HILLSIDE DITCHES PERFORMANCE IN CONTROLLING SOIL EROSION IN BANANA-MAIZE FARMING SYSTEM IN KIROKA VILLAGE, MOROGOGO, TANZANIA

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EXTENDED ABSTRACT

Soil erosion by water is a growing problem in Tanzania particularly in mountainous areas. The control of soil erosion is one of the most significant issues, which results in improving crop production as well as smallholders income. A study was carried out to assess hillside ditches performance in controlling soil erosion in a banana-maize farming system in Kiroka Village, Morogoro, Tanzania. The study intended to characterize the soils, determine soil loss and assess the social economic benefits of the hillside ditches. The methods used were reconnaissance survey, dug of soil profile pit, runoff plots of 12m x 3m with gerlach trough and base line survey using a questionnaire. A checklist and key informants interview were performed respectively.

The data were analysed by using Microsoft Excel computer program and Statistical Package for Social Science (SPSS). Two soil profile pits were characterized at slopes of 26% (named MAH-P1) and 55% (named MAH-P2) at Mahembe hamlet. Both soil profile pits were described during the end of rainy season in July 2015 under the following diagnostics soil properties ustic moisture and iso-hyperthermic temperature regimes. Eleven soil samples from different horizons within the same profile pit were analyzed for physico-chemical properties. Both profiles had dark reddish brown sandy clay loam and sandy clay top soils overlying dominantly clayey subsoils. Both profiles indicated clay eluviations-illuviation as dominant pedogenic process with slightly acidic soil conditions.

Available phosphorus in MAH-P1 was low to medium ranges from 0.91 g/kg to 9.24 g/kg while in MAH-P2 varied from medium to high ranges from 7.8 g/kg to 118.04 g/kg. Organic carbon (OC) in MAH-P1 ranged from 0.12% to 1.70% that is very low to medium and in MAH-P2 ranged from 0.26% to 1.54% also is very low to medium. The nitrogen in MAH-P1 ranged from 0.06% to 0.27% that is very low to medium and in MAH-P2 ranged from 0.06% to 0.11% that is very low to low. C/N ratio for both profiles ranged from 2 to 14. Both profiles had low to very low exchangeable bases except Ca that varied from 17.35 to 2.71 cmol+/kg and CEC in both profiles were high to very high. CEC clay values in both profiles were less than 24 cmol (+)/kg. In the USDA Soil Taxonomy, both profiles were classified as Alfisols that correspond to Luvisols in World Reference Base (WRB).

The results on soil loss showed that the mean seasonal soil loss was 0.067 t/ha with hillside ditches and 0.17 t/ha without hillside ditches. Runoff was 467.5 mm with hillside ditches and 1237.25 mm without hillside ditches. Maize yields were 5911.10 kg/ha with hillside ditches and 2808.611 kg/ha without hillside ditches. The socio-economic study, results showed that, majority of the respondents (76.3%) were aware on soil erosion and Soil and Water Conservation (SWC) techniques. The major constraint facing farmers during crop production was shortage of rainfall.

The Gross Margin Analysis (GMA) for maize under conserved fields was 64.6%, while that under non-conserved fields was 57.2%. The GMA for banana was 48% under conserved fields, while that under non-conserved fields was 43%. According to this study hill side ditches are good in controlling soil erosion, improving crop yields and retention of soil moisture. The study recommends the following farmers should use manure, compost and plants residue to increase soil fertility and construct as much as they can the hillside ditches or using any other soil conservation techniques to reduce soil erosion.

DECLARATION

I, Helena Mathew Mkoba, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Helena Mathew Mkoba Date

(MSc. Candidate)

The above declaration is confirmed by;

Prof. Henry Mahoo Date

(Supervisor)

Prof. Mathew Mulengera Date

(Supervisor)

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DEDICATION

This work is dedicated to my parents, who laid the foundation of my education

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LIST OF ABBREVIATIONS

%	Percentage
AGM	Average Gross Margin
C/N	Carbon Nitrogen Ratio
Ca	Calcium
$CaCl_2$	Calcium Chloride
CEC	Cation Exchange Capacity
cm	Centimeter
Cmol	Centmol
FAO	Food and Agriculture Organization of the United Nations
Fig	Figure
g	Gram
GM	Gross Margin
GMA	Gross Margin Analysis
HADO	Hifadhi Ardhi Dodoma
HASHI	Hifadhi Ardhi Shinyanga
hr	Hour
KCL	Potassium Chloride
Kg	Kilogram
LAMP	Land Management and Environment Programme
MAH – P1	Mahembe profile number 1
MAH – P2	Mahembe Profile number 2
Mg	Magnesium
mm	Millimeter

N	Nitrogen
Na	Sodium
NRCS	Natural Resources Conservation Service
OC	Organic Carbon
OM	Organic Matter
P	Phosphorus
RUSLE	Revised Universal Soil Loss Equation
SCAPA	Soil conservation and Agro-Forestry Project in Arusha
SLEMSA	Soil Loss Estimation Method for Southern Africa
SLM	Sustainable Land Management
SMR	Soil Moisture Regime
SPSS	Statistical Package of Social Sciences
STR	Soil Temperature Regime
SWC	Soil and Water Conservation
TEB	Total Exchangeable Base
Tshs	Tanzania shillings
USDA	United State Department of Agriculture
USDA-NRCS	United State Department of Agriculture Natural Resources Conservation Service
USLE	Universal Soil Loss Equation
WRB	World Reference base

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Soil Erosion

Soil erosion is a process of detachment and transport of soil particles and/or aggregates by water (raindrops and flowing water) and wind (Morgan, 1986). When soil erosion takes place without the influence of man it is known as normal, geological or natural erosion. Soil erosion is one of the most important and challenging problem facing farmers and natural resource managers worldwide (Lal, 1995). It is estimated that of the world's total land area of 13.4 x 10^9 ha, about 2.0 x 10^9 ha is degraded to some extent (World Resources Institute, 1993). Asia and Africa combined account for a total of 1.24 x 10^9 ha of the degraded land, with water erosion being the most prominent degrading process (UNEP, 1993). According to Lal (1995), by the year 2020, yield reduction due to soil erosion may be as much as 16.5% for the African continent and about 14.5% for sub-Saharan Africa.

Soil loss and runoff are the main threats to soil and water conservation in the steep slopes of the Uluguru Mountains (Kingamkono *et al*., 2005). Mahoo (2012) reported that the problem of soil erosion in Kiroka Village is influenced by different human activities such as farming on steep slopes and soil loss causes decline in yields and environmental problems. Soil and Water Conservation Technologies (SWC) that has been practiced in Kiroka village shows positive impacts on improving crop production, reducing soil erosion and retaining soil moisture. However, for better management of land resources, researchers in collaboration with the government and donors established different soil conservation practices in different areas. These practices include terraces, grass strips, hillside ditches, *fanya juu* terraces and conservation agriculture such as no tillage practice (Tenge, 2005).

In Usambara Mountains, Lushoto District, *fanya juu* terraces are constructed on both moderate and steep slopes for reducing soil erosion (Tenge, 2005). In addition, *ngoro* systems in Mbinga District have demonstrated higher productivity returns to land and labour (with or without fertilizer application) (Malley *et al.,* 2003). The study conducted by Kayombo *et al.* (1999) in Mbinga District, has shown that *ngoro* cultivation on steep slopes is efficient in controlling soil erosion, increasing soil moisture at critical times of the year and maintaining soil fertility. Kassie *et al.* (2008) analyzed the impact of stone bunds on the value of crop production in Ethiopia and revealed that their effects on crop productivity differed with agro-ecological settings. Implementing stone bunds increased crop productivity in low rainfall areas whereas in the high rainfall areas this was not the case.

Beside the agro-ecological conditions, studies conducted in Kenya by Nyangena and Kohlin (2009) found that soil erosion was a major determinant of the effect of agro forestry, bunds and terracing on crop productivity. In Anjeni Watershed, Northwest Ethiopia Woubet *et al.* (2013) assessed the long-term impacts of soil and water conservation on land suitability to crops in improving ecosystem services in general and land suitability to crop production in particular. They observed that SWC were best for the betterment of land quality or soil improvement as well in crop production.

A similar study conducted by Tenge, (2005) among smallholder farmers in the West Usambara Highlands in Tanzania estimated the financial efficiency of bench terraces, *fanya juu* terraces and grass strips and revealed that profitability of these SCW practices depended on soil type, slope and opportunity costs of labour. For instance, *fanya juu* terraces constructed on both moderate and steep slopes were economically viable for farmers on gentle slopes (Tenge, 2005). However, soil erosion is often present on steep slopes with unstable soils that accelerate soil surface movement and run-off. Consequently, smallholder farmers with farms located on extremely sloped that ranges from 5 to 40% areas would need additional incentives to make soil conservation technologies economically attractive for them.

1.2 Hillside Ditches Technique

A hillside ditch is a channel that has a supporting ridge on the lower side, constructed across the slope at defined gradient, with or without a vegetative barrier (Natural Resources Conservation Service, 2008). Hillside ditch constructed to reduce surface runoff are built across the hills. Hillside ditches consist of a series of shallow ditches built along the contour lines at appropriate intervals. Hillside ditches not only break long slopes into shorter segments to intercept surface runoff, but also serve as farm paths to facilitate farm operations and transportation. They have been shown to be suitable on slopes with a gradient of less than 40% (Mulengera, 2013). For instance in Kiroka village (Mahembe hamlet) in banana and maize cropping systems, hillside ditches were implemented for reducing soil loss and increase crop productivity (Mahoo, 2012).

1.3 Soil Characterization

Soil characterization information gathered by systematic identification, grouping and delineation of different soils is required when sound interpretations towards land use potential are to be made (Msanya, 2013). In addition, climatic and other ecological characteristics as well as socio-economic factors are also important elements in land management. According to Msanya *et al.* (2003) soil properties and related site characteristics is inevitable for one to be able to advise both current and potential land users on utilization for development of soil/land management technologies such as fertilizer application, soil conservation techniques and improved tillage methods.

Understanding soil genesis, morphology and other key soil properties is a pre-requisite to sustainable use of soil resources Msanya *et al.* (2003) and thus detailed knowledge about them is essential.

1.4 Different Methods on Quantifying Soil Loss

Methods used to estimate soil loss are categorized into two. The first method is indirect methods that include the use of several correlation equations for predicting sheet and rill erosion. These include the Universal Soil Loss Equation (USLE) or its current revised version (RUSLE) (Wischmeier and Smith, 1978; Schwab *et al.,* 1993 and Renard *et al.,* 1997) which estimates long term (at least 20 years) average annual soil loss caused by rill and interrill erosion. The other one is the Soil Loss Estimation Method for Southern Africa (SLEMSA), which was developed in Zimbabwe (Elwell, 1978). In this equation, the annual soil loss rate is usually correlated with rainfall, soil erodibility, slope length and steepness, crop and crop management and soil conservation measures.

The second method is the direct method that include the use of conversional runoff plots by installing gerlach trough, use of erosion pins, pegs and stakes, the use of tracers such as fluorescent dyes to monitor soil creep; small agricultural watershed with appropriate monitoring equipment (Mulengera, 2013). However, the conventional runoff plots technique is perhaps the most widely used method of estimating soil erosion. Kimaro *et al.* (2008) used runoff plots technique with gerlach trough to determine the quantity of soil loss on the northern slopes of the Uluguru Mountains. In Uganda Semalulu *et al.* (2014) used runoff plots techniques to assess the amount of soil loss from farmers fields plots. The results showed that there is reduction in soil loss on the plots with soil conservation compared to those without soil conservation practices.

1.5 Adoption and Non-adoption of Soil and Water Conservation Techniques

Accelerated soil erosion is one of the major constraints to agricultural production in many parts of the Tanzanian highlands. Although several soil and water conservation techniques have been developed and promoted, soil erosion continues to be a problem. Major factors that negatively influence adoption of SWC measures are involvement in off-farm activities, insecure land tenure, location of fields and a lack of short-term benefits (Tenge *et al.,* 2004). A study conducted at West Usambara Highlands in Tanzania by Tenge *et al.* (2004), on social and economic of soil and water conservation, showed that there were some factors affecting the adoption of soil and water conservation to smallholder farmers. The factors included were insecure land tenure, location of fields and lack of short-term benefits from SWC. In order to have positive adoption of the SWC techniques the following advises must be applied: integration of social and economic factors into SWC plans, the creation of more awareness among farmers of soil-erosion effects and long-term benefits of SWC and the development of flexible SWC (Mahoo, 2012).

1.6 Justification

Soil erosion is one of the key environmental issues if mountain ecosystems (Nyssen *et al.,* 2006). Soil erosion may lead to loss of top soil, decrease of soil water capacity, soil fertility and also inhibit vegetation growth (Zhou *et al.,* 2006). For example, in the Usambara Mountains, soil loss due to erosion by water is estimated to vary from 60-100 t/ha/year (Pfeifer, 1990). Similar rates of erosion occur in the Uluguru Mountains where interrills, rill, tillage and landslide soil erosion processes are dominant within mean soil loss ranging from 91-258 t/ha/year (Kimaro, 2003). The same type of erosion and soil loss is experienced in Kiroka village where different crops are planted. This loss led to very high soil loss during the rainy season leading low crop production (Mahoo, 2012).

Hillside ditches have been constructed in Kiroka village (Mahembe farms) for controlling soil erosion, retain moisture in the soil and improve crop productivity in the area (Mahoo, 2012). However, this study was implemented to assess the effectiveness of the hillside ditches technique in controlling soil erosion, quantify the rate of soil eroded and retention of soil moisture.

1.7 Research Objectives

1.7.1 Overall objective

The overall objective of this study was to evaluate the effectiveness and socio-economic benefits associated with hillside ditches in improving the livelihoods of small-scale farmers in rural settings in Kiroka village.

1.7.2 Specific objectives

The specific objectives of the study were as follows:

i. To characterize the soils under the banana-maize farming system with and without conservation structures in the study area
ii. To quantify soil loss from banana-maize farming system with and without conservation structures in the study area
iii. To examine the socio-economic benefits of the banana-maize farming system with and without conservation structures in study area.

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CHAPTER TWO

2.0 CHARACTERIZATION OF THE SOILS IN BANANA-MAIZE FARMING SYSTEM IN KIROKA VILLAGE

ABSTRACT

Standard soil survey was carried out in a banana-maize farming system in Kiroka village based on landforms and other physiographic attributes. Soil profiles were characterized at slopes of 26% (named MAH-P1) and 55% (named MAH-P2) at Mahembe hamlet. Both profiles were described during the end of the rainy season under ustic moisture and iso-hyperthermic temperature regimes. Eleven soil samples from genetic horizons were analyzed for physico-chemical properties. Both profiles had dark reddish brown sandy clay loam and sandy clay top soils overlying dominantly clayey subsoils. Both profiles indicated clay eluviation-illuviation as dominant pedogenic process with slightly acidic soil conditions. Available phosphorus in MAH-P1 was low while in MAH-P2 it varied from high to low. Organic carbon (OC) was very low in both profiles while total nitrogen was medium and low to very low. Both profiles had low to very low exchangeable bases except Ca that varied from 17.35 cmol+/kg to 2.71 cmol+/kg and CEC in both profiles were high to very high. CEC clay values in both profiles were < 24 cmol (+)/kg. In the USDA Soil Taxonomy, both profiles were classified as Alfisols corresponding to Luvisols in World Reference Base (WRB). Manure, compost and plant residues are recommended to increase organic matter content and intercropping of cereals with nitrogen fixing legumes to enhance nitrogen fixation in the soils.

Key words: Soil characterization; physico-chemical properties; soil classification; soil fertility, Tanzania

2.1 INTRODUCTION

2.1.1 Soil characterization

Soil characterization information gathered by systematic identification, grouping and delineation of different soils is required when sound interpretations towards land use potential are to be made. In addition, climatic and other ecological characteristics as well as socio-economic factors are also important elements in land management. According to Msanya *et al*. (2003) soil properties and site characterization is inevitable for one to be able to advise both current and potential land users on utilization for development of soil/land management technologies such as fertilizer application, soil conservation techniques and improved tillage methods.

Understanding of soil genesis, morphology and other key soil properties is a pre-requisite to sustainable use of soil resources Msanya *et al*. (2003) and thus detailed knowledge about them is essential. There is need to have well characterized and defined ecological conditions to aid soil fertility specialists and other stakeholders of soil information to transfer agronomic technologies from one area to another. Well prepared soil resource inventories are benchmark in determining the potential and management requirements of specific areas for various land uses. The soil characterization has been performed in few selected high potential areas in Tanzania, which led to paucity of soil information (Msanya *et al.,* 1991; Msanya and Magogo, 1993; Kilasara *et al.,* 1994).

2.1.2 Soil classification

Soil classification is the systematic arrangement of soils into groups or categories based on their characteristics. Soil classification may organize knowledge and understand relationships among soils. Establishes soil classes in predicting soil behavior and identifying the best uses of soil and estimating of soil productivity (Msanya, 2013). Soil classifications based largely on geologic origin of soil material and soil fertility for agricultural purposes. There are several systems on classifying soil. The first system is Soil Taxonomy that is a basic system of soil classification for making and interpreting soil surveys (Soil Survey Staff, 2014). The second system is World Reference Base for Soil Resources (IUSS Working Group WRB, 2014).

There are many reasons why soils are classified and these have been fairly well defined by Soil Taxonomy and WRB. The importance of soil classification stems from the need to bring systematic to the study of soil, as without classification the knowledge would be factual confusion that is difficult to retain and impossible to understand. Soil classification enables to see relationships among and between soils and their environment. It formulates principles of prediction value establish groups at various levels.(Soil Survey Staff, 2014; IUSS Working Group WRB, 2014). The current study reports on site identification, description and characterization of some typical soils in Kiroka village. The specific objectives of this study were the following:

i. To characterize the soils in terms of their morphological, chemical, physical and mineralogical characteristics and hence their general fertility,
ii. To classify the soils using the United States Department of Agriculture (USDA) Soil Taxonomy and the FAO-Unesco Classification System (WRB) and
iii. To provide data that will be utilized for development of soil/land management technologies such as fertilizer application, soil conservation and improved tillage methods.

2.2 Methodology

2.2.1 Description and selection of the study area

2.2.1.1 Location

The study was carried out in Kiroka village, Morogoro rural District, Morogoro region (Fig. 2.1). Kiroka village is situated in Morogoro rural District, it is about 35 km from Morogoro town along Morogoro-Matombo road. This village lies between 6^0 25'S and 6^0 50'S and $37^0$30'E and $37^0$49'E at an altitude of 887 m asl. The village is along the lower reaches of Mahembe, Mwaya and Kiroka- river valleys.

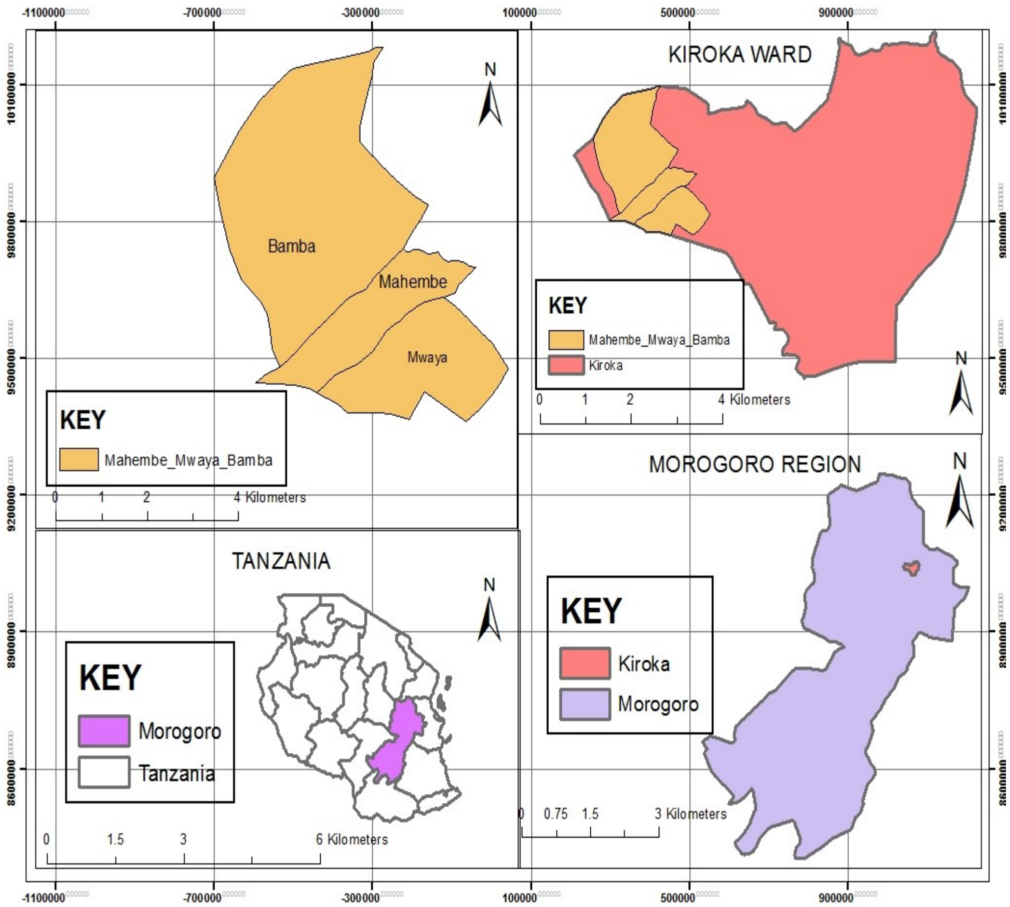

Figure 2.1: Location of the Study Area

2.2.1.2 Climate

The study area receives an average of 1100 mm rainfall per annum (Tanzania Meteorological Agency, 2015) while the annual evapo-transpiration is 1775 mm. The rainfall pattern is weakly bi-modal with two rainy seasons from October to late January and from mid-February to May respectively. The driest months are June to September. Figure 2.2 shows the mean annual rainfall, minimum and maximum temperature of the study area (Tanzania Meteorological Agency, 2015).

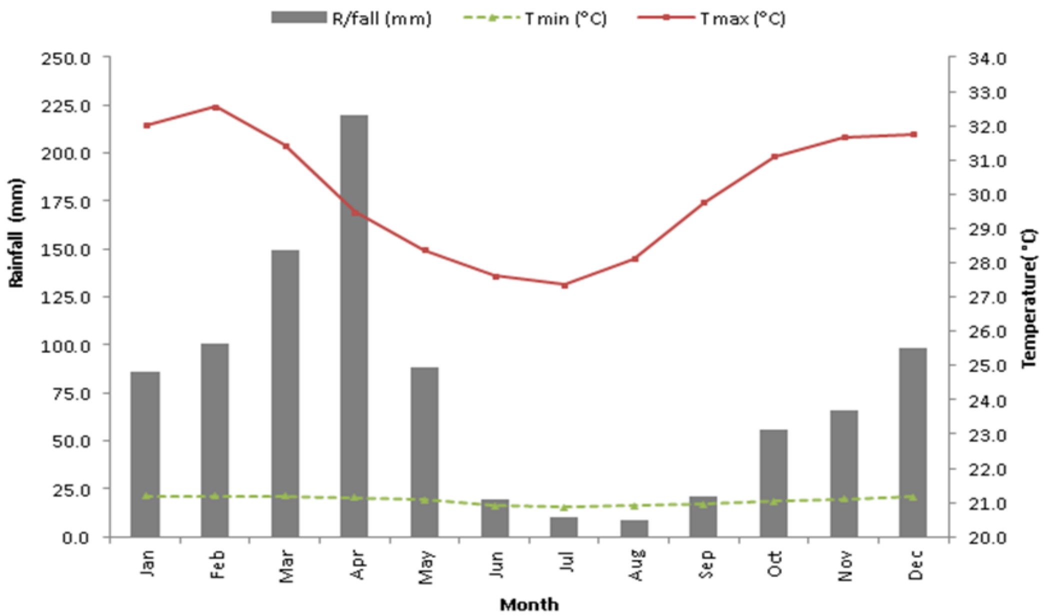

Figure 2.2: Mean annual rainfall, maximum and minimum temperature of the study area (1988 to 2007)

Source: Tanzania Meteorological Agency (2015)

2.2.1.3 Geomorphology and soils

Uluguru Mountains are a host block of Precambrian rocks. They are believed to have been uplifted as a block several times since the formation of the Karoo basins (Rapp *et al.*, 1972). The soils on the mountain ridges based to FAO system of soil classification (FAO,

1998) are *Endoskelic* and *LepticCambisols*, the subsidiary soils to them are *Haplic* and *Chromic Phaeozems* and *OrthieuricRegosols*. The dominant soils on the foothills are *Chromic Lixisols* and *ProfondicAcrisols* associated with *HypeferralicCambisols* and *EndolepticCambisols* (Kimaro *et al.,* 1999 and Kimaro *et al.,* 2005). All the soils are low in depth and eroded. As a result, shallow soils and emerging rocks are commonly found on steep slopes (Rapp *et al.,* 1972 and Kimaro, 2003).

2.2.1.4 Vegetation and land uses

The major types of land use are mainly agriculture and forest reserves. The vegetation type varies with altitude. The forests are covered with montane and sub-montane forests and occupy about 7% of the Uluguru Mountains land surface area. Lower altitude areas below 800 m asl have sub-montane and coastal rain forest occurring on the southern slopes with rainfall estimated at over 1200 mm per annum. The montane forests occur in areas above 800 m from sea level. The present agricultural land use in the study area includes smallholder rain fed and irrigated farming. There is a complex relationship between households and their fields. The farmers have a number of small farm units (shamba) scattered in several places. The main crops grown in Kiroka village are maize, rice, cassava and banana (Mahoo, 2012). The cropping systems include mono-cropping, intercropping and rotation cropping. Farmers intercrop various crops such as banana and maize, maize and beans, maize/paddy. Land preparation is normally done before the onset of the rains by clearing the land slash and burning ready for cultivation.

2.2.1.5 Topography

The mountains in Kiroka village are a faulted block (Kimaro, 2013). The process which has formed this distinctive unit may have started as far back as the Karroo period approximately 300 million years before present with a final uplifting 7 million years ago(Griffith, 1993).

The tectonic activity included the uplift and metamorphosis of Palaeozoic (Usagaran) limestones in the eastern foothills. The low foothills are composed of Mesozoic limestones and shales and cemented Cainozoic sandstones.

2.2.2 Methods

2.2.2.1 Field methods

A reconnaissance survey was carried out using transect walks and descriptions in the field to identify major and representative soils. At each observed site soil morphological characteristics, elevation, slope gradient, parent material (lithology), soil compaction, vegetation and land use/crops data were collected. From the reconnaissance survey, sites that represented major landforms and soils were selected along a transect running in a south-westward direction from Morogoro municipality. In each identified landform unit, soil observations were made to a maximum depth of 2m or to a limiting layer to identify soil properties by augering along the transect.

The sampling sites were geo-referenced using a Global Positioning System (GPS) (model OREGON 400t). The compaction of the soil was determined using penetrometer equipment. These data were filled in forms adopted from the FAO guidelines for soil description (FAO-WRB World Reference Base, 2006). Two soil profile pits were dug. The soils described according to FAO-WRB World Reference Base (2006) guidelines. The soil samples taken from each profile layer were analyzed in the laboratory. Plate 2.1 and plate 2.2 shows the profile pits named as MAH-P1 representing the area with high slope (55%) and MAH-P2 representing the area with moderate slope (26%) at the study area.

Plate 2.1: Profile pit MAH-P1 at 55% slope [Photo – Helena Mkoba, 2015]

Plate 2.2: Profile pit MAH-P2 at 26% slope [Photo – Helena Mkoba, 2015]

2.2.2.2 Laboratory methods

Soil samples were air-dried, grinded and passed through a 2 mm sieve for laboratory analysis. Physical and chemical analyses were conducted as follows. Bulk density was determined using the core method (Black and Hartge, 1986) and texture was determined by the hydrometer method (Day *et al.,* 1965). The pH was measured in water and 1 M

KCL at the ratio of 1:2.5 soils: water or soil: KCL, respectively (McLean, 1986). The 1 M KCL was used to predict presence of some salts such as sulphates or phosphates and other cations that might be found in the soil. Organic carbon was determined by the wet oxidation method (Nelson and Sommers, 1982).

Total N was determined using the micro-Kjeldahl digestion-distillation method as described by Bremner and Mulvaney (1982). Extractable phosphorus was determined using filtrates extracted by the Bray and Kurtz-1(1945) method and determined by spectrophotometer (Watanabe and Olsen 1965). The exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were determined by atomic absorption spectrophotometer (Thomas,1982). The total exchangeable bases (TEB) were calculated arithmetically as the sum of the four exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) for a given soil sample.

2.2.2.3 Soil classification

Based on the field and laboratory data, the soils were classified to tier-2 level of the FAO-WRB World Reference Base (2006) and to subgroup level of the USDA-NRCS Soil Taxonomy (2006).

2.3 Statistical Data Analysis

Soil fertility trends analytical data were subjected to Spearman's rank (Kebeney *et al.,* 2014) correlation to show the relationship among the soil parameters. Other soil data were analyzed by using excel computer programme and the results presented in tables and figures.

2.4 Results and Discussion

2.4.1 General soil characteristics of the study area

The detailed site characteristics of the study area are presented in Table 2.1. Landform of the area is Mountainous, slope form is straight, Soil Moisture Regimes (SMR) is USTIC and Soil Temperature Regimes (STR) iso-hyperthermic. The SMR showed increasing trend with increasing elevation whereas the STR showed a decreasing trend with increasing elevation. This trend has implications on variations in physico-chemical properties across elevation gradient. Similar results in Swedish Forest and South Spain were reported by Seibert *et al.* (2007) and Hattar *et al.* (2010).

Table 2.1: General soil characteristics of the study area

Altitude (masl)	Location	Profile No.	Slope gradient (%)	Landform	Slopeform	SMR	STR
519	$37^0$47′48.8″E $06^0$50′51.9″S	1	55	Mountainous (backslope)	Straight	USTIC	Isohyperth ermic
501	$37^0$4′751.2″E $06^0$50′54.6″S	2	26	Mountainous (backslope)	Straight	USTIC	Isohyperth ermic

*SMR = soil moisture regime, **STR = soil temperature regime

2.4.2 Soil morphological characteristics

Morphological characteristics of the selected two soil profile pits are presented in Table 2.2. Most of the soils are dark reddish brown in color. The consistency was very hard when dry, very friable when moist, very sticky and very plastic when wet. The structure of the soil was weak to moderate coarse and sub-angular blocky. The soil had common coarse and few medium pores. The soil had many fine and few coarse roots. The boundary of the soil layers was gradual smooth. The soil morphological characteristics of the studied profiles revealed varying horizon thicknesses within and between profiles. Hattar *et al.* (2010) reported that soils differ in their horizons thickness, depending on the location along the topo-sequence.

Table 2.2: Soil morphological properties of the study areas

Profile no.	Horizon	Depth (cm)	Boundary	Colors		Structures	Consistency			Specific features
				Dry	Moist		Dry	Moist	Wet	
MAH-P1	Ap	0 - 13	aw	drb5YR 3/2	drb5YR 3/2	WE,FI,GR	SHA	VFR	SP	
	BA	13 - 47	cw	drb2.5YR ¾	drb2.5YR 2.5/4	WE/MO,CO,SB	VHA	FR	VSTandVPL	Few animal barrow
	Bt_1	47 - 78	gs	dr10R 3/6	dur10 R ¾	WE/MO,CO,SB	VHA	FR	VSTandVPL	Few animal barrow
	Bt2	78 – 92	gs	dr10R 3/6	dur10R ¾	MO,ME+CO,SB	VHA	FR	STandPL	
	Bt3	92 – 150	cs	r10R 4/6	dr10R 3/6	WE, FI+ME, SB	SHA	VFR	SSTandSPL	
	BC	150 – 200+		r10R 4/8	dur7.5R 3/4	WE, FI+ME, SB	SHA	FR	SSTandSPL	Animal crotovina
MAH-P2	Ap	0 – 22	aw	db10YR3/3	b7.5YR2.5/1	WE,F,C	SHA	VF	STandSPL	
	AB	22 - 64	gs	drb5YR3/4	vdb7.5YR2.5/3	WE to M,Fto C,SB	VHA	VFI	VSTandVPL	Charcoal
	Bt_1	64 – 89	gs	drb2.5YR3/4	db7.5YR3/3	ST,MandC,A	VHA	FI	STandPL	
	Bt_2	89 – 163	as	rb5YR4/4	rb2.5YR3/4	ST,MandC,A	VHA	FI	STandPL	
	C/CR	163 – 180+		sb7.5YR4/6	yr5YR4/6	M,MandC,A/SBA	SHA	FR	STandPL	

Abbreviations: 1drb = dark reddish brown; dr = dark reddish; dur = dusky red; r = red; b = brown; db = dark brown; st = strong brown; rb = reddish brown; vdr = very dark brown; yr = yellowish red; 2sha = slightly hard; vha = very hard; vfr = very friable; fr = friable; st = sticky; vst = very slightly sticky; pl = plastic; vpl = very plastic;vf= very firm; fi = firm; 3 we = weak; fi = fine; gr = granular; mo = moderate; co = coarse; sb = subangular; me = medium; cr = crumb; a = angular: 4 aw = abundant wavy; cw = clear wavy; gs = gradual smooth; cs = clear smooth: Ap = Organic matter and ploughing /or disturbance; BA = Organic matter and illuviation ; Bt = illuviation and accumulation of silicate clay; BC = Illuviation of parent materials; C = Parent materials/unconsolidated; CR = Parent materials and rocks

2.5 Physical Properties

2.5.1 Soil texture

Results of soil textural of the studied pedons are presented Table 2.3 which clearly indicates that the distribution patterns of the textural separates are similar for both profiles. According to USDA (2006) the textural classes for selected sites from MAH-P1 was sandy clay loam (SCL) and MAH-P2 sand clay (SC). The texture of the soil may have an influence on the soil erosion with a factor of slope. Soil texture has an important role in nutrient management because it influences nutrient retention. Finer textured soils contain and hold an appreciable amount of plant nutrients. The fine textured soils with more than 65% clay and less than 18% sand usually have low fertility status. Studies conducted by Vågen and Winowieck (2012) in Dambidolo (Kenya) and in Mbinga (Tanzania) showed that sand contents control the variability of nutrient storage capacity of the soils. This is because texture is a composite of the coarse fraction (sand) and the finer fractions (silt and clay) and increasing or decreasing one component imparts the opposite effect on the other and hence affects physico-chemical properties of the soils.

Table 2.3: Soil texture

Profile no.	Horizon	Silt + Clay	Clay	Clay (%)	Silt (%)	Sand (%)	Silt/Clay Ratio	Texture Class
MAH-P1	Ap	23.44	20.98	41.96	4.92	53.12	0.12	SC
	BA	31.44	21.98	43.96	18.92	37.12	0.43	C
	Bt_1	32.44	30.98	61.96	2.92	35.12	0.05	C
	Bt2	34.44	31.98	63.96	4.92	31.12	0.08	C
	Bt3	33.44	31.98	63.96	2.92	33.12	0.05	C
	BC	29.44	27.98	55.96	2.92	41.12	0.05	C
MAH-P2	Ap	14.44	10.98	21.96	6.92	71.12	0.32	SCL
	AB	24.44	23.98	47.96	0.92	51.12	0.02	SC
	Bt_1	27.44	25.98	51.96	2.92	45.12	0.06	SC
	Bt_2	28.44	26.98	53.96	2.92	43.12	0.06	C
	C/CR	28.44	25.98	51.96	4.92	43.12	0.09	C

SCL = Sand Clay Loam; SC = Sandy Clay; C = Clay; Ap = Organic matter and ploughing /or disturbance; BA = Organic matter and illuviation; Bt = illuviation and accumulation of silicate clay; BC = Illuviation of parent materials; C = Parent materials/unconsolidated; CR = Parent materials and rocks

The silt/clay ratio is also shown in Table 2.3. The silt/clay ratio for subsoils of the two profiles is very low, indicating that the two profiles are highly weathered. The silt/clay ratio in MAH-P2 are relatively lower than MAH-P1 indicating that the former profile is slightly more weathered than the latter. Figure 2.3 and Figure 2.4 shows the distribution of particle size of the soil. Clay had large percent compared to sand and silt in subsoil and at the topsoil sand is dominant. This means the soil allows water and nutrients to penetrate easily and supports the growth of crops.

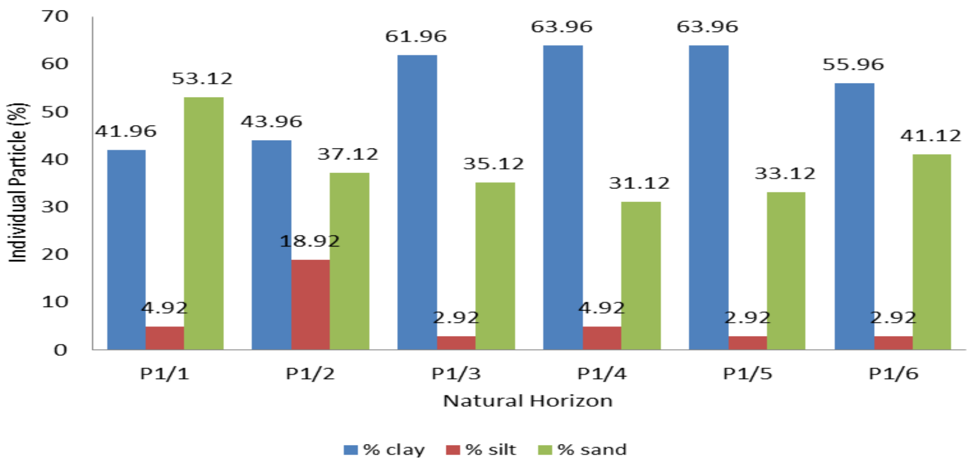

Figure 2.3: Individual soil particle distribution of the MAH – P1

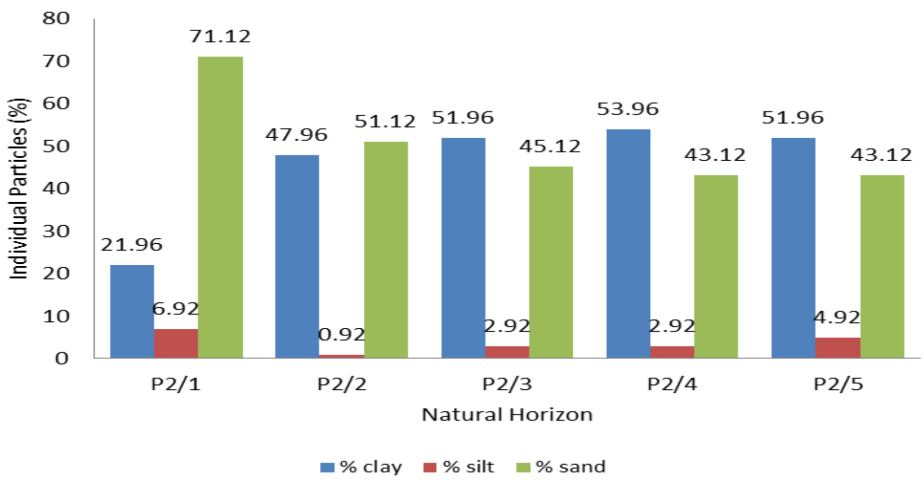

Figure 2.4: Individual soil particle distribution of the MAH-P2

2.5.2 Bulk density and total porosity

The analytical results on bulk density and total porosity of the profiles are shown in Table 2.4. Bulk density determines the magnitude of particle-to-particle contacts which is related to total porosity and has an influence on available soil moisture (Lal and Shukla, 2005). Both profiles had low to high bulk density and this may cause restrictions to root growth and poor movement of air and water through the soil.

Table 2.4: Some physical properties of the studied profiles

Prof no.	Horizon	Depth (cm)	BD gc-3	Total porosity
MAH–P1	Ap	0 -13	1.2	53.2
	BA	13 -47	-	-
	Bt_1	47 – 78	1.38	43.3
	Bt_2	78 – 92	-	-
	Bt_3	92 – 150	1.26	48.0
	BC	150 – 200+	-	-
MAH–P2	Ap	0 – 22	1.36	46.5
	AB	22 – 64	1.61	38.5
	Bt_1	64 – 89	-	-
	Bt_2	89 – 163	1.64	38.9
	C/CR	163 – 180+	-	-

Ap =Organic matter and ploughing /or disturbance; BA =Organic matter and illuviation;Bt =illuviation and accumulation of silicate clay; BC=Illuviation of parent materials; C=Parent materials/unconsolidated; CR =Parent materials and rocks

2.5.3 Penetrometer resistance

Table 2.5 presents the penetrometer resistance of the two studied profiles. Soil resistance increases with increase in bulk density and with decrease in total porosity and soil available moisture content due to increased capillary cohesion (Lal and Shukla, 2005). Both soil profiles had low penetrometer resistance in the upper top-soil and this is attributed to low bulk density shown in Table 2.4. The results further point out possible soil compaction in both profiles, which may cause slow growth and development of crops.

Table 2.5: Penetrometer resistance of the studied profiles

Profile No.	Horizon	Penetrometer (kg/cm^2)
MAH – P1	Ap	20.3
	BA	27.7
	Bt1	31.4
	Bt2	30.5
	Bt3	27.8
	BC	27.3
MAH – P1	Ap	21.4
	AB	31.4
	Bt1	31.8
	Bt2	30.7
	C/CR	24.6

Ap =Organic matter and ploughing /or disturbance; BA=Organic matter and illuviation; Bt illuviation and accumulation of silicate clay; BC =Illuviation of parent materials; C= Parent materials/unconsolidated; CR= Parent materials and rocks

2.6 Chemical Properties

2.6.1 Soil pH

Table 2.6 shows the pH of MAH-P1 ranges from 6.61 to 5.75 which implies that the soil is acidic, while in MAH-P2 the pH ranges from 6.4 to 6.5 which is also acidic. Nearly all surface soils had higher pH values than those in the sub-soils, a trend which indicates leaching of exchangeable bases from surface to the sub-surface horizons.

Table 2.6: Some chemical properties of soils of the profiles in the study area

Profile no.	Horizon	Depth (cm)	pH H_2O
MAH-P1	Ap	0 – 13	6.61
	BA	13 -47	5.75
	Bt_1	47 – 78	6.21
	Bt_2	78 – 92	6.37
	Bt_3	92 – 150	6.41
	BC	150 – 200+	6.32
MAH-P2	Ap	0 – 22	6.53
	AB	22 – 64	6.53
	Bt_1	64 – 89	6.47
	Bt_2	89 – 163	6.49
	C/CR	163 – 180+	6.41

Ap =Organic matter and ploughing or disturbance; BA =Organic matter and illuviation; Bt =illuviation and accumulation of silicate clay; BC =Illuviation of parent materials; C =Parent materials/unconsolidated; CR =Parent materials and rocks

2.6.2 Organic carbon (OC) and total nitrogen (N)

From the results in Table 2.7 show that the organic carbon in MAH-P1 ranges from 0.12% to 1.70% that is very low to medium and in MAH-P2 ranges from 0.26% to 1.54% also is very low to medium. The nitrogen in MAH-P1 ranges from 0.06% to 0.27% that is very low to medium and in MAH-P2 ranges from 0.06% to 0.11% is very low to low. C/N ration for both profiles ranges from 2 to 14. C/N ration gives an indication of the quality of the organic matter in which according to Msanya *et al.* (2001), this result shows the soil is in a good quality to support crops especially maize, however, if erosion continuous might lead to poor quality. Other authors Msanya *et al.* (2001) also found this trend in the soils of different areas in Morogoro rural and urban Districts. Organic matter is ranging from very low to medium values, which implies the soil is supportive to any type of crops e.g. banana and maize.

Table 2.7: Some chemical properties of soils of the profiles in the study area

Profile no.	Horizon	Depth (cm)	OM%	N%	OC %	C/N
MAH-P1	Ap	0 – 13	2.92	0.27	1.70	6.30
	BA	13 -47	1.61	0.11	0.94	8.54
	Bt_1	47 – 78	1.00	0.08	0.58	7.25
	Bt_2	78 – 92	1.20	0.09	0.70	7.78
	Bt_3	92 - 150	0.65	0.07	0.38	5.43
	BC	150 – 200+	0.21	0.06	0.12	2.00
MAH-P2	Ap	0 – 22	2.64	0.11	1.54	14.00
	AB	22 – 64	1.17	0.08	0.68	8.50
	Bt_1	64 – 89	0.75	0.06	0.44	7.33
	Bt_2	89 - 163	0.58	0.06	0.34	5.67
	C/CR	163 – 180+	0.45	0.06	0.26	4.33

Ap =Organic matter and ploughing/or disturbance; BA = Organic matter and illuviation; Bt =illuviation and accumulation of silicate clay; BC = Illuviation of parent materials; C = Parent materials/unconsolidated; CR = Parent materials and rocks, OM= Organic matter, N= Nitrogen, OC= Organic carbon, C/N = Organic carbon nitrogen ratio

2.6.3 Cation exchange capacity (CEC)

CEC is a measure of the capacity of soils to retain nutrients (against leaching) (Msanya *et al*., 2001). From the results in Table 2.8 show that the top surface and sub-surface horizon of the profiles had high values of CEC and decreased with depth. CEC ranges from 14.5 to 65.08 cmol (+)/kg, which is medium to very high (Msanya *et al.*, 2001). The higher the CEC the more clay or organic matter present in the soil thus they attract cation elements such as Mg, Ca and K (Msanya *et al.,* 2001).

This usually means that high CEC (clay) soils have a greater water holding capacity. Therefore, it requires higher rates of fertilizer or lime to change a high CEC soil. Soil with good CEC levels offers a large nutrient reserve. However, when it is poor, it can take a large amount of fertilizer or lime to correct that soil cation level. The CEC usually gives an idea of the potential fertility of the soil. Therefore, the soils of the study area had high water holding capacity and large nutrient reserve.

Table 2.8: Cation exchange capacity

Profile no.	Horizon	Depth (cm)	CEC
	Ap	0 - 13	58.4
MAH-P1	BA	13 - 47	14.5
	Bt_1	47 - 78	65.08
	Bt_2	78 - 92	26.54
	Bt_3	92 - 150	36.84
	BC	150 – 200+	41.82
	Ap	0 – 22	45.6
MAH-P2	AB	22 - 64	49.72
	Bt_1	64 - 89	39.56
	Bt_2	89 - 163	52.66
	C/CR	163-180+	32.96

Ap =Organic matter and ploughing/or disturbance; BA =Organic matter and illuviation; Bt =illuviation and accumulation of silicate clay; BC =Illuviation of parent materials; C=Parent materials/unconsolidated; CR =Parent materials and rocks, CEC =Cation Exchange Capacity

2.6.4 Potassium, sodium, calcium, phosphorus and magnesium

From the results in Table 2.9 show that the levels of K in both profiles ranging from 0.04 to 1.09 cmol(+)/kg and Na ranging from 0.02 to 0.19cmol(+)/kg it was very low. Whereas the levels of Ca was very high ranging from 2.71 to 17.35cmol(+)/kg while Mg in both profiles was in medium average levels ranging from 1.32 to 3.48 cmol(+)/kg, all these interpretation were according to Msanya *et al.,* 2001. Generally, the soils in the study area indicated that they have low soil fertility status, which could be attributed to the nature of parent materials, modes of formation coupled with frequent fires and soil erosion (Nshubemuki and Mbwambo, 2007). The soils in MAH-P1 profile had a low value of P ranging from 0.13 to 9.24 cmol(+)/kg and according to Landon (1991), this soil is adequate for supporting plant growth such as maize and banana. However, in MAH-P2 profile had high levels of P ranges from 1.14 to 118.04 cmol(+)/kg. The high value of P in MAH-P2 is due to soil transformation from one place to another and imported different materials such as ash and charcoal.

Table 2.9: Exchangeable cations and related properties of the profiles in the study area

Profile no.	Horizon	Depth (cm)	Ca cmol(+)/kg	Mg cmol(+)/kg	K cmol(+)/kg	Na cmol(+)/kg	P mgP/Kg
MAH-P1	Ap	0 - 11/13	17.35	3.48	1.09	0.02	0.13
	BA	13 - 47	4.72	1.47	0.38	0.03	9.24
	Bt_1	47 - 78	4.91	1.80	0.07	0.19	5.67
	Bt_2	78 - 92	3.99	1.90	0.06	0.03	1.38
	Bt_3	92 - 150	5.27	2.46	0.05	0.05	0.91
	BC	150 – 200+	2.71	2.06	0.04	0.03	2.33
MAH-P2	Ap	0 – 22	13.51	1.80	0.84	0.04	1.14
	AB	122 - 64	13.88	1.45	0.26	0.05	118.04
	Bt_1	64 - 89	10.95	1.32	0.16	0.05	94.27
	Bt_2	89 - 163	11.13	1.40	0.11	0.02	45.45
	C/CR	163 – 180+	10.40	1.90	0.08	0.07	9.96

Ap =Organic matter and ploughing /or disturbance; B= Organic matter and illuviation; Bt = illuviation and accumulation of silicate clay; BC = Illuviation of parent materials; C=Parent materials/unconsolidated; CR = Parent materials and rock, Ca = Calcium, Mg= Magnesium, K = Potasium, Na = Sodium and P = Phosphorus

2.7 Nutrient Balance

Nutrient ratios of the studied profiles are presented in Table 2.10. Both profiles had Ca/TEB ratio ranging from 0.85 to 0.98 that is more than 0.5 and was high. This high Ca/TEB ratio can cause induced deficiency of Mg that could be a major limitation in the soil. Also it may affect the uptake of other bases particularly Mg and/or K due to Ca induced deficiency (Euroconsult, 1989) and Landon (1991). The ratios of Ca/Mg are generally within the optimum range of 2-4, which are favorable for plant growth and development. However, due to high Ca/TEB ratio, induced deficiency of Mg could be a major limitation in these soils. The Mg/K ratios in both profiles are above the recommended range for optimum nutrient uptake (Euroconsult, 1989 and Landon, 1991) implying potential nutrient imbalance and toxicity.

Table 2.10: Nutrient ratios of top and subsoils of the studied soils

Profile	MAH – P1		MAH – P2	
Nutrient ratio	Top soil (0 – 13)	Sub soil (13 – 180+)	Top soil (0 – 13)	Sub soil (13 – 180+)
Ca/TEB	0.95	0.86 – 0.93	0.96	0.96 – 0.98
Ca/Mg	26.82	6.47 – 16.55	40.18	29.11 – 51.26
Mg/K	3.19	51.5 – 3.87	2.14	5.58 – 23.75
K/TEB	0.01	0.01 – 0.003	0.11	0.001 – 0.003

Ca = Calcium; TEB = Total Exchangeable Base; Mg = Magnesium; K = Potassium

2.8 Soil Classification

The results of soil classification according to USDA Soil Taxonomy-Soil Survey Staff (2006) of the study sites are shown in Table 2.11. MAH–P1 was classified as ochric diagnostic epipedon and argillic/kandic B subsurface horizon (s). MAH–P2 was classified as mollic/umbric diagnostic epipedon and argillic/kandic B subsurface horizon (s). All profiles had natrustalfs in great group, Typic Natrustalfs as a subgroup and family is straight/linear, well to excessively drain and clay soil. Therefore, the name of the soil is Alfisols.

Table 2.11: Summary of the diagnostic horizons and other features, and classification of the studied soil (USDA Soil Taxonomy-Soil Survey Staff, 2006)

Profile Name	Diagnostic epipedon(s) and subsurface horizon(s)	Other diagnostic features	Soil Taxonomy Taxa Order	Suborder	Great group	Subgroup	Family
MAH-P1	Ochric epipedon, argillic/kandic B horizon.	Very deep soil, mountainous (slope gradient 55% - straight), clayey particle size distribution, slightly to medium acid, Ustic SMR, Isohyperthermic STR	Alfisols	Ustalfs	Natrustalfs	TypicNatrustalfs	*Straight/ linear,well to excessively drained, clay,quartz, ustic, isohyperthemicTypicNatrustalfs*
MAH-P2	Mollic/umbric, argillic/kandic	Very deep soil, hilly (slope gradient 26% - straight), clayey particle size distribution, slightly acid, Ustic SMR, Isohyperthermic STR	Alfisols	Ustalfs	Natrustalfs	TypicNatrustalfs	*Straight/ linear,welltoexcessively drained, clay, quartz, ustic, isohyperthemicTypicNatrustalfs*

Table 2.12 shows the result of soil classification according to FAO–WRB World Refence Based (2006). MAH–P1 had Argic diagnostic horizon, Haplic Cutanic Lamellic and Luvisols (Abruptic, Clayic, Rhodic,Chromic) as tier 2 soil name. MAH–P2 hadMollic/Umbric diagnostic horizon, Haplic Cutanic Lamellicand Luvisols (Abruptic, Clayic, Rhodicand Chromic) as tier 2 soil name. Therefore, the name of the soil is Luvisols.

Table 2.12: Diagnostic horizons, other features and FAO-WRB soil names for the studied soil in Kiroka Village

Profile name	Diagnostic horizon(s) and other features	Reference Soil Group (RSG)	Prefix Qualifiers	Suffix Qualifiers	WRB soil name (Tier 2)
MAH-P1	Argic horizon	Luvisols/Acrisols/Lixisols/ Alisols	Lamellic, Cutanic, Haplic	Abruptic, Clayic, Rhodic, Chromic	*Haplic Cutanic Lamellic Luvisols (Abruptic, Clayic, Rhodic, Chromic)*
MAH-P2	Mollic/umbric horizon; Argic	Luvisols/Acrisols/Lixisols/ Alisols	Lamellic, Cutanic, Haplic	Abruptic, Clayic, Rhodic, Chromic	*Haplic Cutanic Lamellic Luvisols (Abruptic, Clayic, Rhodic, Chromic)*

2.9 Soil Fertility Trends of the Soils at Kiroka Village Farms

Results of soil fertility of the major soils of Kiroka farms are shown in Table 2.13. The results show that percentage of sand has negative correlation with soil clay that means there is high amount of sand compared to clay. Sand had positive correlation with bases such as Ca, P, pH and K. Which means it allows the passage of water and nutrients to the plant roots easily. Clay had negative correlation with bases such as Ca, P and K. Clay significantly correlates negatively with calcium, phosphorous, and potasium showing the role that clay plays in the retention or washing away of these cations. Organic matter positively correlates with potassium suggesting that organic matter to be the main source of these nutrients.

Nitrogen correlates positively with organic matter and potasium, which shows that N is a source of these nutrients. Calcium correlates positively with phosphorus, pH and potassium. This indicates there are inter-relationship of plant uptake of these bases from the soil. Similar findings reported that positive correlation between organic carbons with potassium and the soil type is in a good quality to support plant growth e.g. maize and banana (Msanya *et al*., 2007).

Table 2.13: Soil fertility trends of the soils at Kiroka village farms

	Silt %	Sand %	Clay %	N	OM %	Ca	Mg	P	Na	pH H2O	K
Silt %	1.000										
Sand %	0.048	1.000									
Clay %	-0.435	-0.854**	1.000								
N	0.575	0.164	-0.470	1.000							
OM %	0.520	0.314	-0.562	0.949**	1.000						
Ca	-0.106	0.829**	-0.648*	0.243	0.400	1.000					
Mg	0.232	-0.217	0.197	0.275	0.046	-0.178	1.000				
P	-0.048	0.875**	-0.749**	0.075	0.282	0.855**	-0.516	1.000			
Na	-0.295	-0.142	0.219	-0.289	-0.269	-0.088	-0.131	0.014	1.000		
pH H2O	-0.140	0.803**	-0.523	0.167	0.315	0.922**	-0.028	0.763**	-0.238	1.000	
K	0.414	0.761**	-0.918**	0.608*	0.745**	0.745**	-0.274	0.745**	-0.265	0.580	1.000

Spearman's rank correlation at 95 % confidence level; (n=11); ** significant P< 0. 01; * significant P <0.05

2.10 Conclusions and Recommendations

2.10.1 Conclusions

The following conclusions can be made from the study.

i) Soil physico-chemical characteristics differed from one profile to other under similar agro-ecological conditions. Soil physical properties had an influence on the available water content, soil strength and matric potential of which have influence on nutrient uptake and root ramification,

ii) Soil pH in both sites is acidic, low to very low exchangeable cations that had an implications on the CEC, nutrient uptake and consequently nutrient imbalances and induced toxicities,

iii) The soil have low to very low organic carbon and total nitrogen with very low organic matter of poor quality consequently lowering organic carbon and total nitrogen,

iv) Generally, the interactions among soil organic matter and total nitrogen contents with soil texture enhance the growth of maize and banana plantation.

2.10.2 Recommendations

i) Due to the low organic carbon, total nitrogen and organic matter, the use of manure, compost and plant residues were recommended to increasing organic matter content,

ii) Intercropping of cereals with nitrogen fixing legumes to enhance nitrogen in the soils,

iii) Also practicing of soil and water conservation techniques to reduce washed out of soil nutrients.

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CHAPTER THREE

3.0 ASSESSMENT OF SOIL LOSS FROM BANANA-MAIZE FARMING SYSTEM IN KIROKA VILLAGE, MOROGORO

ABSTRACT

Hillside ditch is a channel that has a supporting ridge on the lower side and constructed across the slope at defined gradient. At Kiroka, the hillside ditches were implemented in a banana and maize fields with the purpose of reducing soil loss, retain soil moisture and improving productivity of maize and bananas. The aim of this study was to investigate the performance of hillside ditches in controlling soil erosion in banana-maize farming system at Kiroka village under smallholder farmers. Sediment and runoff data were collected during long rainy season (locally called *masika*) season using runoff plots with gerlach troughs installed. The data were analyzed by using Excel computer program. The results showed that the mean seasonal soil loss was 0.067 t/ha with hillside ditches and 0.17 t/ha without hillside ditches. Runoff was 467.5 mm with hillside ditches and 1237.25 mm without hillside ditches. The results showed that maize yields was 5911.10 kg/ha with hillside ditches and 2808.611 kg/ha without hillside ditches. The plots with hillside ditches performed well in terms of grain size and quantity. More effort is needed to ensure that the concept of hillside ditches is taken up by the government and adopted by the majority of smallholder farmers especially located in mountainous area.

Keywords: hillside ditch; run-off; soil losses; runoff plots; smallholder; Tanzania

3.1 INTRODUCTION

Soil erosion is a key issue in mountain regions worldwide (Leh *et al.,* 2013; Mandal and Sharda, 2013; Haregeweyn *et al.,* 2013; Wang and Shao, 2013). Mountain soils develop in very sensitive environments subject to natural and anthropic disturbances (e.g. Cerdà and Lasanta, 2005; Vanwalleghem *et al.,* 2011; Van der Waal *et al.,* 2012 and GarcíaOrenes *et al.,* 2012). Also mountain soils are often located at the interface with densely settled areas, which may be considerably affected by sediment release from upstream erosion (Ziadat and Taimeh, 2013; Cao *et al.,* 2014; Lieskovsky and Kenderessy, 2014). Considering that mountain soils are generally shallow and their fertility is often concentrated in the uppermost layers. Soil erosion represents a crucial problem affecting the landscape at different scales and is a serious challenge for land management and soil conservation (García-Ruiz and Lana-Renault, 2011; Angassa *et al.,* 2014 and Bravo Espinosa *et al.,* 2014).

In the Uluguru Mountains where interrills, rill, tillage and landslide processes are dominant, they result in mean soil loss ranging from 91–258 t/ha/year (Kimaro, 2003). According to Mahoo (2012), the problem of soil erosion in Kiroka Village is influenced by different human activities including farming on steep slopes. Also soil loss and runoff are the main threats to soil and water conservation in the steep slopes of the Uluguru Mountains (Kingamkono *et al.,* 2005). Soil erosion by water is defined as the detachment and displacement of soil particles by water, resulting in the development of rills and interrills (Govers *et al.,* 1998).

In solving the problem of soil erosion, different soil conservation techniques have been implemented in Lushoto, Uluguru Mountains, Mbinga and other areas in Tanzania.

Specific examples from Tanzania are terraces and grass strips in Lushoto District, Tanga region (Tenge, 2005) and hillside ditches in Kiroka village, Morogoro Region (Mahoo, 2012). A hillside ditch is a channel that has a supporting ridge on the lower side and constructed across the slope at defined gradient (Natural Resources Conservation Service, 2009).

Soil and water conservation efforts typically followed a physical planning approach, with an overriding concern to control runoff and prevent loss of soil by gully erosion. Emphasis was on physical structures to stop runoff by trapping it in situ (tied ridging, *fanya juu* terraces) or discharging it into "protected" waterways. This was typical of the approach of the HADO in Dodoma district (Kalineza *et al.,* 1999) and HASHI projects in Shinyanga district (Tanzania, 1996) and they registered limited success. Also the Soil Conservation and Agro-forestry Programme in Arusha (SCAPA) and LAMP (Local Land Management Programme) have achieved greater success from a multidisciplinary approach with improved agronomic and biological measures to not only reduce soil loss but more importantly to maintain and enhance overall soil productivity (Celander *et al.,* 1996). This has demanded a more community based approach with a strong component of farmer participation.

Soil and water conservation measures (for example, based on the *ngoro* systems) have demonstrated higher productivity returns to land and labour (with or without fertilizer application) (Malley *et al.,* 2003). Soil moisture management has been shown to be as important as nutrient management, especially in drier areas and significant improvements can be achieved by making more effective use of rainfall with mulch, cover crops and reduced tillage (Kalineza *et al.,* 1999). An important lesson for SLM initiatives can be drawn from the experiences of the HADO government livestock destocking policies in

Dodoma and Kondoa Districts (Kalineza *et al.,* 1999). These destocking initiatives proved to be highly unpopular with local farmers. An important lesson is that deliberate efforts are required to bridge gaps in perceptions on land degradation and solutions between the government and local stakeholders. Where local stakeholders are not convinced of the necessity of limiting access to natural resources, they will not be willing to cooperate.

Soil erosion can be assessed through a wide set of indirect and direct methods with different approaches as reviewed by Konz *et al.* (2012). Indirect methods include RUSLE (Revised Universal Soil Loss Equation) which derived from USLE (Wischmeier and Smith, 1978; Schwab *et al.,* 1993 and Renard *et al.,* 1997). This is the most widely accepted empirical method, which originally applied at plot scale, is now being applied on catchments in a wide set of environments, including semi-natural ecosystems. Examples, Meusburger *et al.* (2010) in the Swiss Alps, by Haile and Fetene (2012) in Ethiopia, by Ligonja and Shrestha (2013) in Tanzania and Taguas *et al.* (2013) in Spain were reported that RUSLE/USLE are widespread used in mountain areas. Another indirect method is the Soil Loss Estimation Method for Southern Africa (SLEMSA) that was developed in Zimbabwe (Elwell, 1978). In this method, the annual soil loss rate is usually correlated with rainfall, soil erodibility, length and steepness of slope, crop and crop management and soil conservation measures.

The direct method includes the use of conversional runoff plots or use of erosion pins or pegs and stakes or the use of tracers such as fluorescent dyes to monitor soil creep and small agricultural watershed with appropriate monitoring equipment. However, the conventional runoff plots technique is perhaps the most widely used method of estimating soil erosion (Kimaro *et al.,* 2008). Farmers use hillside ditches to protect their land from erosion, help redirect small amounts of rainwater into stable areas, break long slopes into shorter segments to intercept surface runoff and therefore reduce surface run off. These ditches have already shown positive results in many areas in Tanzania involving a variety of crops. For instance in Kiroka village, Morogoro Region, hillside ditches were implemented for reducing soil loss and increase crop productivity in both banana and maize crop farms (Mahoo, 2012). The main objective of the study was to assess the effectiveness of hillside ditches on controlling soil erosion in a banana-maize farming system at Kiroka village under smallholder farmers. The specific objectives of the study were the following:

i) Quantify soil losses in the fields with and without hillside ditches
ii) Determine the runoff volume in the fields with and without hillside ditches and
iii) Determine influence of hillside ditches on improving maize and banana crop yield.

3.2 Methodology

3.2.1 Description of the study area

3.2.1.1 Location

The study was carried out in Kiroka village, Morogoro Rural District, Morogoro Region (Fig. 3.1). Kiroka Village is situated in Morogoro Rural District and is about 35 km from Morogoro town along the Morogoro- Matombo road. This village lies between 6^0 25'S and 6^0 50'S and $37^0$30'E and $37^0$49'E at an altitude of 887m asl. The village is along the lower reaches of Mahembe, Mwaya and Kiroka- river valleys.

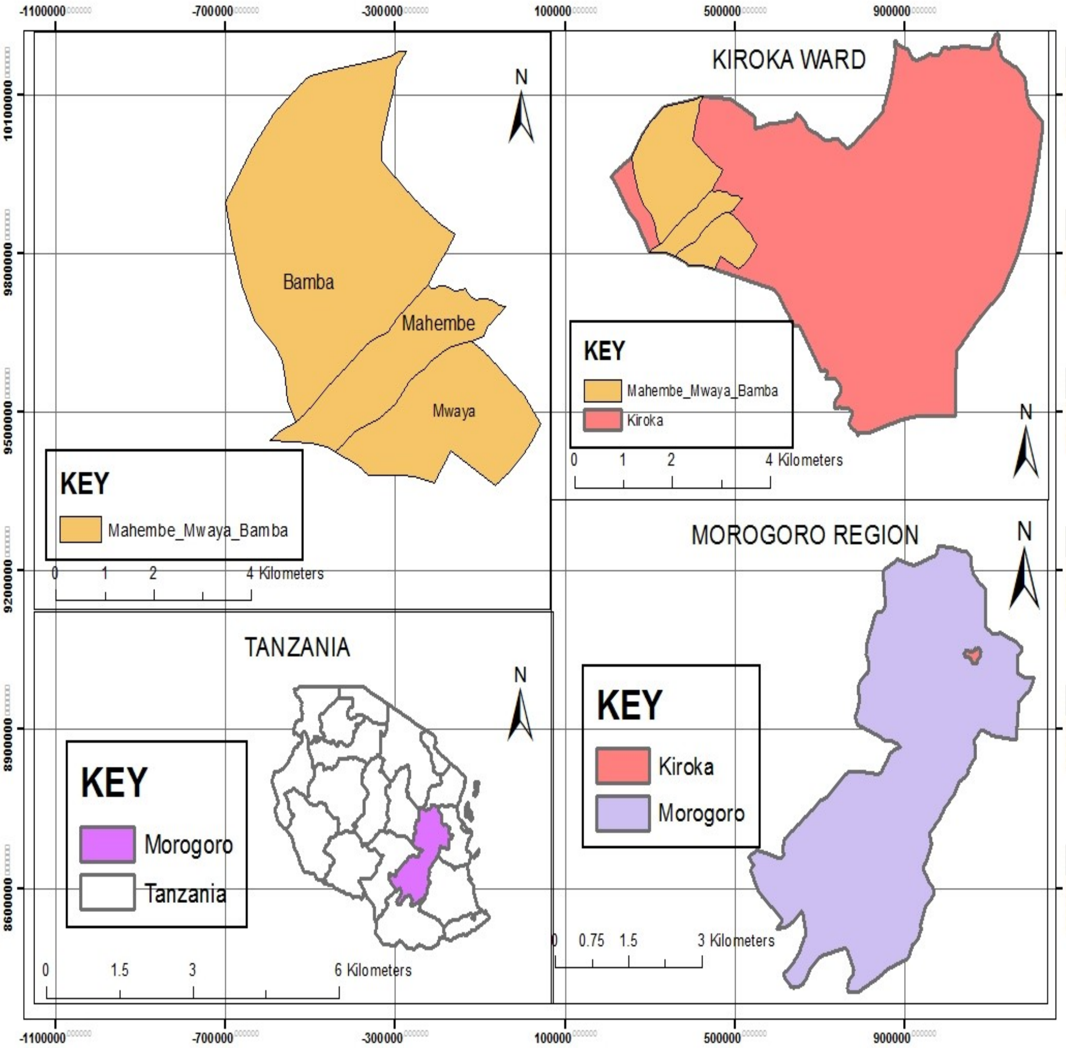

Figure 3.1: Location of the Study Area

3.2.1.2 Climate

The study area receives an average of 1100mm rainfall per annum (Tanzania Meteorological Agency, 2015) while the annual evapo-transpiration is 1775 mm. The rainfall pattern is weakly bi-modal with two rainy seasons from October to late January and from mid-February to May respectively. The driest months are June to September. Figure 3.2 shows the mean annual rainfall, minimum and maximum temperature of the study area (Tanzania Meteorological Agency, 2015).

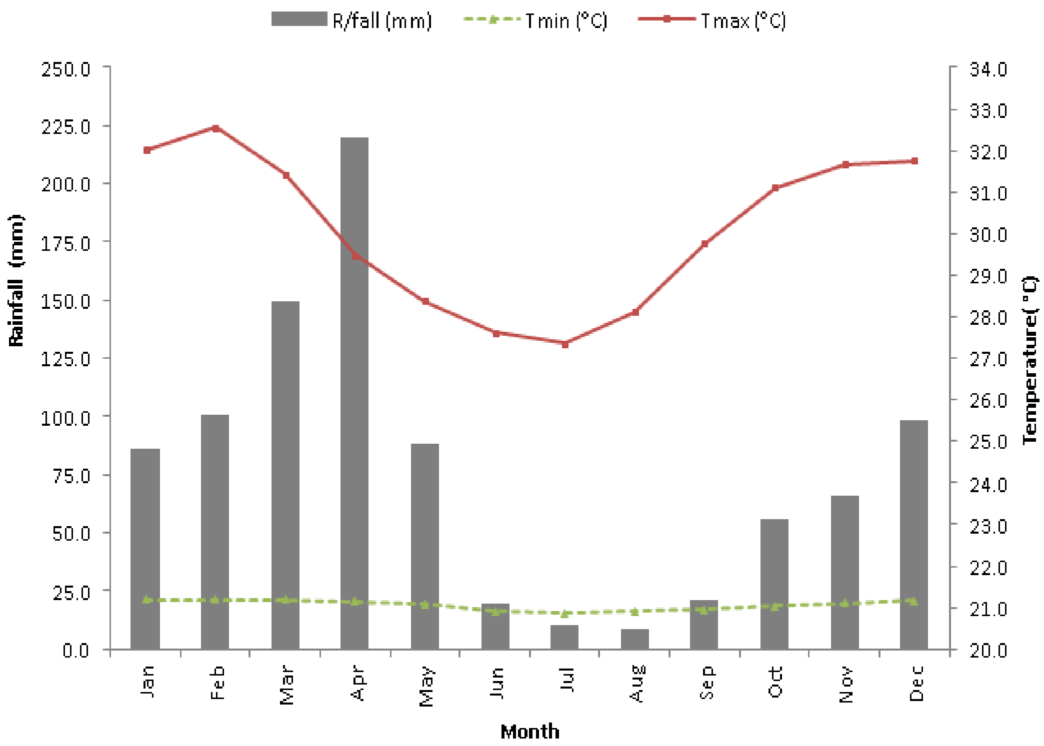

Figure 3.2: Mean annual rainfall, maximum and minimum temperature of the study area (1988 to 2007)

Source: Tanzania Meteorological Agency (2015)

3.2.1.3 Soils

The area is mountainous with strongly dissected mountain ridges and foothills with one big river called Kiroka River used for irrigation in the lowlands. The rocks are meta sediments mainly consisting of hornblende pyroxene granulites, with plagioclase and quartz rich veins (Sampson and Wright, 1964). Based on the World Reference Base for Soil Resources system of soil classification (FAO-WRB, 2006), the soils in the study area are Luvisols. Over 70% of the Kiroka village is under cultivation. The study area is mainly cultivated with maize (Zea mays L.) vegetables, beans and bananas as main crops.

3.3 Methods

3.3.1 Runoff plots experiments

The preparations of the experimental site started in December 2014. This included establishing eight farmer field plots as experimental plots and installing the Gerlach troughs. Four plots of 12m by 3m were established at conserved and other four plots at non-conserved fields with a slope gradient ranging from 20% to 60% respectively. The total number of troughs used per plot was three (3). Therefore, 24 troughs were used for the whole experiment. Figure 3.3 shows the experimental plots location.

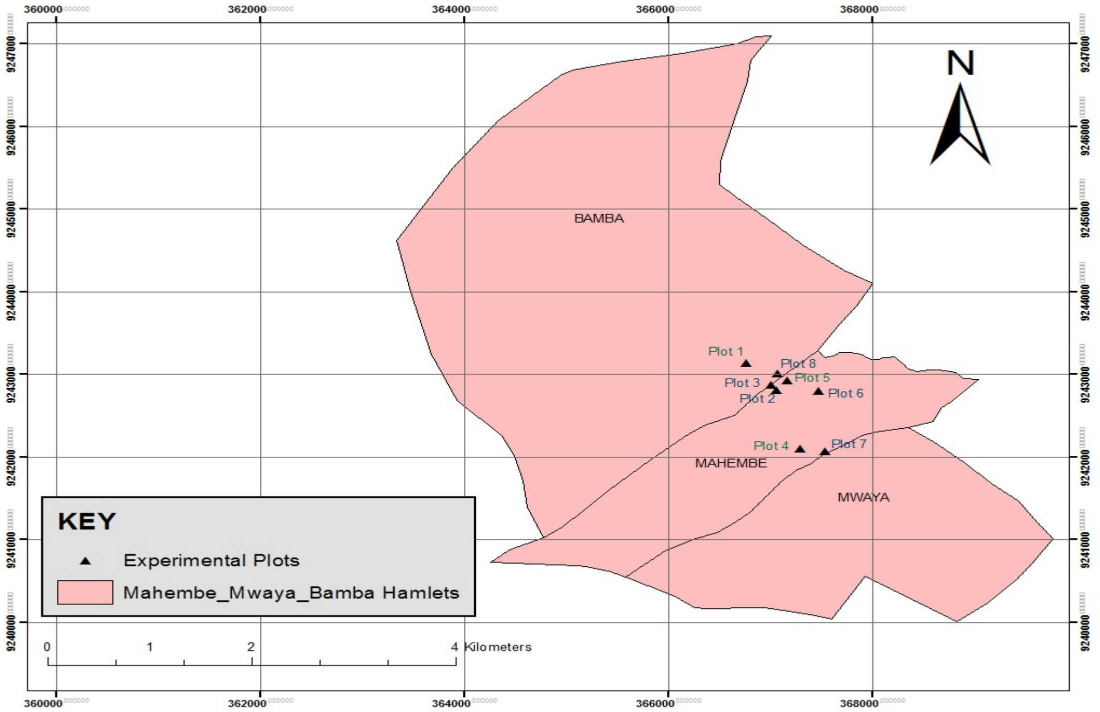

Figure 3.3: Experimental plots location

The rate of soil loss was determined on two areas: the first in farms with hillside ditches and second the farms without hillside ditches. The selection of these farms was mainly based on the farmers who participated in the project "Strengthening the capacity for climate change adaptation through sustainable land and water management" implemented by SUA and facilitated by FAO shown in Table 3.1.

Table 3.1: Selected farms used for the determination of soil loss in the study area

Farm No.	Slope (%)	OC (%)	Sand (%)	Silt (%)	Clay (%)	Si/C ratio	BD (kg/m^3)	OM (%)
Conserved								
H3	20	0.95	71	10	19	0.53	144	1.63
H4	60	1.08	61	8	31	0.26	143	1.86
H5	20	0.07	67	6	27	0.22	128	0.12
H8	60	1.08	52	6	48	0.13	123	1.86
Non-conserved								
H1	20	1.32	47	10	43	0.23	132	2.27
H2	60	0.95	63	6	31	0.19	136	1.63
H6	60	1.16	63	8	29	0.28	145	2.00
H7	20	1.38	63	8	29	0.28	122	2.37

*si/c = silt/clay ratio, BD = bulk density, OM, = organic matter; H1, H2, H6 and H7 are runoff plots without hillside ditches. H3, H4, H5 and H8 are runoff plots with hillside ditches

Total soil loss was measured from 24 individual bounded plots each measuring 3 m×12 m shown in Figure 3.4 and equipped with Gerlach troughs (Sutherland and Bryan, 1989) each with a capacity of 45 litres. The plots were bounded by pieces of wood that protruded 15 cm above the soil surface to prevent inflow and outflow from the plot borders. The Gerlach trough shown in Figure 3.4 has a dimension of 0.5m long, 0.3m wide and 0.3m deep, closed at the sides, having a lip at the up slope side, and fitted with a hinge (movable) lid which was used to measure soil loss from sloping lands (Gerlach, 1967). The agriculture activities such as land preparation, planting and weeding on these erosion plots were done under the supervision of researcher and in accordance with the usual farmers' practice. Sediments and runoff water were collected after every rainfall event from March 2015 to May 2015.

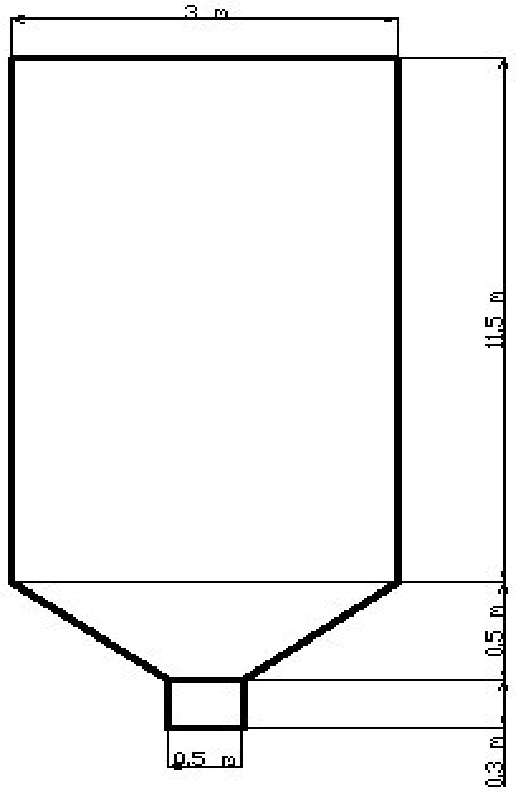

Figure 3.4: Bounded plot for determination of soil loss using Gerlach troughs on farmers fields at Kiroka Village

3.3.2 Experimental design

Closed runoff plots of 12 m x 3 m in a split plot design were set along the lower ridge slopes ranges from 20% to 30%. Maize (Zea Mays) and Bananas were planted in the rainy season (March 2015 to May 2015). Maize was planted in a spacing of 70cm row to row and 30cm plant to plant, during the long rainy season (locally called *masika*). The treatments included in runoff plots were fields with and without hillside ditches in bananas and maize farming systems.

3.3.3 Runoff plots technique

The construction of the runoff plots was as described above; soil and runoff water from each plot was collected after every erosive rainstorm or a group of smaller storms. For each runoff events, the height of water in the trough was measured using a ruler. The runoff is expressed in millimeters (mm) and its rate is in mm/season. The sediment and runoff were then thoroughly stirred and a sample of one litre was taken from the stirred contents. The runoff sample was taken to the laboratory for sediment concentration determination. In the laboratory, the one litre sample was filtered, dried and weighed. The weight (g) of the sediments was determined. The rates of soil loss obtained were expressed in t/ha/season.

3.3.4 Maize yields

Three sub areas of one meter square categorized as top, middle and bottom in each field plot were located in the maize farms from which maize crop was harvested for determination of yields. The harvested maize was weighed after drying, the weight was in kg/plant and expressed in Kg/ha by multiplying with 44 444 plants/ha. The common population for maize recommended in East Africa is 44 444 plant/ha (Mugendi *et al*., 1996).

3.3.5 Analysis of results

Statistical analysis of the results were done using the Microsoft Excel program and results presented in histograms.

3.4 Results and Discussion

3.4.1 Soil losses and runoff volume

The results of soil loss, runoff volume and rainfall from fields shown in Figure 3.5, Figure 3.6 and Appendix 1. Fields without hillside ditches suffered more soil erosion two times compared to the fields with hillside ditches, because there were under steep slopes about 20% to 60% thus easy for top soil to be washed out during heavy raindrops. The study carried out in Lushoto by Mwango *et al*. (2015) reported that conservation techniques were able to reduce soil loss and runoff volume as well as improve crop production. Extensive soil erosion was evident after every rainfall event.

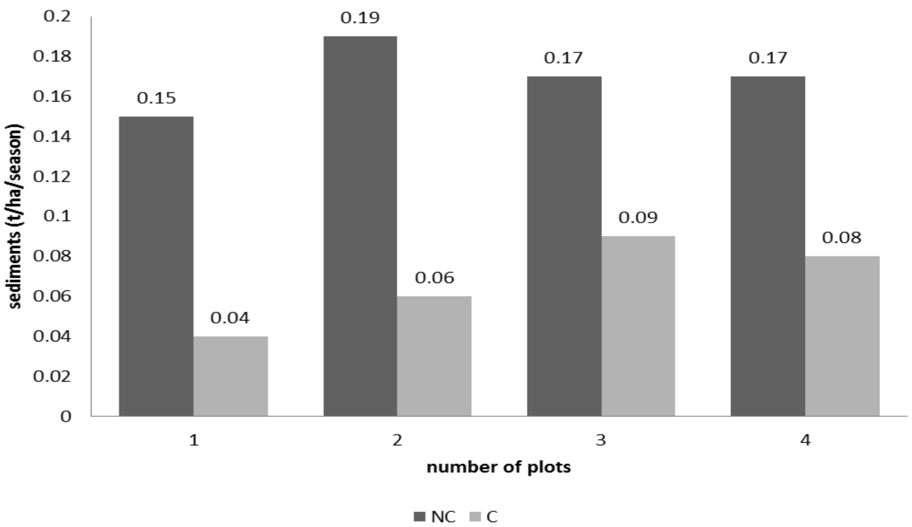

Figure 3.5: Soil loss from fields with (C) and without (NC) hillside ditches

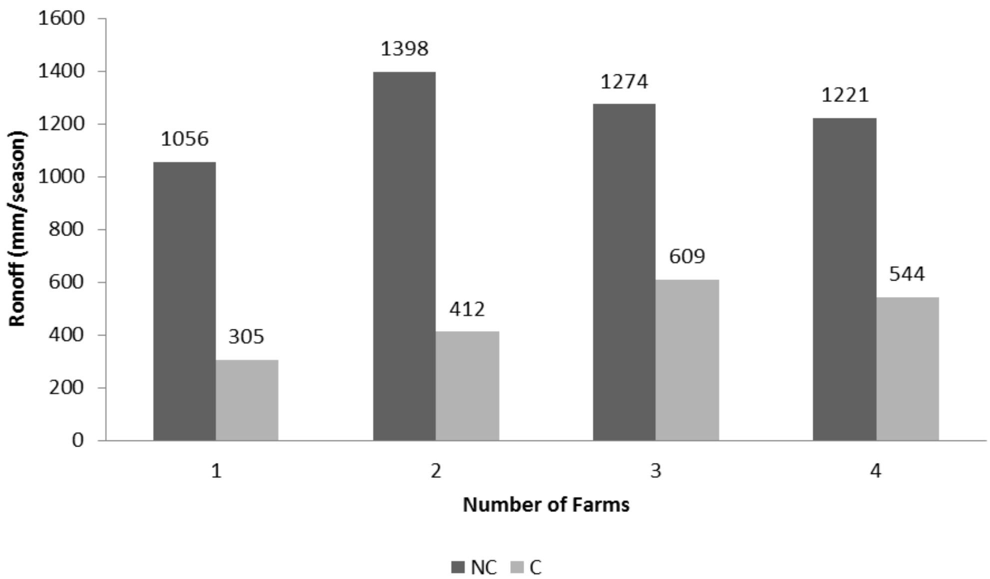

Figure 3.6: Runoff volume from fields with (C) and without (NC) hillside ditches farms

The soil loss, runoff and maize yield from the plots with and without hillside ditches are as follows. The total soil loss was 0.067 t/ha/season in hillside plots while 0.17 t/ha/season in plots without hillside ditches, total runoff volume was 467.5 mm/season in the plots with hillside ditches while 1237.25 mm/season in plots without hillside ditches. This implies that the plots with hillside ditches have small amount of soil loss and runoff volume compared to the plots without hillside ditches, because hillside ditches reduces the slope length and width, therefore the water flows in a low speed and stored in the ditches. The total season maize yields were 5911.10 kg/ha/season in plots with hillside ditches which is higher in fields compared to those without hillside ditches which was 2808.61 kg/ha/season.

3.4.2 Determining the influence of hillside ditches on improving maize crop yield

Results of maize crop yields from fields with and without hillside ditches were shown in Figure 3.7. Fields without hillside ditches have low maize yields per season compared to the fields with hillside ditches.

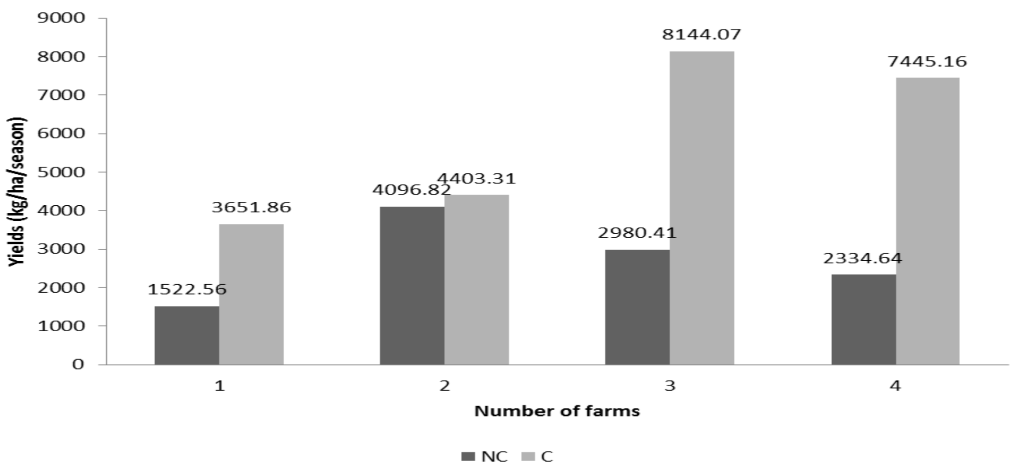

Figure 3.7: Maize yield under with (C) and without (NC) hillside ditches farms

All sites received adequate rainfall of about 503 mm during the experimental period. The water retention in ridges can attribute the difference in grain yield in hillside ditches fields, which was available during the critical grain-filling period. The positive effect of the higher soil moisture obtained during the shortage of rainfall in which the crops were continued to grow up. Measurement of total biomass production illustrates that the hillside ditches plots were producing more vegetative growth before water became limiting.

Due to the variability in environmental factors affecting crop growth such as shortage of rainfall, there is a need for long-term studies or monitoring of crop performance, particularly grain yield. If the difference in topsoil depths continues to increase due to greater soil loss on unprotected slopes, the effect of hillside ditches on soil physical and chemical properties will become more apparent as fertile topsoil will continue to disappear from the untreated fields. Correspondingly, the effect of hillside ditches on crop productivity will increase as well.

3.5 Conclusions and Recommendations

3.5.1 Conclusions

The following conclusions are made from the results of the study.

i) Hillside ditches can be used in hill slope areas for reducing soil erosion, retain soil moisture and hence improve crop production and livelihood of the smallholder farmers,

ii) The quantity of soil lost and runoff volume in farms with hillside ditches was low compared to the farms without hillside ditches. Hence hillside ditches perform well on controlling soil loss and reducing the amount of runoff volume,

iii) In maize production, the plots with hillside ditches performed compared to the farms without hillside ditches.

3.5.2 Recommendations

i) More effort is needed to ensure that the concept of hillside ditches is taken up by the government and adopted by the majority of smallholder farmers especially located in mountainous area.

ii) Government extension officers and researchers should train farmers located in mountainous areas to use SWC measures such as grass strips and ridges for controlling soil erosion.

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CHAPTER FOUR

4 .0 SOCIO-ECONOMIC BENEFITS OF HILLSIDE DITCHES TECHNIQUE IN BANANA-MAIZE FARMING SYSTEM IN KIROKA VILLAGE, MOROGORO, TANZANIA

ABSTRACT

Soil erosion by water is a growing problem in Tanzania particularly in mountainous areas. The control of soil erosion is one of the most significant issues, which results in improving crop production as well as smallholders' income. A study was carried out to examine the socio-economic benefits of banana and maize farming system under conserved and non-conserved fields in Kiroka village. The methodology included conducting a base line survey using tools like questionnaire, checklist and key informants interviews. Ninety eight (98) respondents were drawn from Mahembe, Bamba and Msamvu hamlets. The data collected was analyzed and synthesized using the SPSS and Excel Computer programmes. Results showed that, majority of the respondents (76.3%) were aware of soil erosion and SWC techniques. The major constraints, which farmers face during crop production is shortage of rainfall. The Gross Margin analysis (GMA) for maize under conserved farms was 64.6%, which was higher compared to non-conserved farms with 57.2%. The GMA for banana farming system was 48% under conserved farms, compared to non-conserved farms of 43%. Some of the social benefits is farmers were able to pay school fees, build good houses and buy good seed.

Key Words: Soil erosion; conservation; farming system; Tanzania

4.1 INTRODUCTION

Soil erosion is a major threat in agricultural systems, as it reduces soil fertility and results into loss of crop productivity. Soil erosion also increases production costs to maintain the level of agricultural production in the farm. Soil and water conservation (SWC) technologies that have been practiced worldwide especially in East Africa show positive impacts in improving crop production, reducing soil erosion and soil moisture loss (Celander *et al.,* 1996 and Tenge, 2005). In addition, soil erosion has far reaching economic, political, social and environmental implications (Ananda and Herath, 2003).

Due to its economic implication, farmers are aware of this problem and of the necessity of implementing conservation measures (Martinez and Ramos, 2006). Indeed, the cost of erosion can be used as a proxy to prioritize implementation of soil conservation (Clark, 1996). A study conducted by Tenge, (2005) among smallholder farmers in the West Usambara Highlands in Tanzania estimated the financial efficiency of bench terraces, *fanya juu* terraces and grass strips. The study revealed that profitability of these SWC techniques depend on soil type, slope and opportunity costs of labor and farmers' subjective discount rates.

Consequently, smallholder farmers with farms located on extremely steep areas would need additional incentives to make soil conservation technologies economically attractive for them. Although several SWC technologies have been developed and promoted, soil erosion continues to be a problem. Major factors that negatively influence adoption of SWC measures include among others, insecure land tenure and lack of short-term benefits from SWC. A study conducted in the West Usambara Highlands in Tanzania by Tenge *et al*. (2004), on social and economics of soil and water conservation, showed that the involvement in off-farm activities, insecure land tenure and lack of short-term benefits from SWC are the factors that affect adoption of SWC by smallholder farmers. In order to have positive adoption of SWC technologies the following factors must be considered: integration of social and economic factors into SWC plans, the creation of more awareness among farmers on soil-erosion effects and long-term benefits of SWC and the development of flexible SWC practices (Tenge *et al*., 2004). A study conducted in Ethiopia by Gebre *et al.,* 2013, indicated that farmers accepted that the newly introduced conservation technologies were effective combating soil erosion and improving land productivity. However, there are factors that discourage the farmers to adopt the SWC technologies. These factors are shortage of labour, difficult designs to implement, lack of adequate extension service, shortage of land, distance of cultivation fields and source of income. Gebre *et al.* (2013) emphasized that many problems on adoption of soil and water conservation were related to a lack of farmers involvement in the conservation efforts and suggests that future SWC interventions should follow a participatory approach in the areas. In addition, farmers should have a greater awareness of the economic significance of soil erosion on their cultivated fields; they need training on the impacts of erosion and the conservation technologies available to control soil loss; and farmers with labour shortages need to be provided with support that enables them to retain their conservation technologies.

According to Siachinji-Musiwa (1999), farmers have experienced a decline in soil productivity and continued water shortages in low rainfall areas and they consider these problems to be a natural course, which cannot be avoided. Farmers responses to soil erosion can be categorized into three options. The first one can be both technical (such as cropping patterns, slopes and type of soil) and socio-economic (such as farmers age, skills, land ownership and labour availability). The second option is to intensify production substituting other inputs (such as fertilizers) for top soil depth though fertilizer increases production costs. The third option is to adopt new practices to conserve soil. Since the 1950s, farmers have paid a lot of attention to the options that determine the adoption of soil conservation practices (Franco and Leyva, 2006).

Other factors commonly found in the literature to be related with the adoption of soil conservation practices include the following: the level of non-farming income, labour and/or machinery availability, land tenancy issues (property incentives and investments), the level of risk aversion, continuity of family members(sons/relatives) in farming and the existence of supportive public programmes (Tenge, 2005).

The effects of soil degradation and water shortages on crop productivity have led researchers. Example, in Kiroka village some innovative practices such as mulching, bunding, contour ridging, ripping and minimum tillage were introduced in order to improve agricultural production (Mahoo, 2012). The main objective is to assess the performance of soil and water conserved measures implemented at Kiroka Village farms while the specific objectives were the following:

i) To assess the community awareness and perception on soil erosion, soil and water conservation measures,
ii) To assess the major constraints facing farmers in crop production and
iii) To assess socio-economic benefits of soil conservation measures practiced by the communities in the study area.

4.2 Methodology

4.2.1 Description of the study area

4.2.1.1 Location

The study was carried out in Kiroka village, Morogoro Rural District, Morogoro Region (Fig. 4.1). Kiroka Village is situated in Morogoro Rural District and is about 35 km from Morogoro town along Morogoro-Matombo road. This village lies between 6^0 25'S and 6^0 50'S and $37^0$30'E and $37^0$49'E at an altitude of 887 m above sea level (asl). The village is along the lower reaches of Mahembe, Mwaya and Kiroka- river valleys.

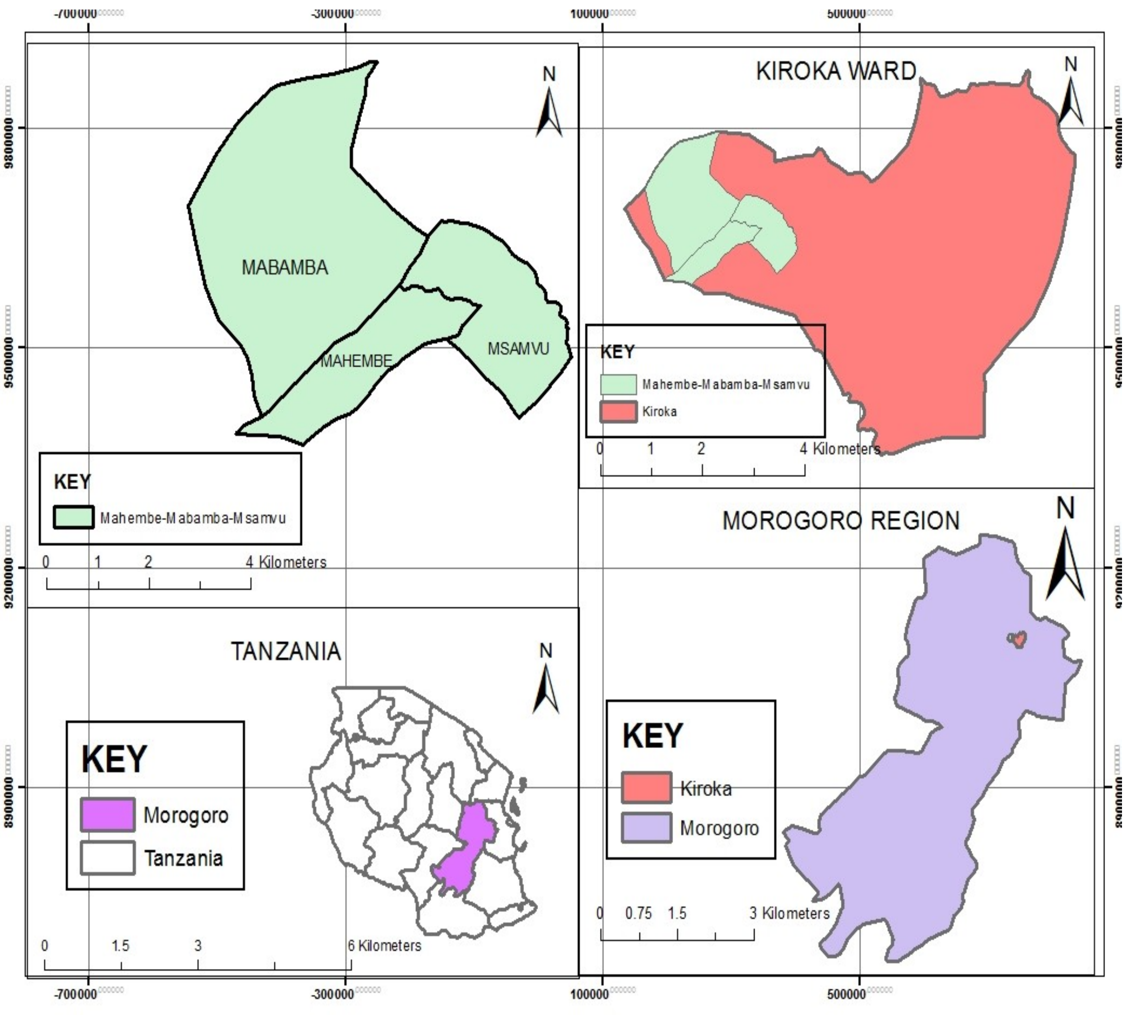

Figure 4.1: Location of the study area

4.2.1.2 Climate

The study area receives an average of 1100 mm of rainfall per annum (Tanzania Meteorological Agency, 2015) while the annual evapo-transpiration is 1775 mm. The rainfall pattern is weakly bi-modal with two rainy seasons from October to late January (locally called *vuli*) and from mid-February to May (locally called *masika*) respectively. The driest months are June to September. Figure 4.2 shows the rainfall and temperature distribution for the Morogoro region from 1988 to 2007 (Tanzania Meteorological Agency, 2015).

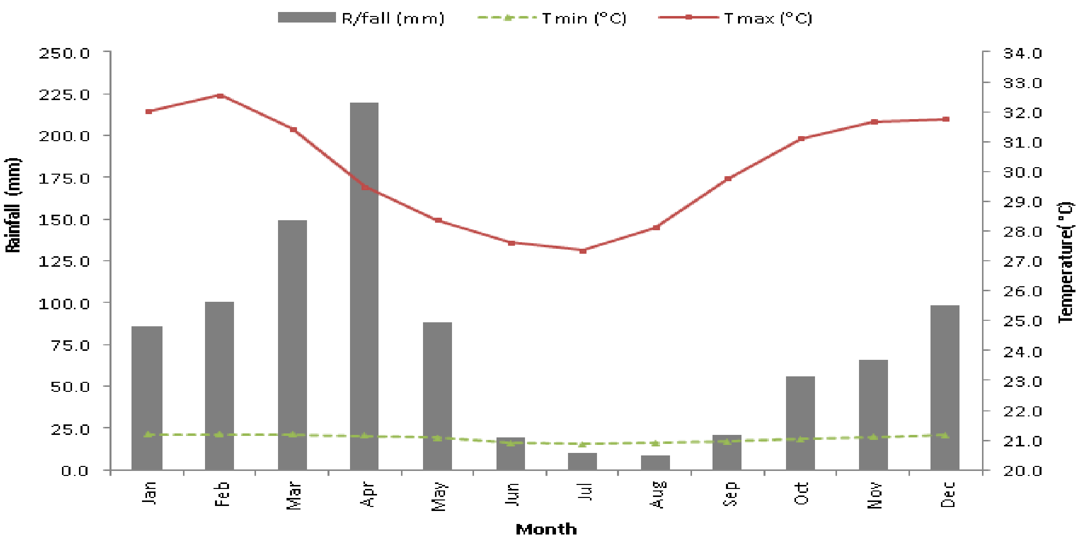

Figure 4.2: Morogoro monthly average rainfall, maximum and minimum temperature (1988 to 2007)

Source: Tanzania Meteorological Agency (2015)

4.3 Methods

4.3.1 Data collection

Data collection involved structured interviews using a questionnaire as shown in

Appendix 2, checklist, informants interview and focus group discussions. A team of enumerators was recruited, trained on the questionnaire administration in order to develop a common understanding and interpretation of the questions. The questionnaire was then pre-tested.

The pre-testing was done in Msamvu hamlet and was carried out by the enumerators with a close monitoring of the researcher. The questionnaire was administered to six farmers, starting with two farmers per enumerator. Discussions with the researcher were done after every interview to elaborate issues that were not tackled well during pre testing. Key informants interview and Focused Group Discussions (FGDs) were carried out in the surveyed villages. Meetings were held with the identified groups in their respective villages to discuss issues on soil erosion and SWC measures in their villages. A total sample of 98 respondents was drawn from Mahembe, Mabamba and Msamvu hamlets. Thirty respondents used conservation techniques in their fields while 68 respondents did not use any soil and water conservation techniques.

4.3.2 Data analysis

Data collected during the questionnaire survey was analyzed and synthesized using the Statistical Package for Social Science (SPSS) version 16 for Windows and Excel Computer programmes. The questionnaires were coded for identification purposes. Each question was identified by a variable name and within variables there were values and value labels for identification of responses from the respondents. After coding the information from the questionnaires, template for entering data in the computer program was created. The coded data was then entered in the SPSS computer program where frequencies, multiple responses, mean, standard deviations and cross tabulations were computed during the analysis. The results are presented in tables, graphs and percentages.

Information collected from the key informants and FGDs were grouped together, synthesized according to the checklist questions and summarized to make it easier for interpretations.

4.4 Results and Discussion

4.4.1 General information

Results in Figure 4.3 show that majority of the respondents were from Mahembe while only few were from Msamvu and others in Mabamba harmlet. It indicates that about 14.3% in Msamvu, 40.8% in Mahembe and 11.2% in Mabamba were male respondents while about 7.1% in Msamvu, 24.5% in Mahembe and 2% in Mabamba were female respondents. It is likely that at Mahembe there will be more labour available to implement SWC structures in their fields.

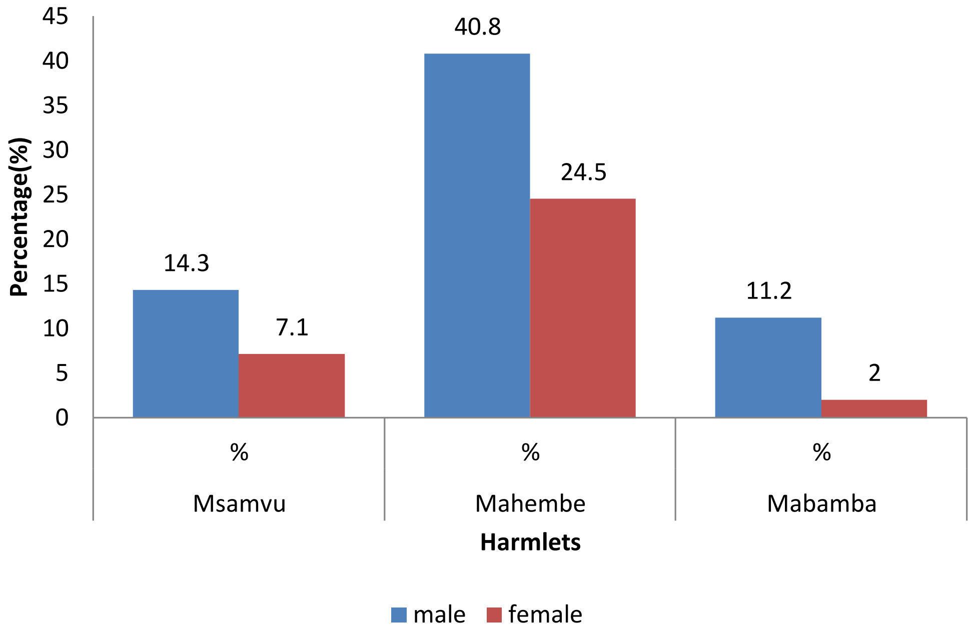

Figure 4.3: Respondents gender distribution

The results in Figure 4.4 show that about 36.7% in Mahembe hamlet has the vast majority of young people, also about 12.2% in Mabamba and Msamvu hamlets, this suggests that the labor force in the village is great. This leads to the point of creating SWC measures more efficiently. This implies that majority of Kiroka farmers were within the working age group.

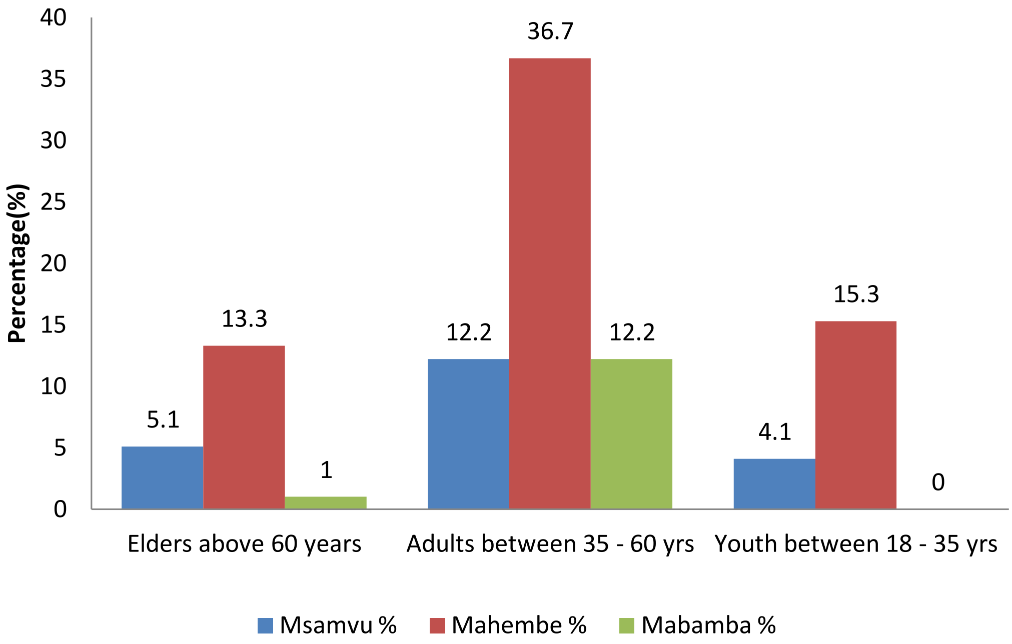

Figure 4.4: Respondents Age

4.4.2 Farmers perception on soil erosion and SWC measures

Soil erosion is a problem that occurring on the land especially agricultural land, which causes a low crop production. The farmers in Mahembe, Mabamba and Msamvu hamlets were aware of the major causes and effects of soil erosion, also the ways/measures on controlling soil erosion. The results in Figure 4.5 show that majority of the farmers (76.3%) were aware on soil erosion and SWC measures.

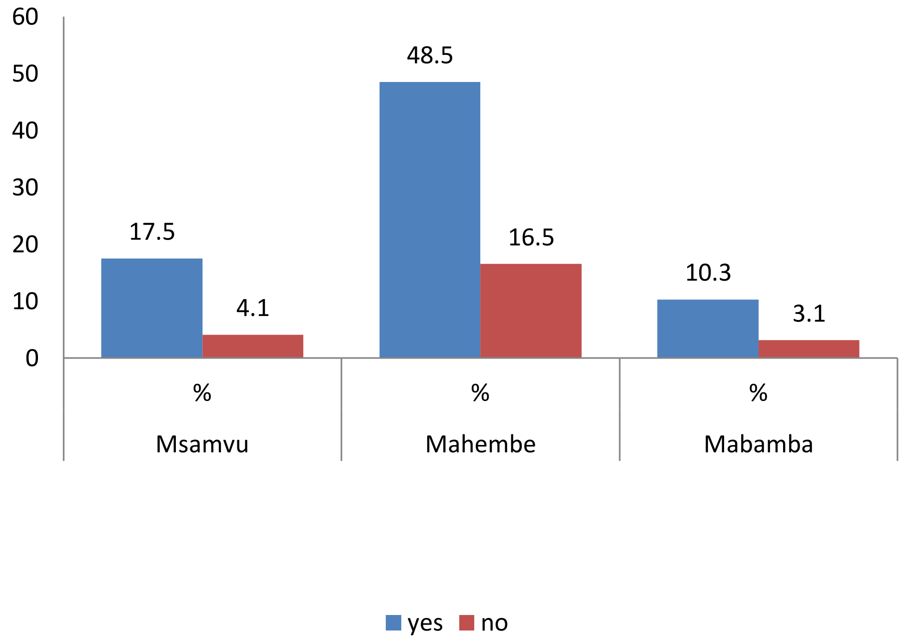

Figure 4.5: Perception on soil erosion and SWC measures

4.4.3 Causes of soil erosion

The major causes of soil erosion were deforestation, over cultivation, poor agricultural practices, cultivation on steep slopes and excessive rainfall. The results in Figure 4.6 show that excessive rainfall was the most dominant source of soil erosion. Also their farms are situated on steep slopes. Therefore, cultivation on steep slopes and poor agricultural practices are another causes of soil erosion.

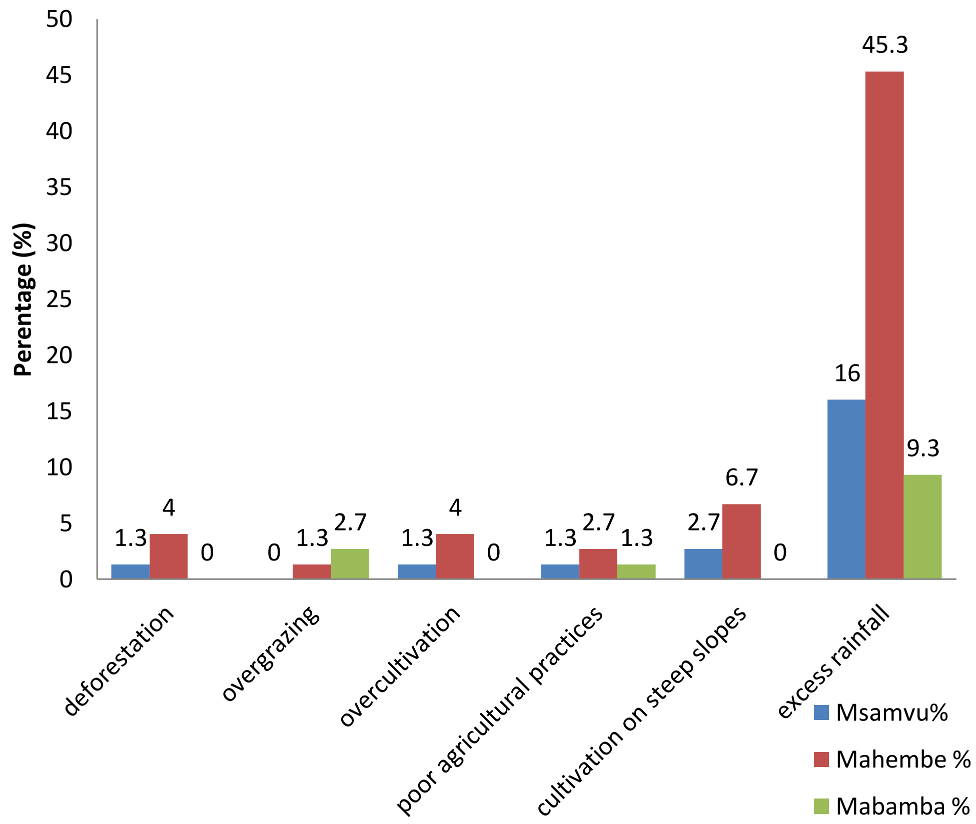

Figure 4.6: Causes of soil erosion

4.4.4 Farmers perception on the soil erosion severity over the past five years and measures on controlling soil erosion

4.4.4.1 Farmers perception on the soil erosion severity over the past five years

Change in soil erosion severity over the past five years has become more severe according to the farmers. The results in Table. 4.1 shows that 62.7% of farmers agreed there is presence of soil erosion on their farms while few farmers (29.3%) mentioned there was little erosion in their farms due to their farms location. The effects of soil erosion reported in this study by the farmers included (i) decline of the agricultural land productivity (yield) (ii) change in type of crops grown and reduced farm plots sizes. The results in Table. 4.2 show that many farmers reported the decline of the agricultural land productivity (yield) on their farms as a major problem (38.9%) followed with reduction of plot size (13.3%) and change type of crops grown (4%).

Table 4.1: Farmers perception on the soil erosion severity over the past five years

	Msamvu %	Mahembe %	Mabamba %	Total %
Has become more severe	14.7	41.3	6.7	62.7
Has become less severe	5.3	17.3	6.7	29.3
No change	2.7	5.3	0	8.0
Total	22.7	64.0	13.3	100.0

Table 4.2: Effect of soil erosion

	Msamvu %	Mahembe %	Mabamba %	Total %
Decline of land productivity (yield)	6.7	28.0	4.0	38.7
Change in type of crop grown	1.3	1.3	1.3	4.0
Reduce farm plot size	4.0	9.3	.0	13.3
All above	10.7	25.3	8.0	44.0
Total	22.7	64.0	13.3	100.0

4.4.4.2 Measures on controlling soil erosion

In Table 4.3 shows that farmers agreed soil erosion can be controlled and about 90.5% mentioned hillside ditches as one way/measure that they were practicing in controlling soil erosion on their farms because it is the easiest way to learn and it performs well in preventing the washing of nutrients and water storage field. Another way/measure included agroforestry techniques, where farmers grow crops and trees, at the same time as a way to prevent soil erosion.

Table 4.3: Measures on controlling soil erosion

	Msamvu (%)	Mahembe (%)	Mabamba (%)	Total (%)
Hillside ditch	20.6	55.6	14.3	90.5
Agroforestry	3.2	4.8	1.6	9.5
Total	23.8	60.3	15.9	100.0

4.4.5 Soil conservation practices

Throughout the discussion, farmers perceptions on the causes of soil erosion were very familiar. From the discussions, farmers said that some of the main causes of soil erosion in Kiroka village included deforestation, improper farming practices and high intensity of rainfall and absence of appropriate soil conservation practices. Many farmers in Mahembe hamlet reported that there was a great demand for conserving soil and water in their villages. Farmers suggested practices such as afforestation, provision of training on environmental conservation, avoiding bush fires and avoiding farming along or near water sources in order to conserve soils. Moreover, laws ensuring environmental conservation should be strictly enforced and penalties should be given to people who break them. The number of factors that contributed to soil degradation includes bad agronomic practices, illegal logging and removal of vegetation cover. Majority (76.3%) of the interviewed farmers reported to have faced soil erosion in their farms. On the other hand, 23.7% of respondents said they have not faced any soil erosion as shown in Table 4.4.

Table 4.4: Soil erosion is a problem in farmers farm plots

	Msamvu (%)	Mahembe (%)	Mabamba (%)	Total (%)
Yes	17.5	48.5	10.3	76.3
No	4.2	16.5	3.1	23.7
Total	21.7	64.9	13.4	100.0

Farmers used hillside ditches as a strategy to minimize soil erosion in order to encourage better root penetration and enhance moisture conservation. The most prominent factors that caused soil degradation in the study area were the removal of soil nutrients mainly through burning of crop residues (poor agronomic practices) shown in Plate 4.1. Cultivating on very steep slopes without any conservation measure is another factor shown in Plate 4.2.

Plate 4.1: Burning of farms on the slopes in Kiroka village [Photo-Helena Mkoba, 2015]

In response to such situations, farmers mentioned why they did not practice any soil conservation measures in their areas. As shown in Table 4.5, 50% of respondents said they did not practice any measures to solve the problem due to shortage of labour, 36.9% due to lack of extension services, while others about 6.2% had no problems on soil erosion and 4.2% believed that it reduces farmers' land size.

Plate 4.2: Flat cultivation on steep slopes in Kiroka village [Photo-Helena Mkoba, 2015]

Table 4.5: Reasons of not using soil and water conservation practices

	Msamvu (%)	Mahembe (%)	Mabamba (%)	Total (%)
No problem of soil erosion	0	4.2	0	4.2
Shortage of labor	14.6	25.0	10.4	50.0
It reduces farmers' land size	2.1	4.2	0	6.2
Inaccessibility of extension services	12.5	25.0	2.1	39.6
Total	29.2	58.3	12.5	100.0

4.4.6 Food production patterns, the challenges/constraints facing production and gross margin analysis

4.4.6.1 Food production patterns

The majority of the respondents depend on agriculture as their source of income. Some of the crops grown on this area were banana, maize, beans, yam, sweet potatoes and vegetables.

The results in Table 4.6 and Table 4.7 show that about 69.4% of the farmers grow banana is a cash crop and 29.6% banana as a food crop. Also in Table 4.8 and Table 4.9 shows that about 85 % of farmers grow maize as a food crop and 18% as a cash crop. Therefore, majority of the farmers depends on banana as cash crop. Most of the farmers on this area depend on rainfed agriculture, this is due to the fact that the location of their farms was situated in the slopes and this result to have low crop yield.

Table 4.6: Banana as a cash crop

	Msamvu %	Mahembe %	Mabamba %	Total %
Yes	10.2	48.0	11.2	69.4
No	11.2	17.3	2.0	30.6
Total	21.4	65.3	13.3	100.0

Table 4.7: Banana as a food crop

	Msamvu %	Mahembe %	Mabamba %	Total %
Yes	7.1	17.3	5.1	29.6
No	14.3	48.0	8.2	70.4
Total	21.4	65.3	13.3	100.0

Table 4.8: Maize as a food crop

	Msamvu %	Mahembe %	Mabamba %	Total %
Yes	20.4	53.1	13.3	86.7
No	1.0	12.2	.0	13.3
Total	21.4	65.3	13.3	100.0

Table 4.9: Maize as a cash crop

	Msamvu %	Mahembe %	Mabamba %	Total %
Yes	4.1	10.2	4.1	18.4
No	17.3	55.1	9.2	81.6
Total	21.4	65.3	13.3	100.0

4.4.6.2 Constraints to crop production

The constraints facing crop production in the target villages are shown in Figure 4.7. Higher costs during production (shortage of capital) and shortage of rainfall were widely reported constraints limiting crop production while shortage of transport, shortage of fertilizer and pests were the least reported constraints.

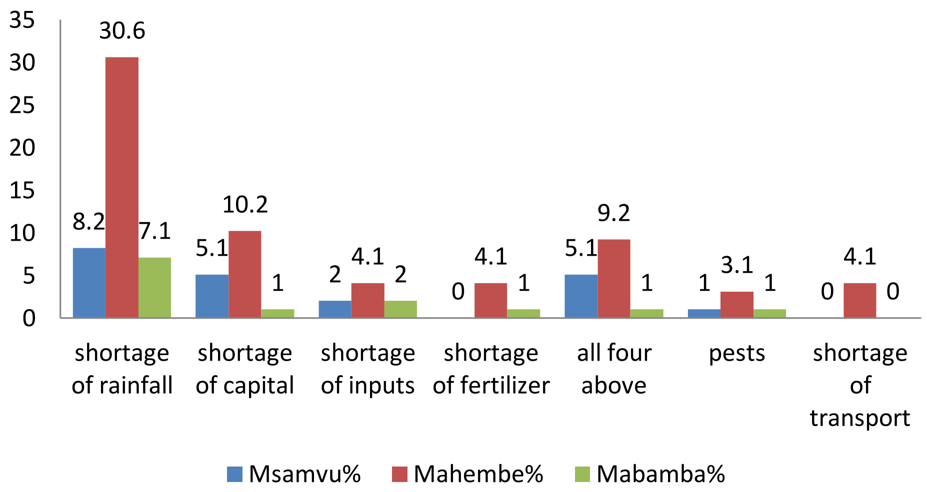

Figure 4.7: Major constraints to crop production

4.4.6.3 Gross margins analysis for crop production

Gross Margin (GM) is a technique that is used to establish economic profitability. It is given as a difference between gross income accrued and variable costs incurred. The analysis is therefore a simplified tool but in many cases, a sufficiently powerful tool for economic analysis (Makeham and Malcolm, 1986). The GM enables one to directly compare the relative profitability of similar enterprises and consequently provide a starting point to deciding or altering the farms overall enterprise mix. It is important to compare AGM of different participants of the same line of investment to know who are able to pursue their economic activities sustainably.

The Average Gross Margin (AGM) for both farmers with and without hillside ditches is presented in Table 4.10 and Table 4.11 respectively. The variables considered in computing AGM are presented in Appendix 2. Results in Table 4.10, show that the AGM and percentage gross margin analysis (PGMA) respectively for maize crop production under conserved and non-conserved farms were 389 034.19 Tshs/kg (64.6%) and 238 579.24 Tsh/kg (52.7%) respectively. The PGMA for maize crop production under conserved farms was largest compared to that of non-conserved farms. This could be because majority of farmers who practices hillside ditch technique on their fields they grow maize as their source of income which helped them to improve their income and manage to take their children to the school due to the higher returns they have earned.

Table 4.10: Gross margins for maize crop production

Practices	Description	Sales/Costs (Tshs)	Percent (%)
Conserved	average revenue (Tshs)	602136.75	
	minus		
	average costs (Tshs)	213102.56	
	AGM	389034.19	64.6
Non-conserved	average revenue (Tshs)	416775.96	
	minus		
	average costs (Tshs)	178196.72	
	AGM	238579.24	57.2

Note: AGM=Average Gross Margin and is given in (Tshs/kg)

The AGM for farmers with and without hillside ditches and growing bananas is presented in Table 4.11. The results show that, the AGM and PGMA for banana crop production under conserved and non-conserved farms were 772 543.86 Tshs/kg (48%) and 299 575.00 Tsh/kg (43%) respectively. The PGMA for banana crop production under conserved farms is higher compared to that of non-conserved farms. This could be because majority of farmers who practices hillside ditch technique on controlling soil erosion in their fields which they grow banana. According to the farmers, banana is a cash and food crop.

Table 4.11: Gross margins for banana crop production

Practices	Description	Sales/Costs (Tshs)	Percent (%)
Nonserved	average revenue (Tshs)	1607543.86	
	minus		
	average costs (Tshs)	835000.00	48
	AGM	772543.86	
Non-Conserved	average revenue (Tshs)	696000.00	
	minus		
	average costs (Tshs)	396425.00	
	AGM	299575.00	43

Note: AGM=Average Gross Margin and is given in (Tshs/kg)

4.4.7 Different ways to improve crop production

The different ways to improve crop production are shown in Table 4.12 were irrigation practices, improved extension services and increases of extension officers are the major improvement to crop production while education, government support and improved infrastructure are the least reported constraints.

Table 4.12: Improvements on crop production

	Msamvu (%)	Mahembe (%)	Mabamba (%)	Total (%)
Irrigation practices	3.1	20.6	4.1	27.8
Improve extension services	5.2	18.6	6.2	29.9
Increase extension officers	1.0	8.2	1.0	10.3
Education	3.1	4.1	1.0	8.2
Government support	2.1	2.1	0	4.1
Improve infrastructure	.0	2.2	.0	2.2
All above	7.2	9.3	1.0	17.5
Total	21.6	65.0	13.4	100.0

4.5 Conclusion and Recommendations

4.5.1 Conclusions

The following conclusions can be made from the results of the study area.

i) Kiroka farmers were aware of soil erosion and knowledgeable on soil and water conservation measures that used to reduce/control soil erosion on their plots.

ii) The few farmers who implemented hillside ditches on their farms reported that soil erosion was controlled and they realized higher crop yields of maize and bananas.

iii) As a result, these farmers were able to pay school fees for their children, food secure and had increased income to buy agricultural inputs.

4.5.2 Recommendations

i) The government in collaboration with donors needs to support the farmers on constructing SWC measures to those who fail to implement it.

ii) The farmers who already have the knowledge should train others to implement the SWC measures.

iii) In addition, farmers should have a greater awareness of the economic significance of soil erosion on their cultivated fields; they need training on the impacts of erosion and the conservation technologies available to control soil loss.

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CHAPTER FIVE

5.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 General conclusions

The following conclusions can be made from the study

i) The physical and chemical soil characteristics in the Kiroka fields differed from one profile to other under similar agro-ecological conditions. Soil physical properties had an influence on the available water content, soil strength and matric potential of which have influence on nutrient uptake and root ramification,

ii) The soil pH in the study sites was acidic, had low to very low exchangeable cations that could have implications on the CEC, nutrient uptake and consequently nutrient imbalances and induced toxicities,

iii) The soil in the study sites had low to very low organic carbon and total nitrogen with very low organic matter of poor quality consequently lowering organic carbon and total nitrogen,

iv) Generally, the interactions among soil organic matter and total nitrogen contents with soil texture enhanced the growth of maize and banana plantation.

v) Hillside ditches reduced soil erosion, retained soil moisture and hence improved crop production and livelihood of the smallholder farmers in the study area. The quantity of soil lost and runoff volume in farms with hillside ditches was least in amount compared to the farms without hillside ditches.

vi) Kiroka farmers were aware of soil erosion and knowledgeable on soil and water conservation measures that used to reduce/control soil erosion on their plots. The few farmers who implemented hillside ditches on their farms reported that soil erosion was controlled and they realized higher crop yields of maize and bananas. As a result, these farmers were able to pay school fees for their children, food secure and had increased income to buy agricultural inputs.

5.2 General recommendations

The following recommendations can be made from the study

i) Due to the low organic carbon, and organic matter, the use of manure, plant residue and compost were recommended to increasing organic matter content,

ii) Intercropping of cereals with nitrogen fixing legumes to enhance nitrogen in the soils,

iii) Practicing of soil and water conservation techniques to reduce washed out of soil nutrients,

iv) The Government extension officers and researchers should train farmers to use local ways such as grass strips and ridges for controlling soil erosion and the farmers who already have the knowledge should train others to implement the SWC measures.

v) The government in collaboration with donors through different projects should support farmers in constructing SWC measures.

APPENDICES

Appendix 1: Soil loss, Runoff and Rainfall data

	Treatments	Soil loss (t/ha/season)	Runoff (mm)	Rainfall (mm)
10.4.2015	H1	0.0000	0	16.2
	H2	0.0128	90	
	H3	0.0011	10	
	H4	0.0000	0	
	H5	0.0063	40	
	H6	0.0102	70	
	H7	0.0000	0	
	H8	0.0011	8	
21.4.2015	H1	0.0188	140	19.2
	H2	0.0313	230	
	H3	0.0047	30	
	H4	0.0044	30	
	H5	0.0160	120	
	H6	0.0035	20	
	H7	0.0184	140	
	H8	0.0099	65	
23.4.2015	H1	0.0299	210	18.1
	H2	0.0087	62	
	H3	0.0028	21	
	H4	0.0039	27	
	H5	0.0097	72	
	H6	0.0368	280	
	H7	0.0169	110	
	H8	0.0011	8	
24.4.2015	H1	0.0113	80	30.1
	H2	0.0126	93	
	H3	0.0066	50	
	H4	0.0103	71	
	H5	0.0123	90	
	H6	0.0178	131	
	H7	0.0166	123	
	H8	0.0120	90	
25.4.2015	H1	0.0148	111	18.6
	H2	0.0108	80	
	H3	0.0068	50	
	H4	0.0112	82	
	H5	0.0142	102	
	H6	0.0287	214	
	H7	0.0171	130	

Table 1: continue……………

	H8	0.0106	80	
	Treatments	Soil loss (t/ha/season)	Runoff (mm)	Rainfall (mm)
26.5.2015	H1	0.0028	20	18
	H2	0.0140	104	
	H3	0.0019	12	
	H4	0.0016	10	
	H5	0.0021	13	
	H6	0.0023	15	
	H7	0.0207	156	
	H8	0.0028	18	
28.4.2015	H1	0.0143	107	31
	H2	0.0112	83	
	H3	0.0029	21	
	H4	0.0089	64	
	H5	0.0064	43	
	H6	0.0104	77	
	H7	0.0148	111	
	H8	0.0091	66	
2.05.2015	H1	0.0056	40	33
	H2	0.0292	219	
	H3	0.0047	32	
	H4	0.0018	10	
	H5	0.0062	43	
	H6	0.0065	45	
	H7	0.0103	73	
	H8	0.0020	18	
3.5.2015	H1	0.0089	67	57.1
	H2	0.0113	82	
	H3	0.0024	16	
	H4	0.0029	21	
	H5	0.0010	6	
	H6	0.0027	19	
	H7	0.0071	50	
	H8	0.0037	26	
4.5.2015	H1	0.0084	61	33
	H2	0.0059	42	
	H3	0.0021	10	
	H4	0.0029	20	
	H5	0.0025	15	
	H6	0.0056	40	
	H7	0.0102	72	
	H8	0.0044	30	

Table 1: continue……………

	Treatments	Soil loss (t/ha/season)	Runoff (mm)	Rainfall (mm)
5.5.2015	H1	0.0035	23	30
	H2	0.0078	55	
	H3	0.0026	20	
	H4	0.0020	12	
	H5	0.0016	10	
	H6	0.0132	99	
	H7	0.0040	28	
	H8	0.0026	14	
7.5.2015	H1	0.0099	71	14.2
	H2	0.0093	78	
	H3	0.0022	13	
	H4	0.0019	11	
	H5	0.0029	21	
	H6	0.0125	93	
	H7	0.0103	73	
	H8	0.0017	10	
8.5.2015	H1	0.0019	11	11.3
	H2	0.0073	52	
	H3	0.0016	10	
	H4	0.0033	21	
	H5	0.0034	22	
	H6	0.0097	71	
	H7	0.0051	33	
	H8	0.0016	11	
11.5.2015	H1	0.0157	115	27
	H2	0.0171	128	
	H3	0.0016	10	
	H4	0.0047	33	
	H5	0.0019	12	
	H6	0.0136	100	
	H7	0.0166	122	
	H8	0.0135	100	

*H1, H2, H6 and H7 are runoff plots without hillside ditches. H3, H4, H5 and H8 are runoff plots with hillside ditches.

Appendix 2: Farmers questionnaire

To examine social economics potential of banana-maize farming system with and without conservation structures in study area

A. General information

i) Questionnaire Number ………………………………………….

ii) Name of Interviewer ……………………………………………

iii) Date of Interview ……………………….................................

iv) Division…………………………………………………….

v) Ward ……………………………………………………….

vi) Village name…………………………………………………..

vii) Hamlet……………………………………………………..

Section 1: Farmer's characteristics (Fill in the gap or tick/circle one)

1.1 Respondent's name……………………………………………………...

1.2 Sex

i) Male

ii) Female

1.3 Age (in years)

Age group(years)	**Tick**
Elders above 60 years	
Adults between 35 - 60 yrs	
Youth between 18 - 35 yrs	
Children below 18 yrs of age	

B: Food Production Patterns, Total Revenue accrued and the Challenges facing Production

1.4 Among these crops, which are cash crops and food crops? (Give 1 for cash crops and 2for food crops)

i) Banana

ii) Paddy/Rice

iii) Maize

iv) Vegetables

v) Others (specify) …………………………………………………

1.5 What is the cropping pattern (tick one)

i) Monocropping

ii) Mixed cropping

iii) Both monocropping and mixed cropping

iv) Crop rotation

1.6 What is the total land area (farm size) for crop production? In acres............

1.7 How did you acquire this land?

i) Inherited

ii) Hired

iii) Bought

iv) Given by village government

v) Others (specify) ……………………………………………….

1.7.1 How much did you acquire the land? …………………………………..

1.8 Form of Production

i) Irrigation system

ii) Rain-fed

iii) Water harvesting

iv) Others (specify)……………………………………………….

1.9 Do you incur any costs during the production of your crops?

i) Yes

ii) No

1.10 If yes, what production costs you incur.

<u>COST BENEFIT ANALYSY.COMMODITY ONE (1)</u>

ACTIVITY	cost/person	total cost
1.Land clearing/acre		
2.Land digging/acre		
3.Land hallowing/acre		
4.Land leveling/acre		
5.Planting/acre		
6.Weeding 1st		
7.Seed/kg		
8.Weeding 2nd		
8.Pestcide /liter		
9.Insectcide/liter		
10.Pesticides applications		
11.Insectcides applications/acre		
13.Fertilizer/bag		
14.Fertilizer application/acre		
16.Harvesting/bag		
17.Threshing/bag		
18.Baging/Packing		
19.Transporting to the store		
20.Loading and unloading/bag		
21.Packaging materials/bag		
22.Processing /bag		
23.Transportation cost to the marketing/bag		

Take note: For the case of communal /family labor, please probe more and convert the cost into cash money.

REVENUE/CONSUMPTION.COMMODITY ONE (1)

Amount/kg/ acre	selling price/kg	total revenue
1.Total harvest		
2.Seed kept		
3.Food kept		
4.Gift taken away		
5.Loan repayment		
6.Reserved in WRS		
7.Payment for exchange labor		

COST BENEFIT ANALYSY.COMMODITY TWO (2)

ACTIVITY	cost/person	total cost
1.Land clearing/acre		
2.Land ploughing/acre		
3.Land hallowing/acre		
4.Land leveling/acre		
5.Planting/acre		
6.Weeding 1st		
7.Seed/kg/acre		
8.Weeding 2nd		
8.Pestcide /liter		
9.Insectcide/liter		
10.Pesticides applications/acre		
11.Insectcides applications/acre		
13.Fertilizer/bag		
14.Fertilizer application		
16.Harvesting/acre		
17.Threshing/bag		
18.Baging/packing		
19.Transporting to the store/bag		
20.Loading and unloading/bag		
21.Packaging materials/bag		
22.Processing /bag		
23.Transportation cost to the marketing/bag		

Take note: For the case of communal /family labor, please probe more and convert the cost into cash money.

REVENUE/CONSUMPTION.COMMODITY TWO (2)

AMOUNT/KG / ACRE	SELLING PRICE / KG	TOTAL REVENUE
1.Total harvest		
2.Seed kept		
3.Food kept		
4.Gift taken away		
5.Loan repayment		
6.Reserved in WRS		
7.Payment for exchange labor		

1.11 Is this production sufficient for your household for a year? (tick one)

i) Sufficient

ii) Not Sufficient

iii) Surpluses

iv) I don't know

1.12 How much have you been producing for the past 3 years?

Year	Type of Crop	Area Cultivated (acre)	Amount Produced (kgs)	Amount Consumed (kgs)	Amount Sold (kgs)	Remarks
2012						
2013						
2014						

1.13 Do you face any constraints during production of your crops?

i) Yes

ii) No

1.14 If yes, mention the major constraints facing you during the production.

i)……………………………… iv) ……………………………….

ii)……………………………… v) ………………………………….

iii)…………………………… vi) ……………………………………

1.15 What do you think should be done to improve food crops production in your village?

i)………………………………iv)………………………………………

ii……………………………… v) ………………………………………..

iii)………………………………vi)……………………………………...

B. Perception of soil erosion problems

1.16 Do you think that soil erosion is a problem in your farm plots?

i) Yes

ii) No

1.17 Give rank to the following major causes of soil erosion in your area?

Rank (1-very high, 2- high, 3- marginal, 4- low, 5- very low)

s/n	Causes	Rank
1	Deforestation	
2	Over grazing	
3	Over cultivation	
3	Poor agricultural practices	
4	Cultivation of steep slopes	
5	Excess rainfall	
6	Poor governmental policies	

1.18 What do you think is the consequences of soil erosion?

i) Land productivity (yield) decline

ii) Change in type of crops grown

iii) Reduces farm plot size

iv) All

v) Others (specify) ………………………………

1.19 Observed change in soil erosion severity over the past 5 years

i) Has become more severe

ii) Has become less severe

iii) No change

1.20 Do you believe that soil erosion can be controlled

i) Yes

ii) No

C. Soil and water Conservation technologies and farmers' attitude

1.21 Do you know the existence of improved soil and water conservation structures?

i) Yes

ii) No

1.22 If yes, which type do you know?

i) Hillside ditch

ii) Fanya juu

iii) Planting of different trees

iv) NA

v) Others specify ……………………………………………

1.23 If yes, what is your source of information?

i) Neighboring farmers

ii) Extension agents (DAs)

iii) NGOs

iv) From field days and Trainings

v) Others, specify…………………………………………

1.24 Have you participated in community conservation activities this year?

i) Yes

ii) No

1.25 Did you undertake the maintenance work by your own?

i) Yes

ii) No

1.26 If no, what were the reasons for not doing?

i) I have shortage of labor

ii) Lack of skill and knowledge

iii) Conservation structures were built without my knowledge and willingness

iv) I expect the land will be transferred to other farmers

v) There was no need for maintenance

vi) Others specify ………………………………………………

1.27 Do you believe that investment in soil and water conservation practices is profitable in the long run?

i) Yes,

ii) No

1.28 If yes what social and economic profits you get

i) …………………………………

ii) …………………………………

iii) …………………………………

iv) …………………………………

1.29 Why don't you use any conservation structures in your farm(s) while others use it?

i) No problem of soil erosion

ii) Shortage of labor

iii) Expecting that the structures will be done by financial incentives

iv) I feel that the land belongs to the government and it is the duty of the government to maintain the land

v) it reduces farmland

vi) Due to problems of rodents and others pests

vii) I did not get extension service

viii) Others specify ………………………………………………….

1.30 What are the problems related to each soil and water conservation structures you implement?

Problems	Fanya chini	agroforestry	Tree planting
Reduce farm land			
Difficult to turn oxen			
Labor intensive			
Difficult to implement (technically)			
Costly			

THANK YOU FOR YOUR COOPERATION