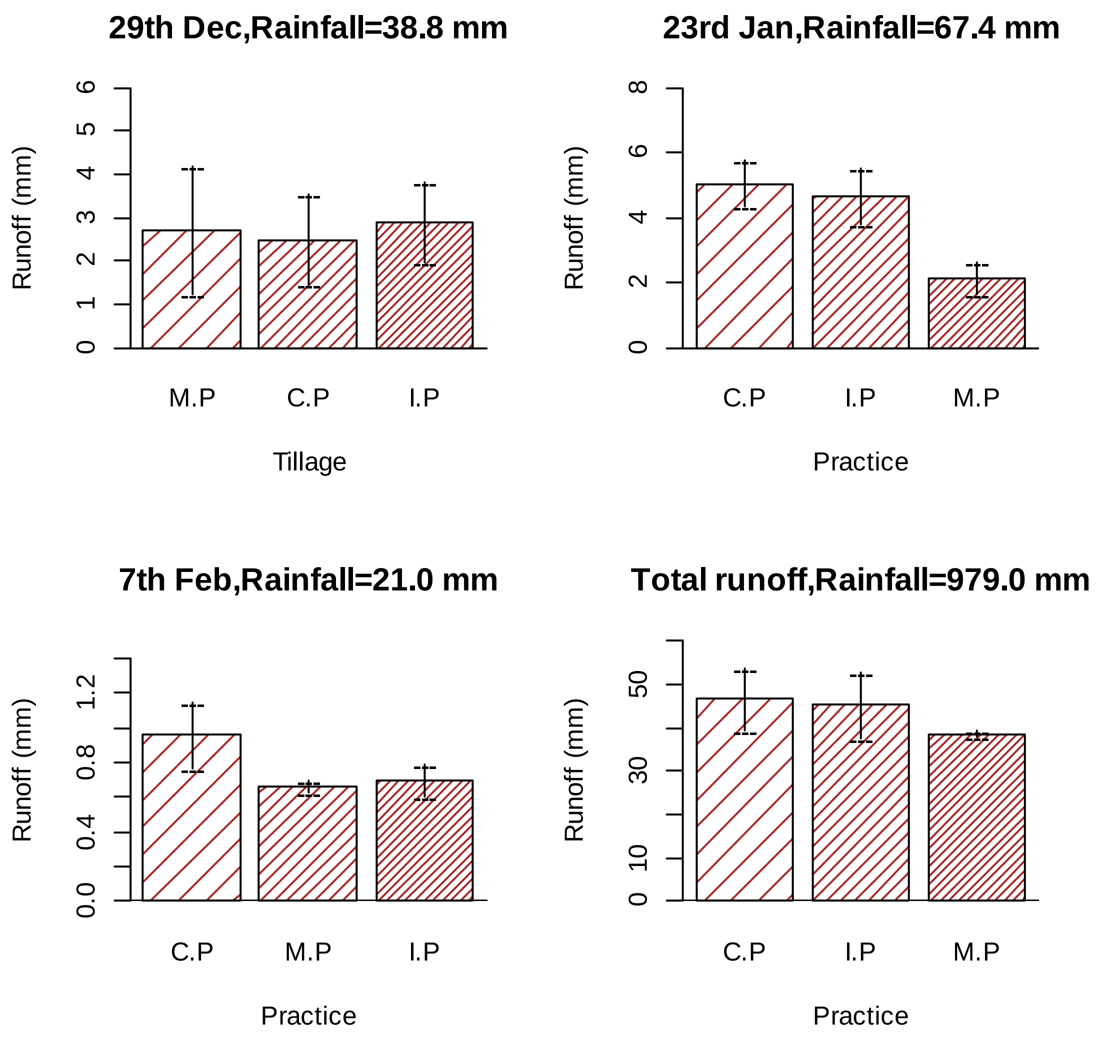

Figure 6: Runoff from mulching, intercropping and conventional practices

4.5 Evolution of root zone soil moisture storage

4.5.1 Total soil moisture storage

The results on soil moisture storage in the root zone under mulching practice are presented in Figure 7. The average total moisture storage was in the range of 250 mm and 400 mm with an average of 335.7 mm. Average total moisture was near field capacity during the early part of the season and declined as the season progressed, to between field capacity and wilting point. This was strongly influenced by the rainfall events during the early part of the study; as the rainfall reduced, the soil moisture storage declined below the field capacity level.

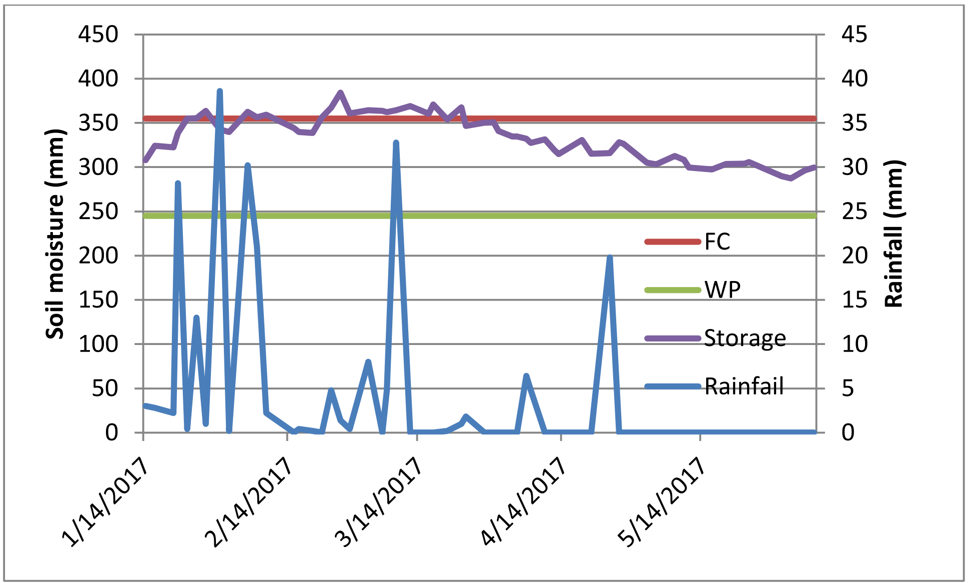

Figure 7: Evolution of water storage under mulching practice

Moisture storage in the conventional practice (Figure 7) had values ranging from 268 mm to 372 mm, and the average was 333 mm. The values were slightly higher in intercropping practice (Figure 9) which had a range of 264 mm to 417 mm with an average of 351 mm. There was less water stored in the soil profile for conventional practice than in mulching and intercropping practices at the end of the rainy season. This implies that there was no moisture stress to the crop throughout the growth period. However, towards the end of the rainy season, the total moisture storage in conventional and intercropping practices was much less than in the mulching treatment soil practice. This means that there was more recharge to the underground water. In this era of climate change, practices that are more resilient to fluctuations in the rainfall patterns are needed to mitigate yield losses associated with droughts and floods.

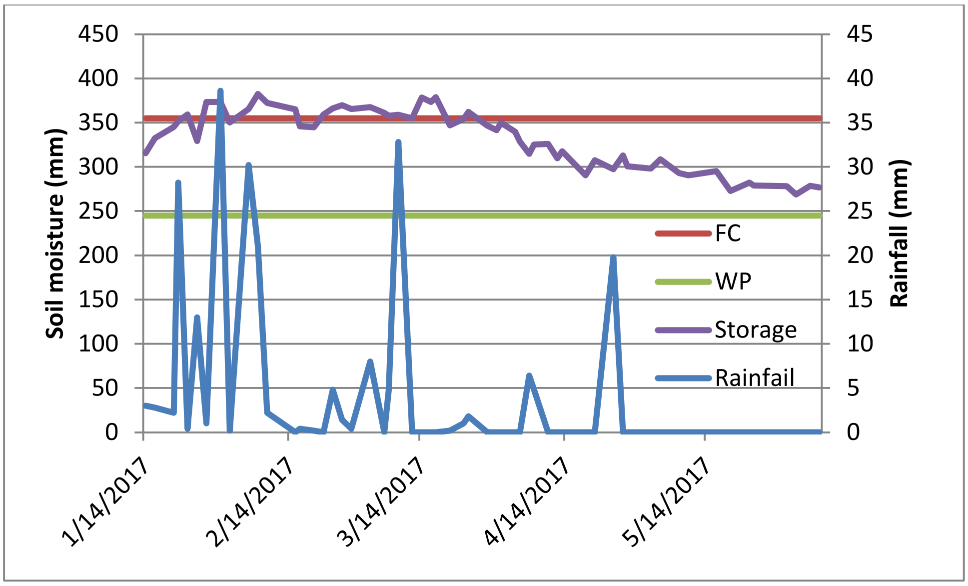

Figure 8: Evolution of water storage under conventional practice

There was more retention of moisture in intercropping practice than in the other two practices. This was because of the vast root system created by the maize-cowpea intercrop. There was increased soil porosity which led to increased soil water infiltration. According to Ahadiyat and Rana (2008), intercropping enhanced soil capacity to store and mobilise water and nutrients in deep soil profiles.

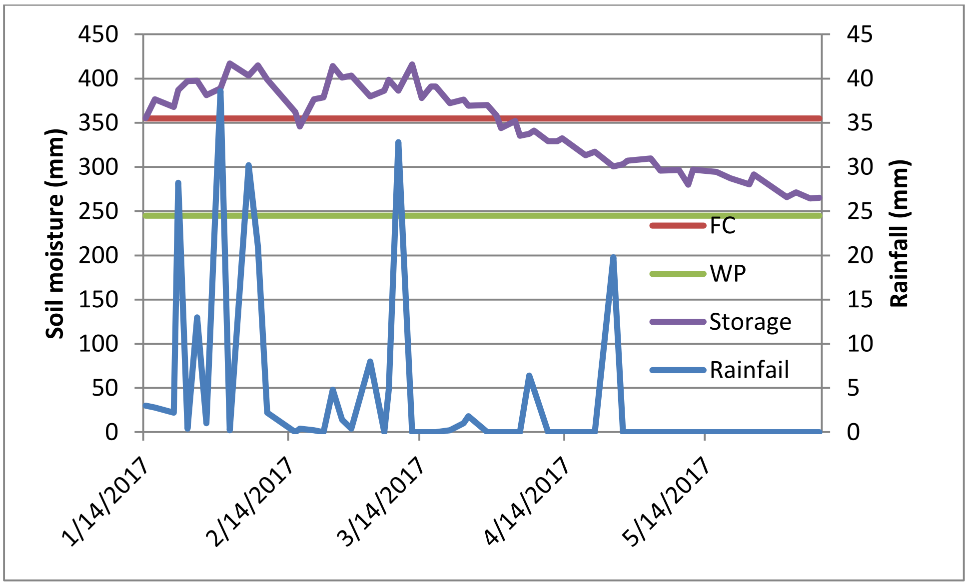

Figure 9: Evolution of water storage under intercropping practice

4.5.2 Effects of practices on seasonal soil moisture regime

The results for effects of practices on seasonal soil moisture of the root zone are presented in Figure 10. The range was from 27% to 30% with an average of 28%. However, the difference was not significant (p>0.05) in all the three practices. The mulching practice had more soil moisture as compared to the other two practices because of reduced evaporation and increased infiltration of rainwater during the growing season (Yang et al., 2003).

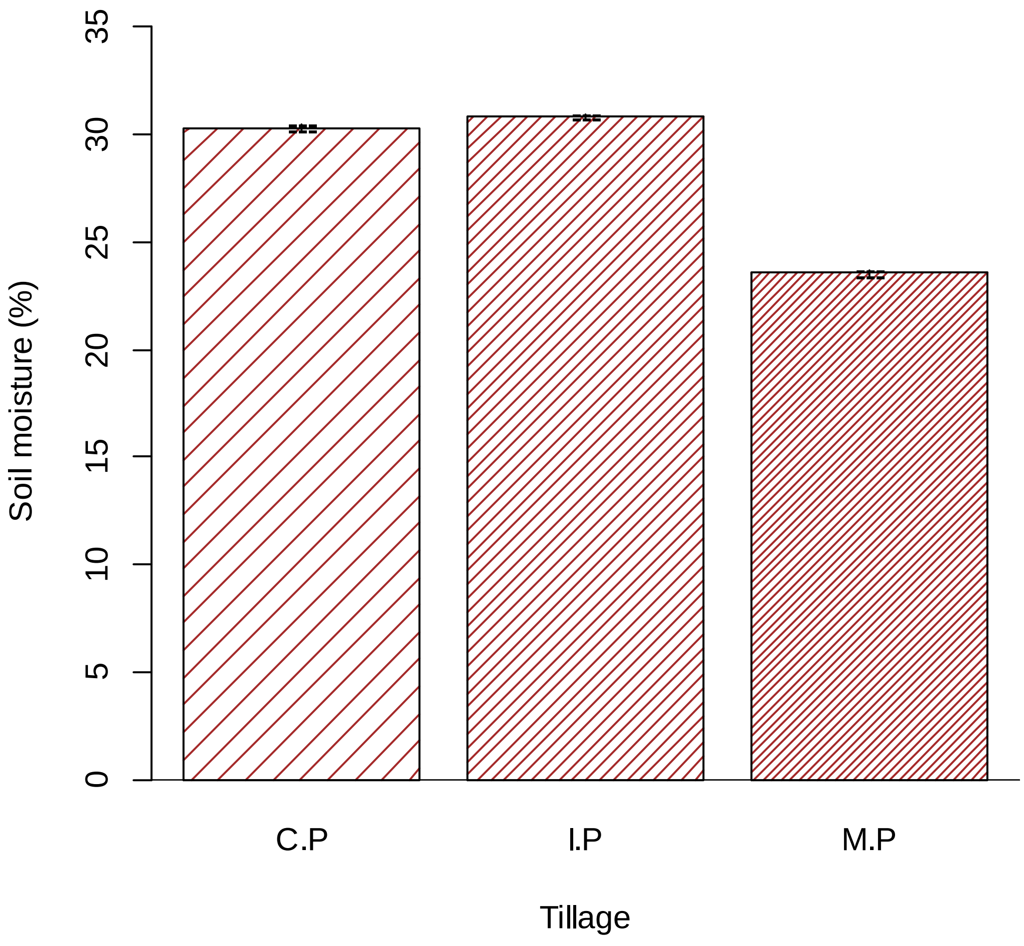

Figure 10: Effect of tillage practices on soil moisture

4.6 Effects on maize

4.6.1 Effects of practice on maize biomass yield

The results of maize aboveground biomass yield are presented in Figure 11. The highest biomass was 28.2 ton/ha which was observed under intercropping practice and it was 35 % of the total biomass obtained. The lowest biomass was recorded in mulching practice at 24.3 ton/ha which was 30 % of the total biomass. The results were not statistically different. The discrepancy in biomass yield might have been due to pest attack by fall army worms (*Spodoptera Frugiperda*). With respect to position on the slope, the highest biomass was 28.3ton/ha in the lower position of the slope, and 25.5ton/ha was the lowest, and it was recorded from the middle position of the slope. There was no significant difference ($p>0.05$) in the biomass yield in regard to treatment and position on the slope. The highest value recorded in the maize- cowpea intercrop could have been due to the complementarity in nutrient and water use that was observed in the Maize-cowpea intercrops as also recorded by Francis, 1986 and Patil et al., 2015. Highest biomass was recorded on the lower slope which can be attributed to the accumulation of organic sediments at lower slopes, leading to better infiltration and more residual nutrients. However, the position on the slope did not significantly affect maize biomass yield.

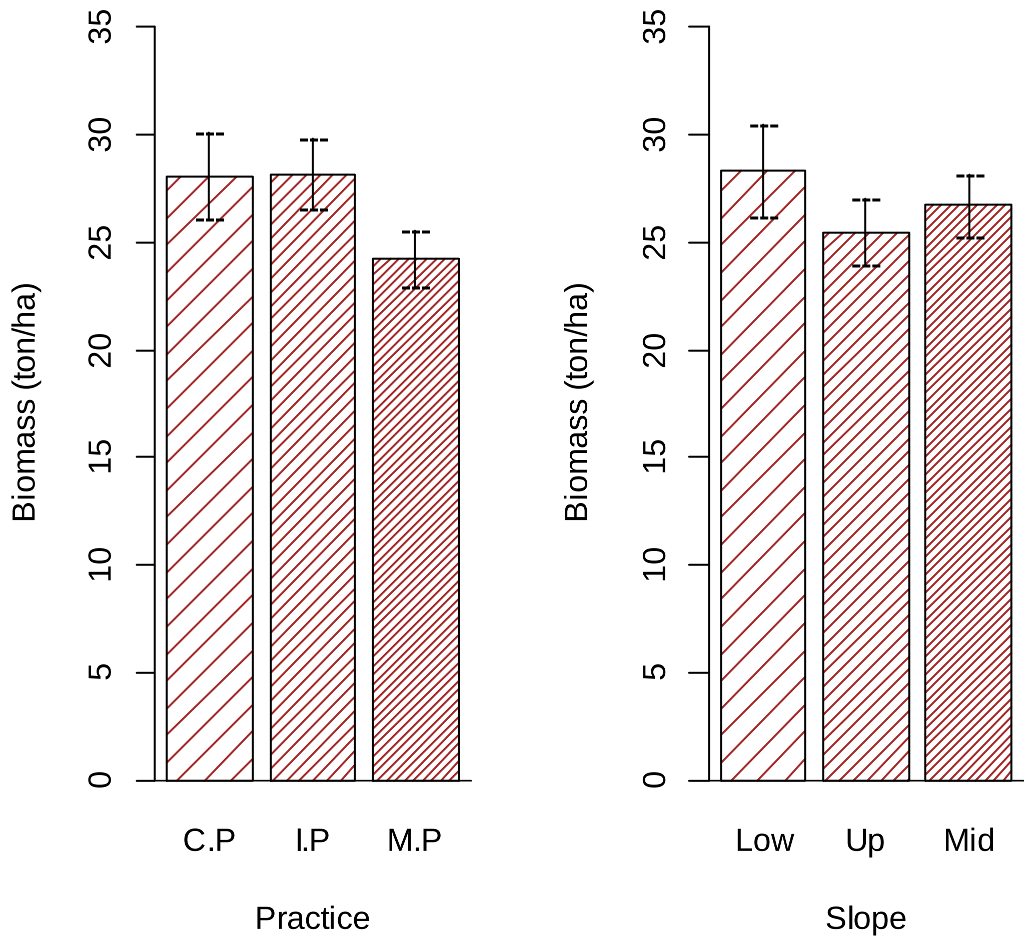

Figure 11: Biomass yield from tillage practices and position on a slope

4.6.2 Effect of practices on stover yield

The results of the effect of cultural practices on stover yield are presented in Figure 12. Intercrop practice had the highest stover of 19.6 ton/ha, and this was 36 % of the total stover obtained, and the lowest was 14.9 ton/ha under mulch tillage which was 27 % of the total stover obtained. This means that the left over stalks, leaves, husks, and cobs from the maize were not significantly affected by the cultural practices. With respect to slope, the lower position had the highest stover of 18.7 ton/ha while the middle position had the lowest with 16.8 ton/ha. There was no significant difference ($p>0.05$) in the stover yield with respect to slope position.

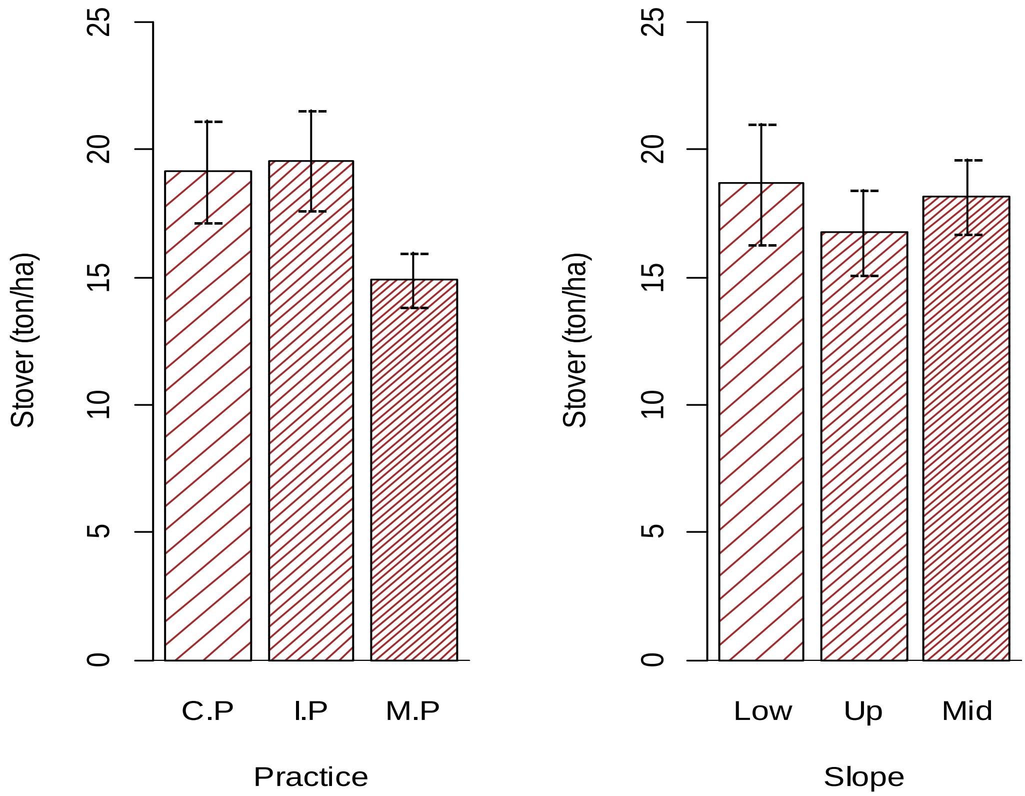

Figure 12: The effect of tillage practices and slope on stover yield

4.6.3 Effect of practices on maize grain yield

The results on the effect of of practices on grain yield are presented in Figure 13. The highest recorded grain yield was 9.4 ton/ha under the mulching practice, and this was 34 % of the total grain yield obtained. The lowest was recorded in intercropping practice which was 8.6 ton/ha, and this was 31 % of the total grain yield obtained. There were no significant differences in the grain yield obtained as a result of treatment and position on the slope ($p>0.05$). This is similar to the findings of Barton et al., (2004), where mulch with polyethylene and straw recorded higher maize yield than under conventional and no-till tillage practices.

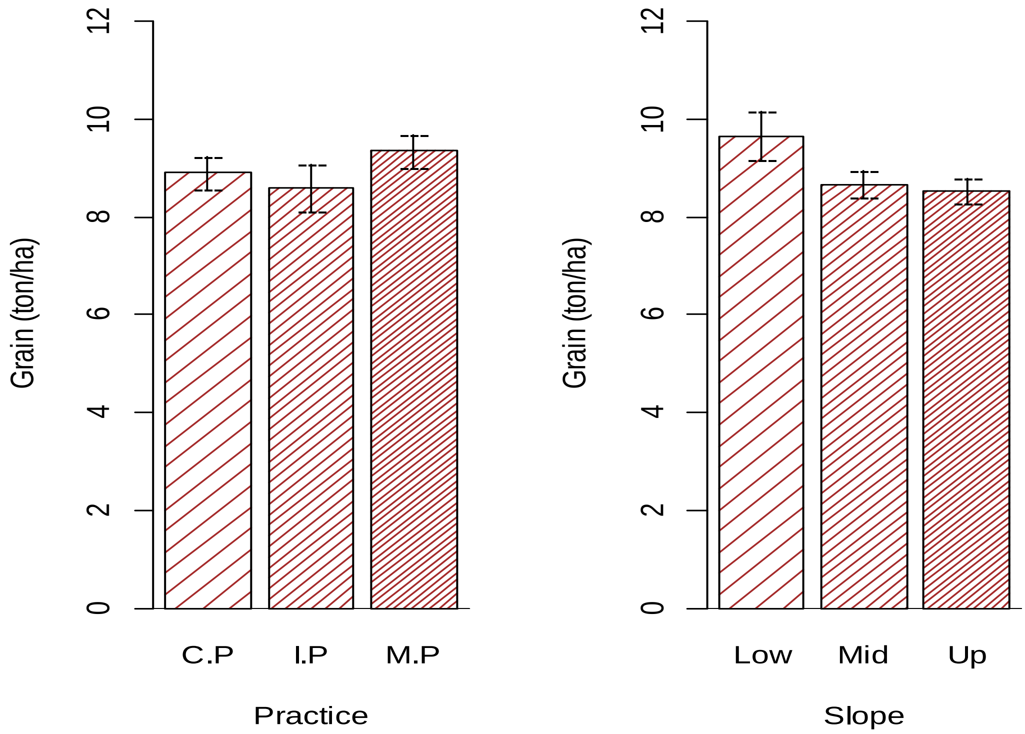

Figure 13: The effect of tillage practices and slope on grain yield

4.6.4 Effects of practices on Harvest index

The results for the effects of practices on harvest index are presented in Figure 14. The highest value of Harvest Index (HI) obtained was 39 % which was under the mulch tillage, and the lowest was 32 % under intercrop. Even with the non-significance of the differences obtained, more of the maize biomass obtained from the mulching practice were converted to grain yield as compared to that obtained from the intercropping and conventional practices. With respect to slope, the lower position had the highest value of 36%, and upper position had the lowest value of 33%.

The highest Harvest index (H.I) was obtained under mulching practice, and there were no statistical differences observed ($p>0.05$) in harvest index in relation to slope among the treatments. Since H.I describes the plant capacity to allocate biomass into reproductive parts of the plant (Shafi et al. 2012), the results indicate that more biomass was converted into grain under the mulch tillage as compared to the other tillage practices.

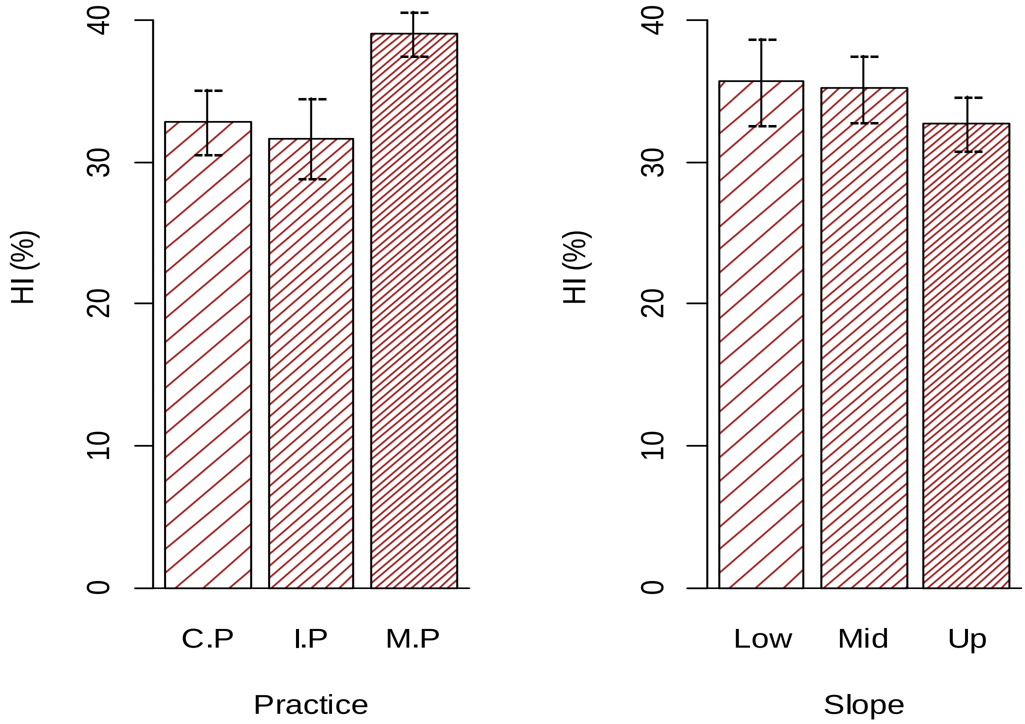

Figure 14: The effect of tillage practices and slope on the harvest index

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

The study was conducted to evaluate the effect of dry wheat straw mulch and maize-cowpea intercrop practices on soil erosion and maize yield. Based on the results obtained in this study, soil loss was significantly reduced by dry wheat straw mulching. There was a lower runoff in mulch and intercrop practice than the conventional practice.

Based on the results of maize growth as assessed by the biomass, stover, grain and harvest index, there was no significant difference in the maize yield obtained. However, yield was higher in mulch and intercrop practices than in the conventional practice.

Dry wheat straw mulch and Maize-cowpea intercrop did not significantly increase the soil moisture in the profile. On the other hand, annual soil loss calculated from the USLE was significantly lower in mulch and intercrop practices than in the conventional practice.

The results imply that mulching practice is effective at reducing soil loss on slope land since there was a reduction of about 55% in soil lost as compared to the conventional practice.

Based on the study, the use of mulching and intercropping practices on a slope of 3% or lower to reduce soil loss is recommended. It is also recommended that for future research in the same area of study should include other practices like no-till, to make comparisons with the mulching practice.

REFERENCES

Almas, M. and Jamal, T. (1999). Nutrients loss through sediment and runoff under the upland banana-pineapple intercropping system. Pakistan J. Soil Sci. 16: 11-16.

Araya A., Keesstra S.D. and Stroosnijder L. (2010) Simulating yield response to water of Teff (Eragrostis tef) with FAO's AquaCrop model. Field Crop Res 116(1–2):196–204.

Aregheore E.M. (2009). Country Pasture /Forage Resource Profiles of Zambia, Food and Agriculture Organisation, Rome, Italy.

Barton A.P., Fullen M.A., Mitchel D.J., Hocking T.J., Lignang L., Zhi W.B., Zheng Y. and Zheng Y.X. (2004). Effects of soil conservation measures on erosion rates and crop productivity on subtropical Ultisols in Yunnan Province in China, Agriculture, Ecosystems and Environment 104 (2004) 343-357.

Blake G.H. and Hartge K.H. (1986). Methods of soil analysis: Bulk density, Am. Soc. Agron. 2nd ed. Agron. No. 9 (Part I): 363–375. ASA WI USA.

Bouyoucos G.J. (1962). Hydrometer method improved for making particle size analysis of soils, Agron. J. 54:464-465.

Brady N.C. and Weil R.R. (2002). The Nature and Properties of Soils, 13th ed. Upper Saddle River, NJ: Prentice-Hall.

Bremner J.M. and Mulvaney C.S. (1982). Methods of soil analysis, part 2 chemical, and microbiological properties, Agri. Sci. 595-624.

Carvalho R. (2007). Water erosion in Red Latosol under different coffee management systems in southern Minas Gerais, Science, and Agrotechnology, 31 (6): 1679-1687.

Chaudhry M. A. and Shafiq M. (1986). Effects of crop management on the soil and water conservation. J.Agric. Res. 24:17-25.

Chiroma A. M., Folorunso O. A. and Alhassan A. B. (2006). Effect of land configuration moreover, wood shavings mulch on properties of a sandy loam soil in North- east Nigeria: changes in chemical properties, Tropicultura 24.3, 129-134.

Corsi T., Friedrich A., Kassam M., Pisante J.C. and Moraes D. (2012). Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: A literature review in integrated crop management (101pp) Vol. 16, AGP/FAO, Rome.

Dale R. M., Corners H. and Snapp S. (2003). Cover crop choices for Michigan, Extension bulletin E 2884, USDA.

Debarba, L. and Amado, T.J.C. 1997. Development of maize production systems in Southern Brazil with sustainability characteristics. Brazilian Journal of Soil Science, 21:473-480.

Dias A.C. (2013). Covering plants in the control of water erosion in the South of Minas Gerais. Science and Agro technology, 37 (5): 410-418.

Di Bonito. M. (2005). Trace elements in the soil pore water. A comparison of sampling methods. PhD thesis, University of Nottingham, 299p .

Diviner 2000 User Guide Version 1.5 (2009). Sentek Pty Limited, Stepney, South Australia.

Du Plessis J. (2003). Maize Production, Directorate Agricultural Information Services, Department of Agriculture, Pretoria, South Africa.

Eswaran H., Lal R. and Reich P.F. (2001). Land Degradation: An Overview. Available online by the United State Department of Agriculture (USDA).

FAO: 1998 Food balance sheet, http//armanncorn: 98ivsub@faostat.fao.org/lim.

Flanagan D. (2002). Erosion encyclopedia of soil science. Marcel Dekker, New York: 395–398.

Francis C. A. (1986). Multiple cropping systems, Macmillan, New York press.

Freitas D., Silva A. and Castro N. (2012). Modelling of soil protection by cover crops of southern Minas Gerais, Agro magazine@nvironment online 6(2): 177-123.

Frye W.W., Ebelhar S.A., Murdock L.W. and Blevins R.L. (1982). Soil erosion effects on properties and productivity of two Kentucky soils, Soil Sci. Soc. Am. J. 46, 1051–1055.

Gilles L. (2009). Water, soil, organic matter and nutrient losses due to water erosion in the maize crop implanted in the native field area, influenced by soil preparation methods and fertilization types. Soil Science Journal, 33 (5): 1427-1440.

Gril J. J., Canler J.P. and Carsoulle J. (1989). Benefit of permanent grass and mulching for limiting runoff and erosion in vineyards: Experimentations using rainfall-simulations in the Beaujolais, Soil technology series.

Horton R.E. (1933). The Role of Infiltration in the Hydrologic Cycle, Transactions of the American Geophysical Union, 14, 446-460.

Hulugalle N.R., Lal R. and Opara-Nadi O.A. (1985). Effect of tillage system and mulch on soil properties and growth of yam (Dioscorea rotundata) and cocoyam (Xanthosoma sagittifolium) on an Ultisol. Journal of Root and Tuber Crops 1-2:9-22.

Hulugalle N.R., Lal R. and Opara-Nadi O.A. (1987). Management of plant residue for cassava (Manihot esculenta) production on an acid Ultisol in southwestern Nigeria. Journal of Field Crops Research 16:1-18.

Ji S. and Unger P.W. (2001) Soil Water Accumulation under Different Precipitation, Potential Evaporation, and Straw Mulch Conditions, Soil Science Society of America Journal, 65, 442-448.

Junge B., Abaidoo. R., Chikoye D and Stahr K. (2008). Soil conservation in Nigeria: past and present on- station and on-farm initiatives, Soil, and Water Conservation Society, Ankeny, Iowa.

Kariaga B.M. (2004). Intercropping Maize with Cowpea and Beans for soil and water management in Western Kenya, 13th International Soil Conservation Organisation Conference, Brisbane.

Kenneth E., Spaeth J.R., Frederick B., Pierson J.R., Mark A., Weltz A. and Wilbert H. (2003). Evaluation of USLE and RUSLE estimated soil loss on rangeland, Journal of range management.

Lal R. (1990). Soil erosion in the tropics: Principles and management. New York: McGraw-Hill.

Lal R., Kimble J. M., Follett R. F. and Cole C. V. (1999). The potential of U.S. cropland to sequester carbon and mitigate the greenhouse effect. Lewis Publishers Boca Raton, Florida.

Laflen J. M., Foster G. R. and Onstadt C. A. (1985). Simulation of individual-storm: soil loss for modelling impact of erosion on crop productivity. Soil Erosion and Conservation. Soil Cons, Ankeny, Iowa.

Lim H. C. and Jackson M. L. (1982). Dissolution for total elemental analysis, Soil science society, Am. Monograph No. 9, Madison, USA.

Lozano S. and Garcia D. (2011). Effects of oil mill waste on surface soil properties, runoff and soil losses in traditional olive groves in southern Spain, Catena 85 (3), 187-193.

Lui B., Lui S. and Zhang S. (2001). Soil loss prediction model, China Science, and Technology Press, Beijing, China.

Maurya P. R. and Lal R. (1981). Effects of different mulch materials on soil properties and the root growth and yield of maize and cowpea, Field Crops Research 4, 33-45.

Mclean E.O. (1982). Soil pH and lime requirement: Methods of Soil Analysis, American Society of Agronomy, Soil Science Society of America, Madison, 199-224.

Millward A. and Mersey J.E. (1999). Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed, Catena. 38:109–129.

Nearing, M.A., Govers, G., and Norton, L.D. (1999). Variability in soil erosion data from replicated plots. Soil Sci. Soc. Am. J. 63:1829-1835.

Nyakatawa E.Z, Reddy K.C.and Lemunyon J.L, (2001). Predicting soil erosion in conservation tillage cotton production systems using the revised universal soil loss equation (RUSLE) Soil Tillage Res., 57 (4), pp. 213-224.

Ogban P. I. and Ekerette I. (2001). Managing the Coastal Plain Soils for Erosion Control and Crop Production in South-eastern Nigeria, J. Sustainable Trop. Agric Res. 2:131 – 138.

Olsen S. R and Sommers L. E. (1982). Methods of Soil Analysis: Phosphorus, agronomy No. 9, American Society of Agronomy, Madison, USA.

Patil S. B., Balakrishnna B. C., and Chitgnapekar B.B. (2015). Modern tillage and integrated nutrient management practice for improving soil fertility and productivity of groundnut under rainfed farming system, Int. Let. Sci. 2:1-42.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

Rauschkolb R.S. (1977). Land degradation, Soils Bull. 13, FAO, Rome.

Relf D. (2015). Reducing erosion and runoff, Virginia Cooperative Extension, Virginia State University.

Rossetti, K.V. (2012). Soil physical attributes in different conditions of plant cover in no-tillage area. Brazilian Journal of Agricultural Sciences, 7: 427-433.

Scot T.W., Pleasant J., Burt R.F. and Otis D.J. (1987). Contributions of groundcover, dry matter, and nitrogen from intercrops and cover crops in a polyculture system. Agron. J. 79;792- 798.

Sentek Pty Ltd, 2009. Diviner 2000 User Guide Version 1.5.

Shafi M., Bakht J., Ali S., Khan H., Khan M.A. and Sharif M. (2012). Effect of planting density on phenology, growth, and yield of maize (Zea mays L.). Pak. J. Bot., 44(2):691-696.

Sharma N.K. and Singh R.J, (2013). Agronomic practices for erosion control, central soil and water conservation research and training institute, Dehradun, India.

Singh M. and Khera K. (2009). Physical indicators of soil quality in relation to soil erodibility under different land uses, Arid. Land. Res. Manage., 23(2): 152-167.

Soil Taxonomy, (1999). United States Department of Agriculture (USDA) Natural Resources Conservation Service, Agricultural handbook no. 436.

Thomas G. W. (1982). Methods of soil analysis: Exchangeable cations, American Society of Agronomy, Madison, USA.

Tian G., Kang B.T. and Brussard L. (1993). Mulching effect of plant residues with chemically contrasting compositions on maize growth and nutrient accumulation, Plant and Soil 153, 179-187.

Ugarte C.M., Zaborski E.R., and Wander M.M. (2012). Nematode indicators as integrative measures of soil condition in organic cropping systems, Soil Biology and Biochemistry 64:103-113.

Unger P.W., (2001). Tillage Systems for soil and water Conservation, FAO Soil

Bulletin 54.

Vandermeer J. (1992). The ecology of intercropping, New York, Cambridge University Press.

Wischmeier W.H and Smith D.D. (1987). Predicting rainfall erosion losses: A guide to conservation planning, Agric. Handbook 5537, Washington D.C., USDA.

Wischmeier W.H. and Smith D.D. (1958). Rainfall energy and its relationship to soil loss, Transactions American Geophysical Union, 39, 458-462, 474.

Wischmeier W.H. (1973). Conservation tillage to control water erosion, Soil Conservation Society, Ankeny, Iowa.

Yang Y.J., Dungan R.S., Ibekwe A.M., Valenzuela-Solano C., Crohn D.M. and Crowley E.D. (2003). Effect of organic mulches on soil bacterial communities one year after application, Biology, and Fertility of Soils, Vol. 38, No. 5, pp. 273–281.

Zhang R. (1997). Determination of soil sorptivity and hydraulic conductivity from the disk Infiltrometer, Soil Sci. Soc. Am.

Zhao N., Fuliang Y., Chuanzhe L., Hao W., Jia L. and Wenbin M. (2014). Investigation of Rainfall-Runoff Processes and Soil Moisture Dynamics in Grassland Plots under Simulated Rainfall Conditions, www.mdpi.com/Journal/Water, ISSN 2073-4441.

APPENDICES

Appendix 1: Analysis of Variance for runoff event in December

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Type of practice	2	0.228	0.114	0.193	0.83
Replication	1	22.118	22.118	37.414	0.00169
Residual	5	2.956	0.591		
Total	8	25.302			

Appendix 2: Analysis of variance for runoff event in January

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	15.078	7.539	4.278	0.0826
Replication	1	0.058	0.058	0.033	0.8632
Residual	5	8.812	1.762		
Total	8	23.948			

Appendix 3: Analysis of variance for runoff event in February

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	109.6	54.8	0.845	0.483
Replication	1	357.3	357.3	5.509	0.0658
Residual	5	324.3	64.9		
Total	8	791.2			

Appendix 4: Analysis of variance for soil loss event in December

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	0.001126	0.000563	0.675	0.5501
Replication	1	0.009283	0.009283	11.129	0.0206
Residual	5	0.004171	0.000834		
Total	8	0.01458			

Appendix 5: Analysis of variance for soil loss event in January

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	0.0000704	0.0000352	0.675	0.5501
Replication	1	0.000802	0.0005802	11.119	0.0207
Residual	5	0.0002609	0.0000522		
Total	8	0.0011333			

Appendix 6: Analysis of variance for soil loss in February

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	0.00000043	0.000000218	0.659	0.557
Replication	1	0.0000036	0.00000365	11.027	0.021
Residual	5	0.00000165	0.000000331		
Total	8	0.00000568			

Appendix 7: Analysis of variance for total Soil loss for the crop season

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	0.5769	0.2885	5.58	0.05325
Replication	1	2.0053	2.0053	38.79	0.00156
Residual	5	0.2585	0.6517		
Total	8	2.8407			

Appendix 8: Analysis of variance for maize biomass

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	88.6	44.3	1.935	0.1672
Replication	1	75.9	75.91	3.315	0.0817
Residual	23	526.6	22.9		
Total	26	691.1			

Appendix 9: Analysis of variance for maize Stover

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Type of practice	2	119.2	59.59	2.595	0.0964
Replication	1	117.1	117.09	5.098	0.0337
Residual	23	528.2	22.97		
Total	26	764.5			

Appendix 10: Analysis of variance for maize grain

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Type of practice	2	2.614	1.307	1.096	0.351
Replication	1	4.443	4.443	3.726	0.066
Residual	23	27.43	1.193		
Total	26	34.487			

Appendix 11 Analysis of variance for harvest Index

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	285.2	142.61	3.567	0.0448
Replication	1	186.6	186.63	4.668	0.0414
Residual	23	919.6	39.98		
Total	26	1391.4			

Appendix 12: Analysis of variance for the USLE

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Type of practice	2	2057.3	1028.6	194.227	1.82E-05
Replication	1	24.6	24.6	4.653	0.0835
Residual	5	26.5	5.3		
Total	8	2108.4			

Appendix 13: Crop management factor C values from different literatures

Crop	SLR (C)	Source
Wheat	0.07	Wischmeier and Smith (1978)
	0.09	Wischmeier (1960)
	0.35	Stone and Hilborn (2012)
Maize/Corn	0.38	Morgan (2005)
	0.4	Stone and Hilborn (2012)
	0.43	Mati and Veihe (2001)
Soya Beans	0.1	Mati and Veihe (2001)
	0.38	Morgan (2005)
	0.5	Stone and Hilborn (2012)
Cowpea	0.24	Nill (1998)

Appendix 14: Soil covers and the corresponding C factor

Type of Cover	C - Factor
None	1
Native vegetation (Undisturbed)	0.01
90% cover, annual grass, no mulch	0.1
Wood fiber (1.7ton/ha)	0.5
Excelsior mat with seed	0.5
Excelsior mat, Jute	0.3
Straw mulch 3.4 ton/ha	0.2
Straw mulch 9.0 ton/ha	0.05

Appendix 15: ANOVA for soil moisture

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. value
Type of practice	2	31103	15552	137.76	2E-06
Replication	1	4005	4005	35.47	2.60E-09
Residual	20871	2356068	2.12		
Total	20874	2391176			

Appendix 16: ANOVA for response of stover to position on slope

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Position on slope	2	17.2	8.62	0.315	0.7331
Replication	1	117.1	117.09	4.274	0.0501
Residual	23	630.2	27.4		
Total	26	764.5			

Appendix 17: ANOVA for the response of Harvest Index to a position on a slope

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Position on slope	2	45.1	22.53	0.447	0.6448
Replication	1	186.6	186.63	3.701	0.0668
Residual	23	1159.7	50.42		
Total	26	1391.4			

Appendix 18: ANOVA for the response of Biomass to a position on a slope

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Position on slope	2	37.3	18.67	0.743	0.4866
Replication	1	75.9	75.91	3.021	0.0955
Residual	23	577.9	25.13		
Total	26	691.1			

Appendix 19**:** ANOVA for the response of Grain to a position on a slope

Source of variation	D.F	Sum sq.	Mean sq.	F-value	Pr. Value
Position on slope	2	6.716	3.358	3.311	0.0545
Replication	1	4.443	4.443	4.381	0.0476
Residual	23	23.328	1.014		
Total	26	34.487			