IMPACT OF SOIL CONSERVATION MEASURES ON SOIL ORGANIC CARBON STOCKS IN THE SOUTH WESTERN HIGHLANDS

A CASE STUDY OF AREAS UNDER CRD AND TAMP

A POSTGRADUATE DISSERTATION PRESENTED TO THE FACULTY OF AGRICULTURE SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A DEGREE OF MASTER OF SCIENCE IN AGRO-ECOLOGY UGANDA MARTYRS UNIVERSITY

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OCTOBER 2016

DECLARATION

This thesis in dedicated to my children may the almighty Allah bless you in all your endeavors.

ACKNOWLEDGEMENTS

The dissertation would have been impossible to prepare without the help of a number of people. I am deeply indebted to my supervisors, Dr. Sekandi Joseph (Uganda Martyrs University Nkozi) and Dr. Jenny Farrmer (Uganda Carbon Beaureu) and to Dr. Drake N Mubiru (National Agricultural Research Laboratories-Kawanda) Prof: Bamwerinde Wilson for the tremendous contribution in reviewing of the proposal and dissertation.

I would not have achieved this or much less without the enduring patience and love from my husband who endured the emotional burden of being married to a student, and daughters Tino, and Arengo and son Ebitu Shaka who often missed my love. I am grateful to my parents Daudi and Margaret Katende for giving me a foundation in life and standing with me always, Iam grateful to my young sister Nakato Hawa for the support always.

I extend my thanks to the extension workers who assisted in the soil sampling and transportation process and to my course mates whose constructive criticism, continuous encouragement and support and hard work helped me work hard. May Allah bless you all.

LIST OF ACRONYMNS

CRD	Center for Rural Development
TAMP	Trans-boundary Agro-ecosystem Management Project
SOC	Soil Organic Carbon
GHGs	Green House Gases
C	Carbon
FAO	Food Agricultural Organization
SOC	Soil Organic Carbon
SWC	Soil and Water Conservation
SSA	Sub Saharan Africa
USA	United States of America
RUSLE	Revised Universal Soil Loss Equation
UNCCD	United Nations Convention to Combat Desertification
lFPRI	International Food Policy Research Institute
SCS	Shifting cultivation systems
FYM	Farm Yard Maure
NAADS	National Agricultural Advisory Services

ABSTRACT

Land degradation caused by erosion is one of the greatest environmental threats that hamper agricultural production in the south western highlands of Uganda, the causes include: over cultivation, overgrazing, slash and burn and deforestation which in turn leads to a gradual co accumulation in the atmosphere causing global warming hence climate change causing excessive droughts and floods leading to Loss of productive land, and undermining rural livelihoods and national food security.

The study assessed the impact of soil conservation measures on soil organic carbon stocks in agro-ecosystems in Kabale District. Assessment of the effects of SWC on SOC in 2 key areas; Center for Rural Development(CRD) located in Mukoni village where SWC measures had been practiced for 2 years and Trans-boundary Agro-ecosystem Management Project(TAMP) in Kaliko and Kagarama were SWC had been practiced for 5years was made. From each site, 3 paired sites were assessed. Soil samples were collected and analyzed for OC using the Walkley-Black(1934) procedure at a depth of 0-15 and 15-30cm. The study was guided by three research questions as derived from the objectives under study. These research objectives were; (1)To identify land use practices being used by the farmers in Kabale District, (2) to evaluate the effectiveness of calliandra hedgerows and organic manure as a soil and water conservation measure on soil organic carbon. From the study, findings revealed that SOC does not statistically increase with the use of calliandra hedgerows and organic manure within 2 years. However with SWC interventions for five years OC increases mainly at the top layer of 0-15 cm. The results therefore showed that it is possible to recover abandoned and or degraded areas, resulting from a number of causes such as deforestation, shifting cultivation, over grazing,swamp reclamation and or over cultivation of ecologically sensitive areas in Kabale District through the promotion of Calliandra (*Calliandra calothyrsus*) and organic manure. Calliandra and organic manure therefore have the potential for restoring degraded land, maintaining soil fertility and, more recently, sequestering C, mitigating C emissions to the atmosphere once maintained through proper management.

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CHAPTER ONE

1.0 INTRODUCTION

This study aimed at assessing the impact of soil and water conservation measures on soil carbon a case study of areas under the Center for Rural Development (CRD) and the Trans-boundary Agro-ecosystem Management Project (TAMP), Kabale district. The chapter presents the background to the study, statement of the problem, research objectives, research questions, conceptual framework, significance of the study as well as the scope of the study, definition of key terms and justification.

1.1 Background

Soils are the heart of the earth's critical zone (US, NRC 2001, planet earth 2005), they are a natural resource that play a vital role to human survival, they support many terrestrial ecosystems (Jenny 1980), and a major source of food for many organisms. Soils represent the largest terrestrial stock of organic carbon, holding between 1400 $x10^{15}$g (Post et al., 1982) and 1500 x 10^{15}g C (Batjes, 1996); this is approximately twice the amount held in the atmosphere and 3 times the amount held in terrestrial vegetation. In most soils (with the exception of calcareous soils) the majority of this carbon is held in the form of soil organic carbon (SOC) (Batjes and Sombroek, 1997). Thus changes in terrestrial SOC stocks (both increases and decreases) can be of global significance and may either mitigate or worsen climate change.

Although there are many different methods of measuring soil quality (Karlen et al. 1997), SOC is often used as a key indicator of soil fertility due to its beneficial effects on numerous soil properties (Wander and Drinkwater 2000). For instance, high levels of SOC are associated with increased cation exchange capacity, base saturation, and available water capacity (de Moraes Sa et al. 2009, Dell et al. 2008). As SOC increases, soil aggregate stability also increases, and soils with highly stable aggregate structures are less prone to erosion and runoff (Dell et al 2008, Devine et al 2011).

Soil organic carbon (SOC) is important as it determines ecosystem and agro-ecosystem function, influencing soil fertility, improving water holding capacity. It is also of global importance because of its role in the global carbon cycle and therefore, the part it plays in the mitigation or worsening of atmospheric levels of greenhouse gases (GHGs). Past long-term experimental studies have shown that SOC is highly sensitive to changes in land use, with changes from native ecosystems such as forest or grassland to agricultural systems almost always resulting in a loss of SOC

Rates of land use change are greatest in the tropics, where the demand for agricultural land is increasing as population levels rise, much of this demand is met by converting native ecosystems to cultivated or pasture land, releasing C from soils to the atmosphere (Batjes and Sombroek 1997). Subsequent poor management of newly converted land, then leads to eventual land degradation.

Deforestation, slash and burn, continuous cultivation, over grazing, and monoculture are cited as such practices leading to the removal of vegetation acting as soil covers exacerbating soil erosion and nutrient losses (FAO 2013), causing crop and economic losses. Under continuous cultivation nutrients in the top soils are decreasing and soils are becoming more acidic.

Over the years, several efforts have been made in developing technologies to reduce the rate of increase of atmospheric concentration of carbon dioxide (CO2) from annual emissions of 8.6 Pg C yr1 from energy, process industry, land-use conversion and soil cultivation. Some of the options have been C sequestration. Carbon sequestration implies transfer of atmospheric CO2 into other long-lived global pools including oceanic, pedologic, biotic and geological strata to reduce the net rate of increase in atmospheric CO2. It uses the two (2) techniques of Abiotic and Biotic sequestrations.

Abiotic sequestration is based on physical and chemical reactions and engineering techniques without intervention of living organisms (e.g. plants, microbes) (Freund & Ormerod 1997).

Biotic sequestration is based on managed intervention of higher plants and micro-organisms in removing CO2 from the atmosphere. It differs from management options which reduce emission or offset emission by increasing efficiency in use of resources like water and energy. The other method has been adopting soil conservation measures that increase soil organic matter important not only as a source of carbon for soil processes but also a sink for carbon sequestration. Changing land use and tillage systems and adopting sustainable cropping systems and the inclusion of perennial vegetation, carbon sequestration rates can be increased to a range of 20–75 g/m2/yr, and SOC may reach a new equilibrium.

The intention of the soil and water conservation measures is to reduce soil erosion, restore soil fertility, rehabilitate degraded lands, improve micro-climate, improve agricultural production and productivity and restore environmental condition.

Despite the use of resources for SWC, only very few studies have been done to analyze the impacts of the measures with respect to accumulation of Soil Organic Carbon (SOC). Different studies have contradictory conclusions; Bewket (2007) reported that SWC measures were inefficient in reducing soil erosion and restoring soil fertility, while Hengsdijk et al. (2005) criticized the validity of his model. Similarly, Eshatu (2004) reported that planted forest did not result in significant changes in organic carbon, nitrogen and soil-organic matter inputs and did not improved soil fertility during a 25-year forest growth. However some , other studies indicated a positive contribution of SWC measures to the reduction of soil erosion, conservation of soil moisture, and restoration of vegetation cover and diversity (e.g., Asefa et al. 2003;Hengsdijk et al. 2005; Vancampenhout et al. 2006; Mekuria et al. 2007; Gebreegziabheret al. 2009). For example, Mekuria et al. (2007) reported significant soil fertility restoration in 5- to 10-year-old exclosures. In spite of these facts, policies, decisions, and planning and implementation of SWC measures have been based on very few cases

In addition, most plot-based studies are focused on assessing the severity of soil erosion in physical terms and lack information on the impact of SWC on soil organic carbon and agricultural production.

In order to fill this information gap and support efforts in combating land degradation, a study that assesses the impacts of SWC measures on soil organic carbon is of great importance

1.2 Problem Statement

The land resource and the ecosystems facing increasing pressures as a result of rapid population growth, urbanization agricultural and livestock intensification characterized by reduction in farm sizes and unsustainable land use, and management practices such as slash and burn, deforestation, over grazing, extensive cultivation and encroachment into wetlands, practices leading to the removal of vegetation acting as soil covers exacerbating soil erosion and nutrient losses (FAO 2013), under continuous cultivation nutrients in the top soils are decreasing and soils are becoming more acidic.

To tackle the issues associated with degradation, more efforts are put into returning the carbon to its permanent storage, the soils, by promoting sustainable soil and water conservation measures that improve vegetation cover of the degraded land, and has a direct effect on the soil fertility and productivity (Arnalds, 2002, 2004).

The Trans-boundary Agro-ecosystem Management Project (TAMP), has since 2010 promoted sustainable land use and improved agricultural production through promotion of practices such as planting of calliandra hedgerows and use of organic manure in communities surrounding the river

Kagera. Similarly a new project called the Center for Rural Development (CRD) has for 2 years promoted soil conservation in the Kagera catchment area.

Assessment of how these practices are changing soil organic carbon has not been done as yet therefore this research aimed at assessing the impacts of these soil and water conservation measures on soil organic carbon.

1.3 Purpose of the Study

This research aimed at evaluating the success of soil conservation methods in accumulating soil organic carbon, one of the key elements of the soil extremely important in all soil processes. The study aimed at contributing information on which measures and the period within which they increase organic soil carbon to stakeholders.

1.4 Objectives of the study

The general objective of the study was to assess the impact of soil conservation measures on soil carbon stocks in agro-ecosystems.

1.5 Specific Objectives

To identify land use practices being used by the farmers in Kabale District.

To evaluate the effectiveness of calliandra hedgerows and organic manure as a soil conservation measure on soil organic carbon accumulation in Kabale District

1.6 Research Questions

What soil and water conservation measures are being implemented in the study area?

Is there a significant difference in the soil organic carbon between areas with soil conservation and those without (control plots)?

1.7 Significance of the Study

There are numerous benefits of soil and water conservation, important among these are; improved quality of soil and water resources, decreased nutrient losses from ecosystems, reduced soil erosion, better wildlife habitat, increased water conservation, restored degraded soils and increased input efficiency. SOC is a natural process essential for recycling of elements and water. Principal benefits of SOC sequestration to soil quality are: improvement in soil structure, reduction in soil erosion, decrease in non-point source pollution, increase in plant-available water reserves, increase in storage of plant nutrients, denaturing of pollutants, increase in soil quality, increase in agronomic productivity of food security and moderation of climate.

It was therefore necessary to undertake this study in order to establish these soil and water conservation measures and their contribution to Soil Organic Carbon stocks as well as the critical factors that negatively affect Soil Organic Carbon through the land use practices that these farmers embrace.

The results of this study are essential in contributing to the existing pulse body of knowledge especially the Soil Organic Carbon aspect whose information is scanty locally yet critical to the existence of the eco-system. Information from this study is vital to;

i. Farmers to equip themselves with better conservation measures for their farms to enhance their produce because an understanding of Carbon will even bring to their notice that Carbon sequestered in soils and trees can be traded just as any farm produce (for example corn, milk, meat) because trading C credits is a rapidly growing industry with a well-established market in Europe (Gressel 2007; McGowan 2007; Johnson & Heinen 2004; Brahic 2006) and the USA through Chicago Climate Exchange (Breslau 2006). Trading C credits provide a much needed income stream for the farmer, and an essential incentive to invest in soil restoration (e.g. erosion control, irrigation, fertilizers), break the agrarian stagnation and advance food security.
ii. Extension officers who educate and inform farmers who ignorantly did not know that some of the land use practices they embrace have a significant impact on Atmospheric Carbon and consequently on the weather vagaries like climate change and global warming which later affected us all.

iii. Policy makers also use this information to create or amend existing policies such as the SALT and RUSLE method for example data from soil erosion studies can be used in soil erosion prediction models. requires site-specific parameters that adequately address the erosion hazard specific to the locality, policy makers also understood the consequences of some land use practices like deforestation, wetland mismanagement, overgrazing and shift cultivation conversion to degradation by farmers, which later impact on global surface temperatures leading to notable shifts in the eco-system.

1.8 Justification for the Study

Terrestrial ecosystems have been the source of atmospheric CO2 ever since the dawn of settled agriculture 10000 years ago, and of CH4 since the domestication of cattle and cultivation of rice paddies about 5000 years ago. Total amount of C emitted by terrestrial ecosystems is estimated at 320 Pg in the pre-industrial era and 136 Pg since 1850. Of the 136 Pg, 78 Pg is emitted from world soils consisting of 26 Pg from erosion and 52 Pg from mineralization. Increasing atmospheric CO2 concentration will enhance NPP by CO2 fertilization effect. Restoration of degraded ecosystems and coupling of C with N and P cycles also enhances the terrestrial C pool. (Phil. Trans. R. Soc. B ,2008). Therefore, the process of biotic C sequestration strengthens and enhances ecosystem services while enhancing agronomic production. The process is cost-effective for adoption on agricultural and forest soils/ ecosystem are available for most eco-regions of the world (IPCC 1999). . Using of the two terrestrial C sequestration methods of Hegde grows (a form of agro-forestry also) and manure application can help to accumulate SOC. Using such methods for restoring degraded soils and ecosystems is a strategy with multiple benefits for water quality, while improving soil quality and agronomic productivity.

Therefore, it is important to understand locally the contribution of these methods not only limited to their contribution in maintaining Atmospheric Carbon but as well as their efficiency in improving land conservation not only for agriculture but as well conservation of ecologically sensitive areas and the eco-system in general that continues to be endangered to make judgments about how they can also be integrated into the policy framework for easier implementation. The main aim of this study therefore is to assess the impact of soil conservation measures on Soil Organic Carbon in Kabale District.

1.9 Scope of the Study

1.9.1Geographical scope

The study was carried out in Mukoni ,Kariko and Hamurambi villages found in Kabale District. The project targeted farmers around Lake Bunyonyi ,where there is a new SC project with an organization called CRD and similarly the TAMP established farmer field schools in seven areas of the Kagera water shade.

1.9.2 Content scope

The study focused on determining the impact of soil conservation measures on Soil Organic Carbon.

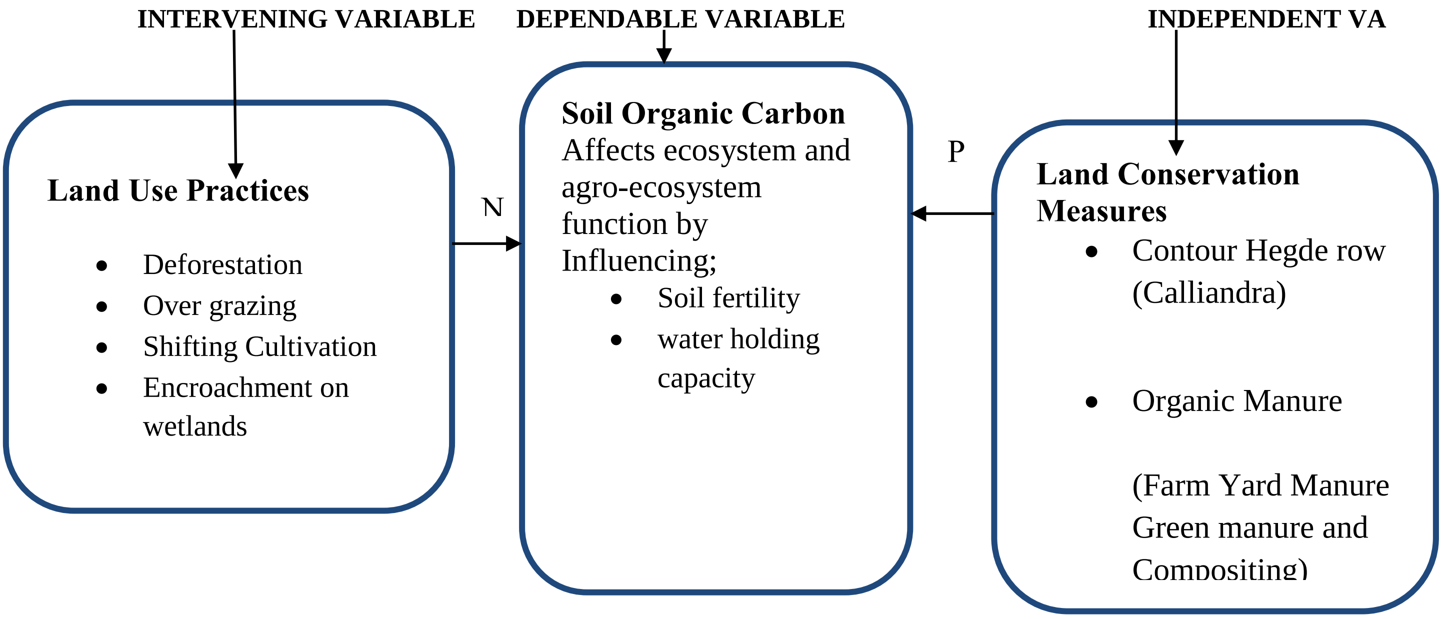
1.9.3 Time scope

The research activity specifically considered farmers that had embraced calliandra Hegde row and manure application for two years and above. This implied that all farmers whose years of operation less than the stated duration above were not considered in the study but only used as control experiments.

CONCEPTUAL FRAME WORK

The conceptual frame work aided the researcher to illustrate the relationship between dependent variables such as soil fertility, water holding capacity, plant nutrient storage among others, independent variables such as organic manure, contour hedges among others and intervening variables such as Deforestation, Over grazing, Shifting Cultivation, Encroachment on wetlands.

A conceptual frame work was developed and presented as below.



Where: P stands for positive effects

N stands for negative effects

The **Independent Variable** was conceptualized in terms of contour Hedge Grows (Calliandra) and Organic manure application.

The **Dependent Variable** was conceptualized in terms of Soil Organic Carbon which has the capacity to influence Soil Organic Matter and ultimately soil fertility and water holding capacities, reduction in soil erosion, decrease in non-point source pollution, increase in plant-available water reserves, increase in storage of plant nutrients, denaturing of pollutants consequently affecting Atmospheric Carbon.

The Intervening Variable was conceptualized in terms the Land use practices such as Deforestation, over grazing, shifting cultivation and Wetland encroachment that increase atmospheric carbon that destabilizes SOC leading to dangerous climatic changes like GHGs and Global warming

DEFINITION OF KEY TERMS

Wetland Loss

Wetland loss is defined as “the loss of wetland area due to conversion of wetlands to non-wetland areas as a result of human activity”, whereas wetland degradation is “the impairment of wetland functions as a result of human activities (Moser *et al*., 1996).

Deforestation

Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (van Kooten and Bulte, 2000).

Over Grazing

The common definition of overgrazing or rangeland overuse, is the exploitation of a rangeland beyond its carrying capacity (CC)

Carbon Sequestration

Carbon sequestration implies transfer of atmospheric CO2 into other long-lived global pools including oceanic, pedologic, biotic and geological strata to reduce the net rate of increase in atmospheric CO2.

Land degradation

According to the United Nations Convention to Combat Desertification (UNCCD), land degradation is defined as a natural process or a human activity that causes the land to be unable to provide intended services for an extended time (FAO, 2004)

Soil Organic Carbon Soil organic matter is the organic fraction of the soil that is made up of decomposed plant and animal materials as well as microbial organisms, but does not include fresh and un-decomposed plant materials, such as straw and litter, lying on the soil surface.(Dr Yin)

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter basically focused on literature related to the topic of study. Particularly, it focused on review of published literature in relation to the study topic which was arranged using a thematic approach according to the research objectives such as; understanding the land use practices that are being used by the farmers in Kabale District, evaluating the effect of hedgerows as a soil conservation measure on soil organic carbon, evaluating the impact of organic manure as a soil conservation measure on soil organic carbon, quantifying long term changes in soil carbon using the Roth C model.

Overview of Kabale District

Kabale district used to be called Kigezi district until 1980. It is located in south-western Uganda bordering Rwanda and the districts of Kisoro, Rukungiri, Ntungamo and Bushenyi.

The name Kabale means "a small stone". It originated from apiece of iron ore that was so heavy that people used to come from far and near to see and feel its weight. The stone was eventually taken to the then protectorate headquarters at Entebbe.

The relief of Kabale ranges between 1,800m and 4,000m above sea level, with the highest points being to the southern part of the district. In the South-West of the country the plateau reaches its greatest heights with hill summit levels above 2000m in Kigezi. The rise of the plateaux levels to the west is emphasised by the impressive mountains topography found along the borderlands. The major volcanoes of the west in Kigezi consist of young conical hills rising to a maximum of over 4000m.

The soils of Kabale District are mainly volcanic, ferralitic and peat soils. The volcanic soils are mainly found in Muko sub-county in Kabale District. The ferralitic soils are the most widespread in the district and are in the advanced stage of weathering and have little or no mineral reserves to draw on. They largely depend on bases held in the clay and organic complexes for their fertility. Productivity of the ferralitic soils depends on favourable, adequate depth and maintenance of the humic top soil. The peat soils in Kabale district are mainly papyrus swamps. The peat soils are formed as a result of accumulation of a thick layer of organic matter below swamp vegetation due to slow decomposition. Peat swamps produce the rich organic soils for agriculture which dominate the valleys of Kabale district.

Kabale has intensely cropped hillsides and high population densities. Erosion and consequent soil degradation have been assumed to be a major problem since before independence (Carswell 2002), and that assumption continues today (NEIC 1994; Kazoora 2002). Kabale District is densely populated. With an area of 1,679.1 square kilometers (648.3 sq mi), the population density in the district in 2012 was estimated at 296.7 people per km² (768.6 people per mi²).The land is heavily fragmented. Fragmentation of land holdings is severe. On average, 16 fields are cultivated per household, and the average household farm is 2.25 ha. Fragmentation diversifies the micro-ecologies that farmers exploit, from the hilltop to the valley, reducing their risk throughout the year and in seasons of variable rainfall. Having so many fields, however, reduces the labour and other resources invested by farmers particularly in their distant hillside fields. Available organic materials, such as manure and crop residues, are used only on fields nearest the homestead. The fields farther from the home receive no inputs but are left fallow more often. In Kabale, the rural poor generally live off the land on which they grow crops for subsistence and sale, graze their livestock, collect water and obtain wood for cooking, lighting and construction of houses (Maureen 2011).

Land is considered important for production and food sufficiency. As land deteriorates in quality, the poor become poorer. Poor agricultural yields resulting from degraded soils lead households to obtain alternative sources of livelihood to make up for the short fall through deforestation or encroaching on ecologically fragile areas such as wetlands and steep hillsides.

Areas abandoned due to severe land degradation are normally left under woodlots consisting of mainly eucalyptus trees. Use of inorganic fertilizers is rare, while use of manure, compost and mulches can occasionally be noticed though inadequately applied. The predominant soil replenishment method is bush fallowing mainly during the dry seasons (de Sherbinin et al. 2007). He also argued that as the population increases and agricultural land becomes limited, farmers reduce or abandon fallowing. As a result, the land has no time to restore itself through natural processes. The encroachment on less resilient land could cause resource decline within a short period of time (de Sherbinin et al. 2007). Thus, land potential declines with time and can lead to an ecological catastrophe (Turner and Shajaat Ali 1996).

Erosion control bunds had been installed by the colonial administration in Kabale and are still being maintained by farmers, but as field boundary markers rather than as structures to prevent erosion (Olson and Berry, 2003). Farmers perceive their lack of ability to fallow to be a more important reason for declining fertility than erosion, though they do regret the loss of good topsoil from their fields being deposited onto the fields below owned by other farmers.

Soil erosion in the area is mainly attributed to the steep slopes, population pressure, deforestation, poor farming methods and vulnerable soils. However, the major factor fuelling soil erosion on the steep slopes is that farmers are increasingly destroying contour bunds on terraces to pave way for more farmland.

As a result, soil erosion has been accelerated which in periods of heavy rainfall results in silting and flooding of the valley-bottom fields and landslides are also becoming very common.
This regular practice has reduced the attraction of placing more long-term erosion control devices such as grass lines or hedgerows of agro-forestry species (Olson and Berry, 2003). In the valleys that used to be under water-logged, swamps have been reclaimed for agricultural production, but these areas are currently characterized by flooding and declining agricultural productivity.
Capacity building to help farmers and other land users to develop farming practices and systems that conserve soil, ensure sustained fertility and, where possible, reverse chemical, structural and biological degradation of the soil, is done through establishment of farmer field schools where farmers learn, innovate different methods of land management and later carry the innovations to their personal fields.

2.1 Land Use Practices in Kabale District

In 1994, the International Food Policy Research Institute (lFPRI) began an initiative for "A 2020 Vision for Food, Agriculture, and the Environment" to evaluate current conditions and trends in food production, consumption, and distribution and to facilitate an international consensus on the directions that policy should take over the next 25 years. Among the most hotly debated elements in those projections is the extent and effect of land degradation. Some perceive that land degradation poses a potential threat not only to global food supplies but general climate change through changing Soil Organic Carbon over the long term (Pimentel et al. 1995; Brown and Kane 1994), Resources over-exploitation and inappropriate land use such as over-grazing, deforestation, expansion of cultivation and grazing into marginal lands, and backward

Agricultural practices are considered as the major causes of land degradation (Nana- Sinkam 1995; Stocking and Murnaghan 2000; FAO 2004; FRA 2005). The major driver in Uganda and Kabale specifically is conversion of forest and marginal lands into agriculture due to the growing population pressure together with inappropriate agricultural practices.

2.1.1 Deforestation

Tropical forests are strong carbon sinks, and deforestation of these forests contributes 20% of the total anthropogenic CO2 emissions to the atmosphere (Baccini et al. 2008).

Deforestation is primarily a concern for the developing countries of the tropics (Myers, 1994) as it is shrinking areas of the tropical forests (Barraclough and Ghimire, 2000) causing loss of biodiversity and enhancing the greenhouse effect (Angelsen *et al*., 1999). Extensive tropical deforestation is a relatively modern event that gained momentum in the 20th century and particularly in the last half of the 20th century. The FAO FRA 2001 and 2010 reports indicate considerable deforestation in the world during 1990-2010 but this was almost entirely confined to tropical regions (Anon., 2001a; 2010).In the developing world, 1.6 billion people depend on forests for their food, fuel, and livelihoods.

Natural resources are interdependent, and degradation of one affects the other. Biomass-cover change influences ecosystem services and processes (Wallace 2007). Ecosystem services acquired include provision, regulation, cultural and supporting services (Wallace 2007). Hence, vegetation degradation influences those ecosystem services and processes. For example, vegetation degradation negatively influences soil formation, nutrient and water cycles, climate and erosion regulation, food supply, bio-chemical cycle and others (Wallace 2007). Therefore, the impact of vegetation and forest cover destruction has a wide range of impacts (Richter et al. 1999; Lemenih et al. 2005; Wallace 2007; Kalinina et al. 2009).

The recurrent droughts, severe soil erosion, sedimentation of reservoirs and water bodies, soil quality deterioration, surface- and ground-water resource reduction and biodiversity loss are some of problems related to deforestation and vegetation clearance (Asefa et al. 2003; Lemenih et al. 2005).

Vegetation cover degradation has also threatened the bio-diversity potential, and the plant seed reserve has also become eroded due to surface cover clearance and soil degradation (Asefa et al. 2003; Khater et al. 2003; Wassie et al 2009).

Pearce and Brown (1994) identified two main forces affecting deforestation as Competition between humans and other species for the remaining ecological niches on land and in coastal regions. This factor is substantially demonstrated by the conversion of forest land to other uses such as agriculture, infrastructure, urban development, industry and others. As well is the failure in the working of the economic systems to reflect the true value of the environment. Basically, many of the functions of tropical forests are not marketed and as such are ignored in decision making. Additionally, decisions to convert tropical forests are themselves encouraged by fiscal and other incentives.

Tropical forests are one of the last frontiers in the search for subsistence land for the most vulnerable people worldwide (Myers, 1992. Deforestation devastates biodiversity and natural habitats and degrades natural resources. In the longer run, the loss of biodiversity, habitat, and natural resources will affect food production in both developed and developing countries. Both processes of deforestation and forest degradation are associated with release of greenhouse gases into the atmosphere (Anon, 2007). Forests generate the bulk of rainfall worldwide and act as a thermostat for the Earth. When they are felled or burned, the Carbon-dioxide stored by the trees escapes back into the air as atmospheric Carbon which affects Soil Organic Carbon hence creating change in climate (Repetto, R. 1988.).

It should be noted however that Forest ecosystems can store C as lignin and other relatively resistant polymeric C compounds. Presently, the net rate of C sequestration in forest ecosystems (other than those being deforested) is 1.7G0.5 Pg C yrK1 (Fan et al. 1998). The forest C is sequestered not only in the harvestable timber, but also in woody debris, wood products and other woody plants encroaching upon grasslands (Wofsy 2001).

Therefore Afforestation is one of the viable options of C sequestration in terrestrial ecosystems (IPCC 1999; Fang et al. 2001; Lamb et al. 2005) which later contributes to Soil Organic Carbon.

2.1.2 Shifting Cultivation

Weinstock & Sunito (1989:20-21) define ‘shifting cultivators’ as people “who practice a form of rotational agriculture with a fallow period longer than the period of cultivation. Unless faced with population pressure or other constraints, land is used only one to three years and fallowed for a relatively long period (up to 20 or more years)”.

‘Forest pioneers’ are defined as people “who may utilise slashing and burning of the existing vegetation but with the primary intention of establishing permanent or semi-permanent agricultural production. Although some subsistence food crops may be planted, the planting of cash crops (most often perennials) is the primary focus of attention. Land is usually not fallowed but is used continuously and is abandoned only after total or near total exhaustion of the native fertility of the soil since there is no long term plan to again return to the same site".

Shifting cultivation systems (SCS) and their impacts on soil and vegetation have been widely studied by many research groups (Juo and Manu, 1996; Palm *et al.*, 1996; Nandwa and Bekunda, 1998; Giardina *et al*., 2000). Shifting cultivation (SC) is one of the main subsistence activities of small-scale societies and rural populations in tropical forests. This system has been practiced for thousands of years (Harris, 1971; Dove and Kammen, 1997) and is based on the ecological processes of forest ecosystems (Boserup, 1965; Altieri, 1999). Over the past three centuries, the practice of SC has been restricted to forested areas of the tropics Kibale inclusive. The basic phases of SCS are the following: (1) conversion, (2) cultivation, and (3) fallow (Kleinman *et al*., 1995).
The conversion phase is related to the opening of an area in which the cultivation will be performed. In this phase, a clearing is opened up, generally within a vegetable mosaic with plants at varied successional stages, to obtain a space for the crop. This opening is commonly cleared with manual tools, and after the trees are felled, fire is used to help clean the area and to increase the productivity of the crop (McGrath, 1987; Kleinman *et al*., 1995). According to the studies researched here, the two main causes of the impacts on the physical properties of the soil in the conversion phase were the cutting down of the vegetation and the use of fire to open up the crop area. Soil Organ Carbon (SOC) is a component of the soil properties. SOC influences the physical soil property of structure. This causes a negative impact, mainly on the structure of the soil, which is presented as the main argument to conclude that this type of land use is unsustainable. The biological properties of the soil are negatively impacted by the action of fire and by repetitions of the cultivation cycles. The reduction of the amount of organic matter, caused by the use of fire, influences the structure, composition, and diversity of the biota (micro-, meso-, and macrofauna) of the soil.

The exposure of the soil increases its temperature by promoting an increase in desiccation which diminishes the activity of micro-, meso- and macrofauna. Nevertheless, after the use of fire, fauna biomass and diversity decrease, compromising soil fertility via a reduction on the mineralization of nutrients. In summary, the number of cultivation cycles impacts soil fauna biomass negatively, leading to a decrease in the nutrient recycling activity rate.

2.1.3 Over Grazing. The common definition of overgrazing or rangeland overuse, is the exploitation of a rangeland beyond its carrying capacity (CC), further defined as the number of animals that the rangeland can support on a sustainable basis (Stevenson, 1991). Critics, exemplified by Behnke (1992) argue that it makes little sense to talk about overgrazing as defined in this way--without taking into account the management objectives of the rangeland users. He contends that the confusion between "ecological" and "economic" Carrying Capacity (CC) has resulted in misleading CC estimates, and that a distinction ought to be made between the two.

The ecological CC occurs at the point where the production of forage on the rangeland equals the rate of its consumption by animals. At this point, the animal population ceases to grow because the limited feed supplies equate death rates to birth rates, and there is no surplus production either of animals or biomass. Overgrazing is exacerbated by sociological phenomena called "the tragedy of the common." People share land but raise animals for themselves and try to enrich themselves by rising as many as they can. This leads to more animals than the land can support. Here the pastures degraded by overgrazing are subject to soil erosion. Stripping trees to provide fodder for grazing animals can also be a problem in some dry areas of the tropics but is probably not a major cause of deforestation.

2.2.4 Encroachment on Wetlands

All over the world, wetlands are hot spots of biodiversity and as a result they supply a plethora of goods and services to people living within them and in their adjoining areas. Increasing human population, coupled with the growing need for increased food production to meet the high demand, have put tremendous pressure on wetlands around the world (IUCN 1999; O'Conell 2003). Globally, the processes that impact on wetlands fall into five main categories that include the loss of wetland area, changes to the water regime, changes in water quality, overexploitation of wetland resources and introductions of alien species. Other threats to wetlands are natural activities like mass wasting, droughts, and overgrazing by domestic animals and wildlife. These threats have induced changes that have eroded the ecological and socioeconomic values and services derived from wetlands.

On the contrary wetlands and the associated soils or histosols constitute a large pedologic pool estimated at approximately 450 Pg (Gorham 1991; Warner et al. 1993). Gorham (1991) and Kobak et al. (1998) estimated that C sequestration in wetlands/ peatsoils since the post-glaciation period resulted in the C accumulation at the rate of 0.1 Pg C yrK1 over 10 000–18 000 years. However, drainage of peatlands and their subsequent cultivation made these ecosystems a net source of CO_2. Large areas of wetlands have been drained worldwide for agriculture (Armentano & Menges 1986) and forestry (Paavilainen & Paivanen,1995). Drained wetland soils decompose and subside at the rate of approximately 1–2 cm yrK1 primarily due to oxidation (Rojstaczer & Deverel 1995; Hillman 1997; Wosten et al. 1997). Restoration of wetlands can lead to reversal of the process and make restored wetlands once again a sink of atmospheric CO_2 positively contributing to Soil Organic Carbon (SOC) which is a component of the soil properties.

In conclusion, Land degradation is a serious global environmental problem. A global assessment of human-induced soil degradation (GLASOD) indicated that globally about 560 million hectares (36% of total) of farmlands had degraded at an annual rate of 5 to 6 million hectares (Scherr 1999). Land degradation is severe in developing countries, particularly in Africa, where almost all inhabited lands in Sub-Sahara Africa (SSA) are prone to soil and environmental degradation (Nana-Sinkam 1995; Scherr 1999; FAO 2004; Vlek et al. 2008). It can be difficult to assess the actual extent and impact of land degradation. Farmers often mask the effects of degradation by converting their land to less demanding uses or increasing levels of compensating inputs (for example, applying more fertilizer just to maintain stable yields), less-demanding cassava may be substituted for maize, fallow periods may be lengthened, cropland converted to grazing land, or grazing lands converted to shrubs or forests.

"Land degradation" refers to a temporary or permanent decline in the productive capacity of the land, or its potential for environmental management. "Land'" includes not only the soil resource, but also the water, vegetation, landscape, and microclimatic components of an ecosystem.

Some types of land degradation are, for all practical purposes, irreversible. Examples are severe gullying and advanced salinization. In these cases, the long-term biological and environmental potential of the land has been compromised. Displacement of soil material (erosion) is also irreversible, although its long-term effects on productive capacity depend on the depth and quality of soil remaining. Most types of soil degradation, however, can be prevented or reversed by, for example, adding nutrients to nutrient-depleted soil, rebuilding topsoil through soil amendments, re-establishing vegetation, or buffering soil acidity.

The practicality of rehabilitating degraded landscapes depends on the costs relative to the value of output or environmental benefits expected consequently efforts should be directed towards land improvement such that effects of Atmospheric Carbon are reduced so this also affects Soil Organic Carbon.

2.2 Soil and Water Conservation Measures

Several natural strategies for increasing the SOC pool have been developed because in Tropical Africa there is a wide range of degraded soils with a depleted SOC pool. Important among these are those degraded by erosion, nutrient depletion, acidification and leaching, structural decline and pollution/contamination.

To circumvent this problem, the Government of Uganda has taken different measures such as policy interventions, conducted studies, and implemented massive soil and water conservation (SWC) and capacity building programs. The intention of the interventions is to reduce soil erosion, restore soil fertility, rehabilitate degraded lands, improve micro-climate, improve agricultural production

and productivity (Vancampenhout et al. 2006; Bewket 2007; Mekuria et al. 2007).

According to the researcher the use of the two terrestrial CO_2 sequestration methods of Hegde rows (a form of agro-forestry also) and manure application can help to manage Atmospheric Carbon and consequently Soil Organic Carbon. Using such methods for restoring degraded soils and ecosystems is a strategy with multiple benefits for water quality, biomass productivity and for reducing net CO_2 emission (Grainger (1995). These two land conservation measures are broadly discussed below.

Although farmers are aware that the above negative consequences are a result of their land management practices, they have not taken any initiative to adopt better practices that could reverse land degradation.

The assumption is that the perceived benefits outweigh the negative consequences, but it is not empirically clear the tradeoffs that farmers face in choosing between good and bad land management practices.

2.2.1 Contour Hedge rows (Calliandra)

Soil erosion by water is a global problem and more so in the tropical regions due to the torrential nature of rainfall and highly erodible soils. While several methods exist for control of water erosion, the use of tree hedges (hedgerows) on contours of steep slopes has become increasingly important (Young, 1989, 1997; Angima et al., 2000). Establishment of hedges starts with construction of an earth banked terrace, creating a trench at the lower end of the terrace measuring off 10 m lengths upwards into the terrace. (Bamwerinde, 2014). Trees in hedgerow systems can serve as soil erosion barriers and nutrient retention enhancers through their influence on the supply and availability of nutrients in the soil through biological N_2 fixation, retrieval of nutrients from below the rooting zone of crops, and reduction in nutrient losses from leaching and erosion such as P and N. One tree species used in agro-forestry systems that has had remarkable success in conserving soil, nutrient cycling, and nutrient retention is calliandra (*Calliandra calothyrsus*).

Calliandra, indigenous to Central America, is a small tree that reaches about 10m in height and grows naturally in moist, tropical regions up to an altitude of 1500m (Paterson, 1994). Calliandra can improve soil quality and increase yields of associated crops and grass species such as Napier grass (*Pennisetum purpureum*) (National Research Council, 1983; Nitrogen Fixing Trees Association, 1988; Goudreddy, 1992).

Calliandra Calothyrsus trees are closely planted along the contours on hilly and steep slopes to create natural and effective barriers for reduction of the surface runoff and retention of eroded sediment.

Calliandra hedge barriers are a fairly cheap, effective, and sustainable way of controlling soil erosion and landslides on vulnerable steep slopes, especially where trash lines and Napier grass strips are inadequate to mitigate dispersed and concentrated soil and water runoff. Once established, the living barrier is durable with minimal additional maintenance cost to the farmer apart from pruning. The average length of a hedgerow is 50 to 70 m, corresponding to the width of a single terrace. The height varies according to intended use of the mature shoots. To use the stems as stakes, the hedgerow is allowed to reach a height of 4 to 6 m at maturity while a height of 1 to 2 m is sufficient for harvesting foliage as livestock fodder (Bamwerinde, 2014).. Widespread experimental findings have shown that contour Hedge grow Intercropping (HI) reduce soil erosion effectively and suggest that contour HI is one of the best ways of controlling accelerated erosion on sloping agricultural fields (Young, 1989; Garrity, 1994). Studies have also revealed that HI could improve physical and chemical aspects of degraded tropical soils, hence ensuring sustainability of high annual crop yields (Kang *et al.,* 1990). This is a form of Agro-forestry yet as already noted forest ecosystems store C as lignin and other relatively resistant polymeric C compounds with the net rate of C sequestration in forest ecosystems (other than those being deforested) as 1.7G0.5 Pg C yrK1(Fan et al. 1998) which is one of the viable options of C sequestration in terrestrial ecosystems (IPCC 1999; Fang et al. 2001; Lamb et al. 2005).

2.3 Manure

Plants need a well balanced diet, for better growth and yield. (Boller and Hani, 2004). The word **manure** came from Middle English "manuren" meaning "to cultivate land," and initially from French "main-oeuvre" = "hand work" alluding to the work which involved manuring land. Manure is not just the urine and feaces from livestock, but also the bedding, runoff, spilled feed, parlor wash, and anything else mixed with it.

Soil organic matter is the key to soil fertility and productivity. In the absence of organic matter, the soil is a mixture of sand, silt and clay. Organic matter induces life into this inert mixture and promotes biological activities. Although the beneficial influence of organic matter on the physical, chemical and biological properties of the soil is widely known. The excessive reliance on chemical fertilizers and the negligence shown to the conservation and use of organic sources of nutrients have not only caused the exhaustion of soil of its nutrient reserves but also resulted in soil health problems not conducive to achieving consistent increase in agricultural production.

Manure contains valuable plant nutrients, like nitrogen (N), phosphorus (P), potassium (K), and sulfur (S). Plants need only 16 nutrients for good growth. It must be provided either by the soil or by animal manure or mineral fertilizer. Some other mineral nutrient elements, e.g. Na, Si, Co, have a beneficial effect on some plants but are not essential. About 13 essential mineral nutrients are required for growth (Mc Lean, 1987)Manure nutrients come from the feed that the animals have eaten. In fact, most of the nutrients that animals eat end up in their manure (Wagner and George, 2004).

About half of the nitrogen in manure is in the form of ammonium and about half is in the form of organic material. Microbes that consume the organic compounds excrete ammonium.
One of the four things will happen to the ammonium - regardless of whether it comes directly from the manure or from microbes consuming the organic compounds. The ammonium may either be used by plants immediately, converted to ammonia and lost to the air or converted to nitrate which will be used by plants or microbes. The "immobilized" nutrients become available to plants when the microbes are consumed by other organisms that release ammonium as a waste product.

In the warmth of summer, plants and microbes grow more vigorously and use ammonium and nitrate quickly. Losses of nitrate to leaching are greater in spring and autumn when fewer plants and microbes can turn it into organic matter (Wagner and Georg 2004)

For all organic matter however, atmospheric carbon dioxide serves as the main source of carbon. Carbon dioxide is converted to organic carbon largely by the action of photoautotrophic organisms; the higher green plants on land and algae in aquatic habitats. Carbon is being contentiously fixed into organic form through the process of photosynthesis and once bound; the carbon becomes unavailable for use in the generation of new plant life. Carbon fixation involves a reduction of carbon dioxide by hydrogen donor NADPH (reduced form of the co-enzyme nicotinamide adenine dinucleotide phosphate, NADP) and the synthesis of carbohydrate from reduced carbon through complex cyclic mechanism called the Calvin cycle. In synopsis, Organic matter is a complex mixture of many chemical substances. These materials serve as precursors of soil humus. The most commonly found and well understood organic compounds finding their way into the soil and are subjected to normal decomposition processes are; carbohydrates (sugars, starches, hemicelluloses, cellulose, pectins, gums, mucilages, etc.;), proteins, aminoacids, amins, etc.; .

fats oil, waxes, resins, etc; alcohol, aldehydes, Ketones, etc; organic acid; lignin; compounds having ring structures (phenols, tannins, hydrocarbons), alkaloids and compounds with organic bases -- pyridine and purine, and miscellaneous substances -- antibiotics, auxins, vitamins, enzymes and pigments. The inorganic constituents, usually present in ash containing major and minor elements amounting 12-15 percent by weight. Organic Manure has however been divided into two classes that is Farm Yard Manure and Green Manure which are detailed below.

2.3.1Farm Yard Manure (FYM)

FYM is partially composed dung, urine, bedding and straw. Dung comes mostly as undigested material and the urine from the digested material. More than 50 percent of the organic matter that is present in dung is in the form of complex products consists of lignin and protein which are resistant to further decomposition and therefore the nutrients present in dung are released very slowly. The nutrients from urine, becomes readily available (Garg et al. 2005). An average-size cow produces 4 to 6 tonnes of fresh dung per year. Dung contains about 50 per cent of the nitrogen, 15 per cent of potash and almost all of the phosphorus that is excreted by animals. Straw, saw dust or other bedding materials are used in cattle sheds to reduce the loss of urine and to increase the bulk of manure. On an average, about 3 - 5 kg bedding material per animal is used by farmers. FYM contains approximately 5 - 6 kg nitrogen, 1.2 - 2.0 kg phosphorus and 5 - 6 kg potash per tonne. The quantity and quality of FYM depend upon the type (draught, mulch) and age of the animals, the way they are feed and the care taken to collect and store the material.

2.3.2 Green Manure

Green manure can be defined as a practice of ploughing or turning into the soil un-decomposed green plant tissues for improving physical structure as well as soil fertility.

Green manure, wherever feasible, is the principal supplementary means of adding organic matter to the soil. The green-manure crop supplies organic matter as well as additional nitrogen, particularly if it is a legume crop, due to its ability to fix nitrogen from the air with the help of its root nodule bacteria (Whitmore, 2000). The green-manure crops also exercise a protective action against erosion and leaching. Green manure to be incorporated in soil before flowering stage because they are grown for their green leafy material, which is high in nutrients and protects the soil. Green manures will not break down in to the soil so quickly, but gradually, add some nutrients to the soil for the next crop. Green manure approaches to crop production may improve economic viability, while reducing the environmental impacts of agriculture (Cherry et al., 2006).

2.3.3 Compost manure

Compost manure is that fertilizer made by farmers from plants, animal dung, urine and left overs, that have been decomposed by the existing micro-organisms(Whitmore, 2000).. Large quantity of fresh crop residues, on application directly to soil, causes extremely severe nitrogen immobilization and development of excessive reduced condition in the soil. To overcome such problems organic residues are piled up, moistened, turned occasionally to aerate and allowed adequate time to decompose partially and bring down the carbon nitrogen ratio to about 30.These are most times concentrated in a small area, enabling them to decompose fast. The purpose of making compost manure is to recycle the nutrients in the plant animal left overs back to the soil and to also create humus (soils brochure series 04, 2009).The collected organic refuse may be of rural and urban origin and may include straw, leaves, paddy husk, ground nut husk, sugarcane trash, bagasse, cattle dung, urine, crop residues, city garbage, night soil, sewage, kitchen and vegetable wastes, hedge clippings, water hyacinth and all other residues counting organic matter.

The final product is brown to black colored humified material which on addition to soil replenishes plant nutrients, maintains soil organic matter content and helps in improving the physical, chemical and biological conditions of the soil.

In general, composting is carried out in open pit or above ground, by filing alternate layers of organic wastes and other materials including top soil, cattle dung, half decompose farm yard manure, rock phosphate and other amendments.

If the organic wastes are largely high-carbohydrate materials, some fertilizer nitrogen is needed. The addition of poultry waste and farm yard manure while layering the compost pit, tends to speed up decomposition and helps to improve the texture of the product. Good aeration in the compost pile is essential (Rynk et al., 1992). It is good to mix succulent organic materials with the materials that decompose slowly. This prevents packing into soggy anaerobic mixtures. Since composting is a biological process, sufficient moisture for the proper development of microorganisms is essential. The materials should not be too dry or soggy. The requirement of moisture for microorganisms is almost similar to that of higher plants. The optimum moisture content of the composting materials has been found to be 60 percent of the total water holding capacity of the substrate.

In summary application of manures and other organic amendments is another important strategy of SOC sequestration. Several long-term experiments in Europe have shown that the rate of SOC sequestration is greater with application of organic manures than with chemical fertilizers (Jenkinson 1990: Witter et al. 1993; Christensen 1996).

Increase in the SOC pool in the 0–30 cm depth by long-term use of manure compared to chemical fertilizers was 10% over 100 years in Denmark (Christensen 1996), 22% over 90 years in Germany (Korschens & Muller 1996. The data

from Morrow plots in Illinois also indicates that manured plots contained 44.6 Mg haK1 more SOC than un-manured control (Anderson et al. 1990).

Farmers have been exposed to various land management practices such as contour ploughing, terracing, manure application, agro-forestry, among others. These practices have been tested on farms and approved efficient. However, not all farmers are applying them despite the recognition that their land is getting increasingly degraded. Several studies have attempted to determine the reasons why technologies may or may not be taken up.

2.4 Soil Organic Carbon

2.4.1 Soil Organic Carbon

One of the most important indicators of soil quality is soil organic matter (SOM), which is an important building block for the soil structure, formation of stable aggregates, and is able to improve the infiltration rates and the storage capacity for water (Jones *et al*. 2005). SOM presents a major pool of carbon in the biosphere and can act both as a source and a sink for carbon dioxide and other greenhouse gases. Agricultural intensification and cultivation in general results in a serious decrease in SOM as compared to that in the natural vegetation. Presently, the protection of soil organic matter is one of the main tasks, because SOM in addition to its soil fertilizing function can act in the elimination of the soil contamination and carbon sequestration.

Under steady state conditions, each soil reaches equilibrium carbon content, depending on a number of factors such as the land use, land management, soil type, and climate. This equilibrium can be disturbed by the land use and land management changes or climatic changes. Generally, each soil type is characterized by its specific content of organic carbon.

CHAPTER THREE

3.0 Methodology

3.1 Introduction

This chapter presents the overall plans and strategies that were used to conduct the research, including data collection. The research proposed a suitable research design, methods of data collection, study population, study area and sample size to enable the researcher collect and analyze data on the impact of soil conservation measures on Soil Organic Carbon stocks, a case study of areas covered by Center for Rural Development and Trans boundary Agro eco-system Management Project (TAMP) in Kabale District, Western Uganda.

3.2 Research Design.

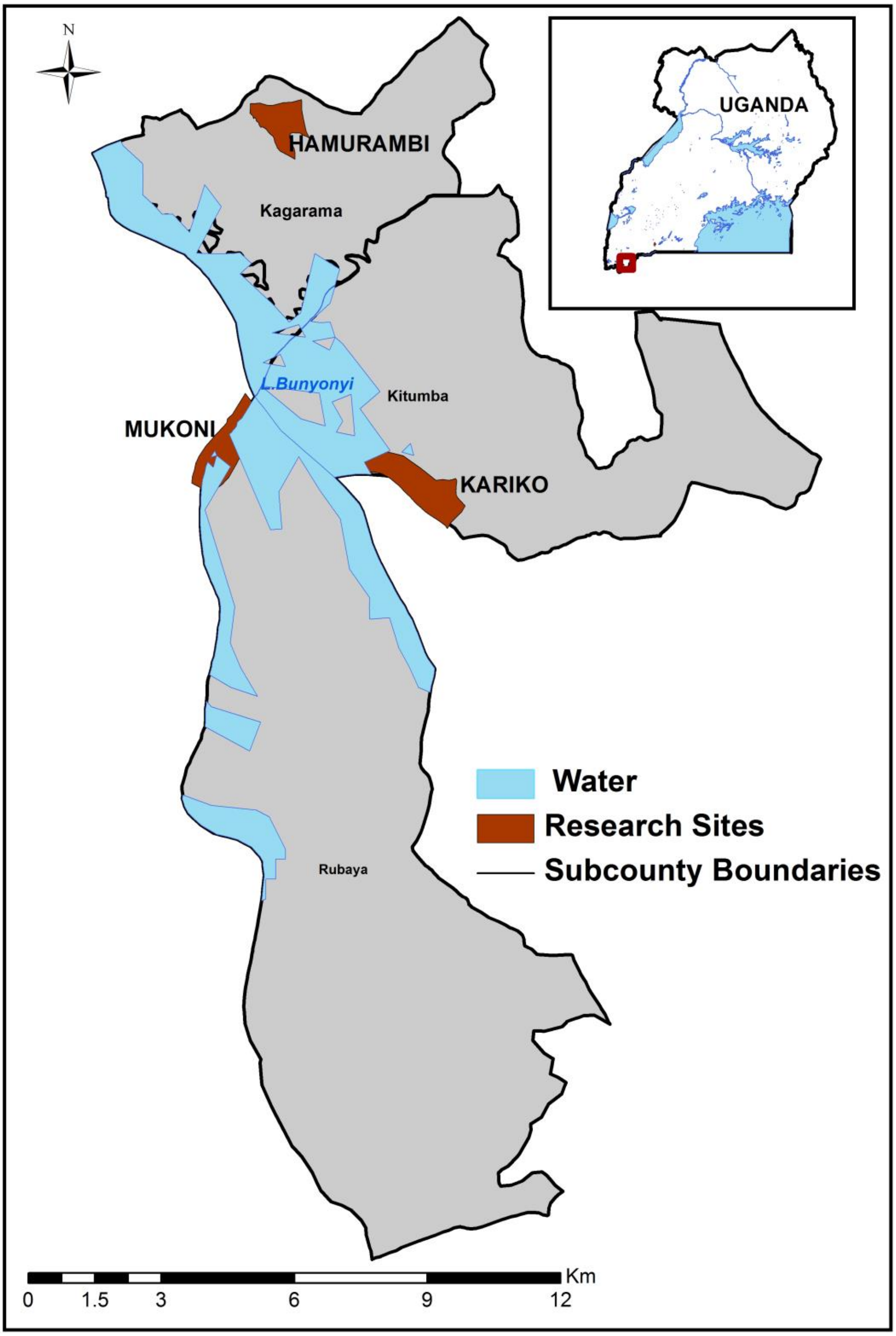
The study used a cross-sectional research design within the general framework of a mixed methodology that is experimental, where the randomized block design was used and qualitative methods to investigate the impact of soil and water conservation measures on SOC stocks.

3.3 Area and Population of the Study.

3.3.1 Study Area

The study was conducted in Mukoni, Kariko and Hamurambi villages found in Kagarama sub county, Kabale District. Kabale District is a highland district lying approximately 420 kilometers south west of Kampala the capital city of Uganda. The district covers 1,729 square kilometers (UBOS, 2015) the topography is mainly green, interlocking and heavily cultivated hills with spectacular valleys. The altitude of the district ranges between 1,219 m, (1218mnd 2,347 m (7,700 ft) above sea level. This altitude makes it colder than the rest of the country. Temperatures average about 18 °C (17 °C) during the day and fall to about 10 °C (50 °F) at night. The relative humidity is between 90% and 100% in the morning and decreases to between 42% and 75% in the afternoon the district population is estimated at about 545,200 people (UBOS, 2015). Kabale District is densely populated; with an area of 1,729.6 square kilometers, the population density in the district is estimated at 315.2 persons per km^2 vis-à-vis the national average of 174 persons km^{-1} . In that regard, the land is heavily fragmented.

Fig1: Map showing the study sites



3.4 Sample size and Sampling Procedures

3.4.1 Sample Size

A sample of 20 respondents was used in the study. Out of the 20 respondents, 12 were selected from the six (6) paired plots in the 2 study sites. The other six included 2 NAADS Agricultural Officers, 4 chairpersons of the farmer field schools (FFS) and 2 key informants – one informant from each site to verify information got from the study participants.

3.4.2 Sampling Procedure.

A two stage sampling technique was adopted, in the first stage, a purposive sampling method was used, targeting groups of farmers active in the farmer field schools. From the FFS, 6 members practicing soil and water conservation (SWC) were chosen by considering the topography, and time spent while practicing SWC. Six (6) farms were chosen from Mukoni village, Rubaya sub county Kabale District, for soil sampling through consultations from the coordinator and extension workers of the CRD project and the TAMP project . The sites included 3 farms under soil conservation using caliandra and organic manure for a period of 2 years and 3 farms under no soil conservation to act as reference sites. Soils mapped as ferralitic were selected for sampling in order to minimize variation among soil characteristics. All the six (6) sites were under similar crops.

Another six (6) sites were chosen in Kaliko and Hamurambi villages, in Kagarama sub county, Kabale District. These included 3sites where soil conservation had been done for 4years and 3sites where no soil conservation measures had ever been used as reference sites. The sites were also under the same crop (sorghum) and were on the same slope location.

3.4.3 Field Sampling

Soil samples were collected in May 2015 from all the twelve sites. To gather soil for SOC analysis from each location, simple random sampling was done using the "hat and draw" method from 5 separate sampling holes with a bucket auger in the following depth intervals: 0-15 and 15-30cm All six sampling locations were collected randomly within each field, to avoid bias during sample collection process.

Two bulk density samples were also taken with metal core at the 0-15 cm (surface layer) and 15-30 cm (sub layer) at each auger hole site. All samples were stored in sealed plastic bags and weighed before oven drying.

3.5 Data Collection Methods Tools and Methods

QA survey tool in form of a questionnaire was developed and uploaded on a mobile phone app called ODK**.** Questions in the survey tool were both open and close ended**.** The soil auger was used to collect soil samples from which a nutrient analysis for carbon, Phosphorus, Potassium Calcium, Magnesium and particle size was done. On site discussions were made with farmers where soil samples were collected to identify land use practices on the specific farms and field observations were made.

3.5.1 Survey tool (Questionnaire)

A detailed questionnaire was developed and uploaded on a mobile app covering all the major objectives of this study together with the moderating variable. The questions were both open and closed ended for easier analysis as this was also equally economical in terms of time and money. Data was collected from the farmers whose land was used for the biophysical measurements. Information was collected on their land management practices, including soil and water conservation activities, for the specific study plots as well as in general. Questions were also asked about their perceptions on soil quality and their opinion on soil quality in their plots.

The survey was based on the ALTER project 'Land Management Survey' that was originally developed for organic soils in Kabale District, and was modified for this particular

3.5.2 Interview Method and Interview guide.

According to Amin (2005), an interview is an oral questionnaire where investigators gather data through direct verbal interaction with participants. This was a conversation between the two or more respondents with the researcher and was based on oral interviews with key informants that is, the agricultural officers, the project chairpersons and other knowledgeable local village leaders in the area. The questions were focused on a description of the status of records of the previous soil and water conservation measures in the study area. The interviews were also used to probe perceptions of the different land users on soils and soil quality, pests and diseases, perceptions on change occurring on plots, the different soil and water conservation measures, the change in production and productivity of crops between the farmers with SWC and those without SWC.

3.6 Laboratory analysis

In early October 2015, the Walkley-Black procedure (1934) was employed to determine SOC content of the samples collected from 0-15 and 15-30-cm depths. This method utilizes potassium dichromate ($K_2Cr_2O_7$) and sulfuric acid (H_2SO_4) to oxidize soil organic matter, wherein the amount of reduced dichromate ion is proportional to the organic matter content. For each sample, 5 grams of air-dried soil was mixed with 10 mL of 1 N $K_2Cr_2O_7$ and 20 mL of conc. H_2SO_4, and then mixed with 100 mL of deionized water once the solutions cooled. Solutions were left overnight to settle and the percent transmittance (T) of all solutions was measured with a spectrophotometer at 620 nm. Particle size was determined using the hydrometer method (Gee and Bauder, 1986) after dispersion in a mixer of sodium hexametaphosphate, soil pH was measured using water (1:2.5) on oven dried soil. Bulk density samples were also weighed calculated based on oven-dry weight and core volume

3.7 Research Procedure

The researcher got permission from Uganda Martyrs University Faculty of Agriculture to investigate the impact of soil conservation measures on Soil Organic Carbon stocks in Kabale District. Permission was sought from the project manager TAMP and the CRD, Kabale District officials and the area chair chairperson where the selected farmers were found.

From Mukoni village, Rubaya sub county, 3 farmers who had planted Calliandra hedgerows and had been applying organic manure for a period of 2 years were selected, another 3 members in the same area who had not used any soil conservation measures were selected to act as a control. In Hamurambi and Kaliko, the villages where TAMP operates, 3 farmers who had planted calliandra hedgerows and had been using manure for 4 years and above were selected, 3 farmers who had never practiced soil conservation were sampled as a control. From each paired site 20 soil samples at a depth of 0-15cm and 15-30cm were collected making a total of 120 samples from the six (6) locations**.** The samples were analyzed for soil carbon, nitrogen, potassium and phosphorus. The researcher also personally collected data from the farmers where soil samples were collected to help understand the land management practices in the study area.

3.8 Statistical Analyses:

Data was subjected to ANOVA to determine the main effects of soil conservation on SOC and depth as well as their interactions. A separate one-way ANOVA model was used to test whether differences in mean total SOC between Soil conservation and control treatments were significant. Significance for all statistical analyses was determined at α= 0.05. All analyses were done using Statistix V. 2.0 (Statistix for Windows, 1998).

3.9 Data Sources and Types

The study used two sources of data, including secondary sources from documents while primary sources of data were collected from the field. This gave first hand information for analysis and secondary sources of data were collected from documents related to the content of the research. The type of data collected included quantitative and qualitative data. Secondary data was obtained from scholarly journals, annual reports from NAADS, and Ministry of Agriculture and Animal Husbandry and the internet as well.

3.10 Data Quality Assurance and Validity

The pre-testing tools were adopted to use more than one method in order to overcome the deficiencies of single method studies.

3.11 Qualitative,

3.11.1Qualitative Data analysis

The researcher gathered information using questionnaires and the Soil Auger for soil samples. After receiving the data from the respondents it was analyzed to derive meaning for this research study.

Qualitative data was analyzed using narrative and explanatory methodologies while Quantitative data was analyzed using number and percentage methodologies. The researcher tabulated the quantitative data into classes to show the number of distribution of classes falling into different categories in order to give comparison between frequencies and percentages.

3.12 Ethical Considerations

During data collection, the researcher created an ethical environment in order to recognize and uphold privacy, anonymity and confidentiality. The researcher received consent from the respondents and made sure that the findings collected from the respondents are kept secretly and the views obtained in the field are not tied on the individual respondents.

3.13 Study Limitations and delimitations of the study

Limited literature sources, the researcher faced problems in gathering relevant information about the study. This was due to few research studies that have been carried out in relation to the field required by the researcher. However this was solved by looking for more secondary sources and some of the primary source that provided more information required by the research study.

CHAPTER FOUR

Presentation and Interpretation of the Study Findings

4.0 Introduction

This chapter presents the results and discussions of the research study carried out in Mukoni, Kariko and Kagarama villages, located in the River Kagera catchment area, Kabale District. Qualitative results of land management practices and statistical presentations of the influence of soil and water conservation on soil organic carbon are presented below.

4.1 RESULTS

4.1.0 Social data analysis

The survey aimed at understanding land use and management practices in the study plots where biophysical data was collected and presentations were made qualitatively with opinions and understanding of the land use and management gathered from the farmers

4.1.1 Land use and management practices interview findings.

Accelerated soil degradation caused by soil erosion and other unsustainable land use practices are caused by the land users (farmers), findings from both sites (CRD and TAMP) reveal that the farmers appreciate the negative impacts caused by unsustainable land uses such as continuous cultivation, mono-cropping slash and burn, crop residue burning and over grazing, all which encourage soil erosion and soil fertility decline. The interviews were used to assess and understand the land use practices of the different land owners of the study plots and have a general understanding of the plots history and current status.

4.2 Study plots

4.2.1 Information on study plots

According to the survey, most of the study plots lie on 0.5 acres of land l located on the upper part of the slope, cultivation on these plots started in the early 1970s for the original owners. Currently, all the users have been cultivating on these plots for over 15 years now with the following cropping system: sorghum is planted in December and harvested in July while beans are planted in August and September and harvesting is done in October and November. However the current crop in the study plots was sorghum which, as already stated above, is planted in December and harvested in July. Weeding is done twice, where first weeding is done in February and the second weeding in March; the weed residues are left in the gardens most of it placed in strips to control soil erosion and water runoff. After harvesting the sorghum, residues are handled differently by the land users, some farmers burn or feed them to animals while other incorporate them into the soils. Farmers do not allow animals to graze in plots, but in December when it is dry, stray animals usually end up grazing in the plots. Six of the plots in the study were under SWC and the other 6 are without SWC.

4.2.2 Knowledge on soils

When asked what the indicators of good soils were, fine texture, colour (black) , the vigour of crops grown on such soils and the yields got were given. the respondents indicated that plots with SWC were all gradually showing those signs, reportedly the plots at one point had easily erodible soils, crop yields were reducing there was general decline in productivity until SWC interventions

4.2.3 Description of pests and diseases overtime

Reportedly, the farmers are experiencing more and more pest and disease surges on the plots, leading to an increase in damage of beans and potatoes. These were reported to be the crops mostly attacked by pests and diseases. The pests and diseases were said to attack the crops mostly at the post germination stage; the diseases are mainly fungal infections, which require chemical remedies. The farmers use fungicides such as mancozeb, and oxides for fungal diseases whereas dimethoate was reported as the remedy for black aphids that attack beans. Farmers find themselves spraying the beans thrice,which impacts them financially. Interestingly where there is application of manure, disease attacks are minimal compared to the plots without manure

4.3 Land use and Management practices

The study focused on understanding land management among farmers with SWC and those without, the farmers with SWC made the following interventions:, digging of trenches, planting of trees (e.g. calliandra/ grevellia, applying compost and farmyard manure, planting grass strips (fodder/ stabilization) crop rotation, incorporating crop residues; while the farmers not practicing SWC made no such interventions, to the contrary they burn the crop residues, cut down trees and cultivate throughout the year on the same plots

According to Bamwerinde (2013), Kabale District is one of the highland districts in south western Uganda and is one of the areas where land degradation in form of deforestation, over cultivation, bush burning and shifting cultivation is on a rampant increase. This could be attributed to an increase in the population and a subsequent decrease in land for cultivation. Upon this background, TAMP and CRD have been promoting soil management techniques such as; agro forestry, organic manure, digging of trenches, fallowing, crop residue incorporation and crop rotation.

4.3.1 Crop residue management

According to the findings, management of crop residues differs among the farmers with and with no conservation measures. Sorghum and beans were reported as the major type of crop residues used by the farmers practicing SWC in their plots. The sorghum and bean residues were placed in the garden inform of strips at the end of every cropping season, that is, in July and December. Reportedly, this helps in controlling soil erosion. On the other hand, labour implications in form of crop residue management and competition for the residues as animal feeds, impedes some farmers from using the residues as mulch or for soil fertility enhancement. Instead after harvesting, the residues are heaped in one corner and burnt or used as animal feeds.

4.3.2 Planting trees

Reportedly calliandra trees are planted on both the lower and upper end of the study plots. Seeds were provided by both CRD and TAMP projects which were then planted in nurseries of the farmer field schools. The members of the FFS are are given seedlings for free while , nonmembers buy the seedlings FFS. Caliandra hedgerows in Kabale are promoted for soil erosion control, maintaining soil fertility provide stakes for climbing beans , for fodder reducing competition for crop residues from livestock feeds and as a source wood fuel. In Kabale Caliandra takes an average of 2 years to mature. However accessibility to, and financial implications of planting caliandra seedlings was cited as one of the impedements of planting Caliandra control plots. Caliandra is known for its ability to enhance soil fertility farmers confess planting it on plots where they plant crops for economic benefits. These also preffered planting Caliandra to plots nearby homesteads for easy supervision, another challenge raised is animal browsing.

4.3.3 Application of animal manure.

Animal manure is applied conventionally on plots near the homestead rather than on plots far from the homesteads were little or no manure is applied at all this was reported by Briggs and Twomlow (2002) who reported that farmers in Southern Western Uganda only applied animal manure on plots near homesteads. Farmers applying manure spread in the garden at the beginning of every cropping season, that is in December when they are planting sorghum and in August for the second season. furthermore the farmers benefiting from the two projects are encouraged again through the farmer field school to each rare livestock so as to make animal manure availability easy. On the other hand the farmers not applying manure, reported that the study plots were located far from the home steads, the distances doesn’t permit transfer of animal manure from home to these fields, secondly the crops grown on the study plots are meant for home consumption not for commercial purposes so they don't find inspiration in proper management of the land.

4.3.4 Crop rotation

Crop rotations are widely practiced , it is reported that the people of South Western Uganda have for long been practicing rotations between beans, potatoes and Sorghum as a form of indigenous soil fertility management in form of Biological Nitrogen Fixation (BNF) and litter nutrient cycling

4.3.5 Fallowing

Fallowing is one SWC that is not practiced, land scarcity makes it impossible to rest the land therefore cultivation is done all year around, however some farmers manage their land with conservation measures while others do not, the farmers without conservation are confessing that due to over cultivation they are witnessing a decline in crop yields with yields declining from 800kg from ½ an acre to 300kg per 0.5 acre. Farmers embracing soil and water conservation measures are realizing a gradual increase in yields.

4.4 STATISTICAL ANALYSES

The Trans-boundary Agro-ecosystem Management Project (TAMP) has since 2010 been implemented in Kaliko, Hamurambi and Kagarama, -Rubaya Subcounty all in Kabale District. According to baseline reports, most areas in the project site had undergone severe land degradation including serious soil erosion. The project intervened by selecting a number of Farmer Field Schools in Kagera watershed area where SWC measures were implemented. Then one of the objectives of the project was to assess the effect of SWC on soil physiochemical and land productivity by comparing changes in soil properties and productivity on plots with SWC and those without.

Similarly, the Center for Rural Development (CRD) project has also since 2013 been implemented in Mukoni village, Rubanda sub county in Kabale District. Like the TAMP, the CRD project has intervened by assessing the effect of SWC on the soil physicochemical properties and land productivity by comparing changes in soil properties and productivity on plots with SWC and those without. An ANOVA comparing baseline conditions prior to establishment of SWC was made (Table1).

Table1: Mean differences between the CRD and TAMP Non SWC Sites

Site	OC%	pH%	P(ppm)	Ca(ppm)	K(ppm)	Mg(ppm)	BDg/cc
CRD	4.4a	5.0a	21.75a	1281.9a	168.3a	483.67a	1.23a
TAMP	2.6b	4.6b	4.7b	1102.8.a	108.9b	496.3a	1.28a

Figures in the same column imply significant differences.

The analysis revealed a statistical significant mean difference between the controls of the 2 sites in OC,P, pH, and K, however there was no significant mean differences in Mg, Ca, and BD

There were also significant site × treatment interactions for pH, P, Ca, Mg, and K but not for OC and bulk density, indicating that for those physicochemical properties with significant site × treatment interactions there were other site factors besides SWC measures responsible for the differences.

According to LSD at $P \leq 0.05$, the CRD project plots had on average significantly higher pH, OC, P, Ca, and K than the TAMP plots, whereas Mg and bulk density were not significantly different between the two sites.

Since the baseline conditions were different at each site, averages from plots of each project were considered differently and are presented here after.

4.4.1 Effects of Calliandra hedgerows and organic manure on SOC (CRD)

An ANOVA revealed that there was a statistical significant mean difference between the sites with and without Calliandra hedgerows and organic manure in SOC, P, Mg, K , Ca and pH. Whereas there was no statistical mean difference in BD (P=0.2821) There was no significant main differences of SOC stocks between the top layer (0-15) and sub layer (15-30cm).

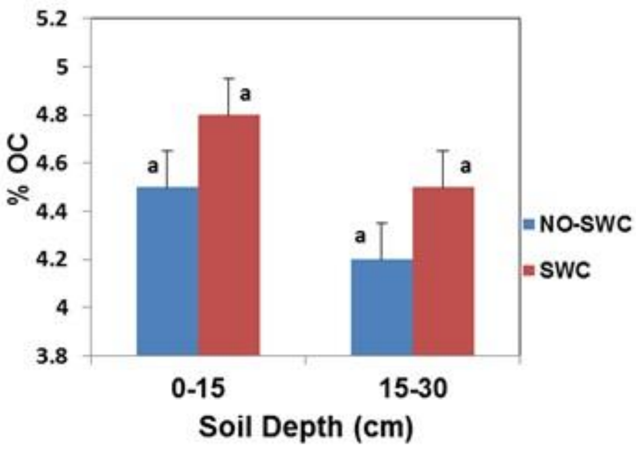


Fig2 Average OC as affected by land management at the CRD sites [means with the same letter are not significantly different at *P ≤ 0.05, Error Bars are SE*

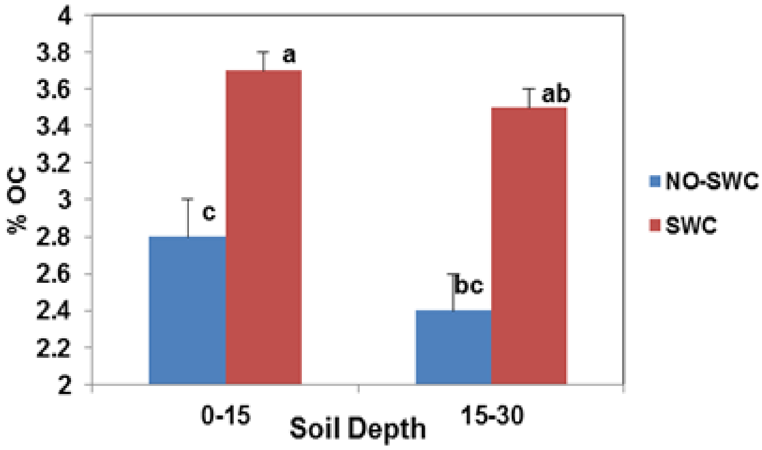


Fig3 Average OC as affected by land management at the TAMP sites. plots [means with the same letter are not significantly different at *P ≤ 0.05 Error Bars are SE*

Soil organic carbon (CRD): SOC is important for it determines soil quality and soil physical properties and crop nutrition (SHIMELES, 2012) properties affected by SOC are aggregate stability, infiltration, bulk density aeration, and water movement. The analysis made using statistical methods revealed that the mean total Organic carbon of CRD was high (SOC=4.5) and well above SOC critical levels (1.0%), even before SWC interventions. While the impact of Calliandra hedgerows and organic manure was not statistically significant at CRD in SOC (P=0.69) at the 0-15cm soil depth, a 0.3% (Fig2) increase of SOC was realized in sites with Conservation measures. There was also no significant mean difference between SOC at the two depths, 0-15cm and 15-30cm (P=0.9665). However as noticed in the 0-15cm soil layer, there is a gradual increase of SOC as depth increases in the conservation areas.

The results from the CRD could be because; as much as Calliandra fixes Nitrogen in the soil and acts as a contour stabilizer in the soil it matures between 6 months- 2 years. In soils that are acidic like those of Kabale it takes much longer meaning that within a 2 year period the hedges are not thick enough to reduce nutrient loss through soil erosion and leaching. Also the high level of polyphenols in Calliandra restrict soil microbial organic matter breakdown (Gutteridge,1992) to enable accumulation of soil organic carbon after the given period . The changes realized could be because of application of organic manure, findings are supported by Habtamu (2015) who registered an increase of soil organic carbon 2 years after application of organic manure in maize.

SOC takes time to accumulate to significant levels in the sub layer depths this finding is as seen in Cherry et al,(2006) who states that Green manure will not break down into the soil so quickly but gradually and some nutrients to the soil for the next crop. Furthermore due to fact that Calliandra requires at least 2 seasons to establish and become effective with constant application of manure and water to the seedlings to ensure accelerated growth where before such a time SOC remains at shorter depths.

And also some plants have the ability to fix Nitrogen which is a component of SOC from air with the help of their root nodule bacteria with their short roots which will not break down the soil quickly leaving it at the top layer without penetrating deep into the deeper soil depth.

Soil organic carbon (TAMP) Soils from TAMP showed a low organic carbon 2.8 (fig 4) content but a significant mean difference between SOC in soils with and without SWC (p=0.0003) was realized with SOC increasing to 3.7% from 2.4 % (Fig3). Although there is a significant increase in SOC at the TAMP sites and a slight increase of SOC down the soil profile, there was no statistical significant mean difference in SOC between the 2 soil depths(0-15 and 15-30cm) Addition of organic manure in the soils increases the organic carbon content of the soil, Bayu, et al (2006) in his findings revealed that organic manure increased SOC up to 13% over the control.

This is also in line with (Mc Lean, 1987) who showed in his literature that Manure contains valuable plant nutrients, like nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) and also an increase in OC leads to an increase in PH making micro bases such as Calcium (Ca), Magnesium (Mg) and Potassium (K) more available. Caliandra has been linked to improvement of soil as a soil conservation measure which later contributes to minerals in the soil. Hedges reduce transportation and trap material such as plant litter from areas above them, with time the added litter accumulates increasing SOM. This finding is in line with (Angima et al, 2000) who asserts that the use of tree hedges (hedgerows) on contours of steep slopes has become increasingly important since they can serve as soil erosion barriers and nutrient retention enhancers through their influence on the supply and availability of nutrients SOC inclusive.

4.4.2 Effects of calliandra hedgerows and organic manure on pH

A one way ANOVA revealed that there was a significant mean difference of pH (P=0.4944) between CRD and TAMP, with CRD registering a significant mean effect of Calliandra Hedge rows and organic manure (P= 0.0000) while TAMP registered no significant main effect of calliandra hedge rows on pH (P=0.0003). There was a significant main differences of pH between the top layer (0-15) and sub layer (15-30cm) for both sites.

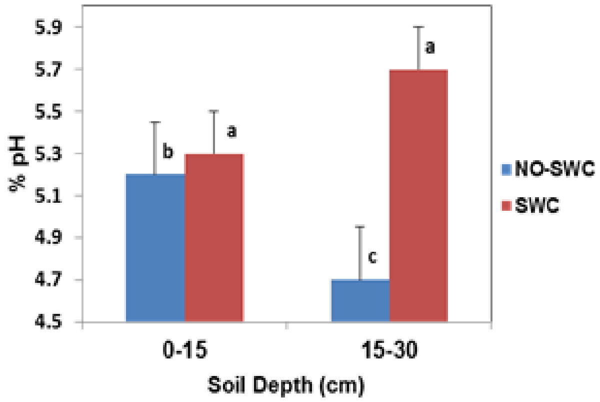


Fig4 Average pH as affected by land management between at CRD plots (means with the same letter are not significantly different at $P \leq 0.05$),*Error Bars are SE*

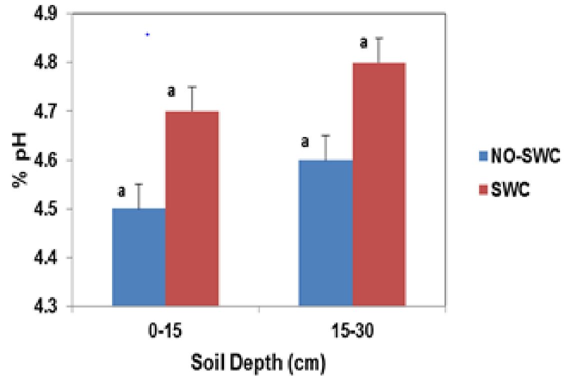


Fig5: Average pH as affected by land management between at the TAMP sites [means with the same letter are not significantly different at $P \leq 0.05$, *Error Bars are SE*

pH (CRD). Soil pH is important for it influences soil microbial activities and significantly influences plant growth. Soils of the CRD are acidic but an increase of pH was registered after the use of SWC, the mean value of pH for the CRD site shows a significant difference between the sites with and with no SWC pH (P=0.000). The soil analysis results (Fig4) showed that soil pH for all the soils sampled were slightly acidic . Low base saturation is an indicator of soil acidity and the removal of basic cations is a major process causing soil acidification in nature (Norton et al., 1999). Every one-half unit drop in soil pH percent base saturation declines by about 15% (Baruah and Barthakur, 1998). The highest pH value associated with the SWC sites at a lower soil depth could be attributed to the presence of higher exchangeable cations due to the effect of leaching and translocation from the upper soil horizons. As a result, most tropical soils have the problem of nutrient availability for the production of agricultural crops such as potassium, calcium, magnesium and phosphorous.

This finding is supported by (J Mgwe,s 2009) who realized an increase in pH with organic manure amendments.

pH (TAMP), Soils in the TAMP sites are acidic with values going well under critical levels, SWC interventions increased the pH in SWC sites at the upper depth(0-15cm) compared to the control. However statistical analysis showed no significant mean difference (p=0.2181) in pH between plots with and without Conservation (Fig5). There was no significant difference between pH of the upper

(0-15cm) and lower (15-30cm) p=0.5735 soil depths but we see an increase in pH down the soil profile in the TAMP sites, which could be explained by the soil inversion process.

4.4.3 Effects of calliandra hedgerows and organic manure on BD

A one way ANOVA revealed that there was a significant mean difference of BD (P=0.0000) between CRD and TAMP, with CRD registering a significant mean effect of BD

Calliandra Hedge rows and organic manure on BD (P= 0.2821) while TAMP registered no significant main effect of calliandra hedge rows on BD (P=0.0630). There was a significant main differences of BD between the top layer (0-15) and sub layer (15-30cm) for both sites (P=0.0000)

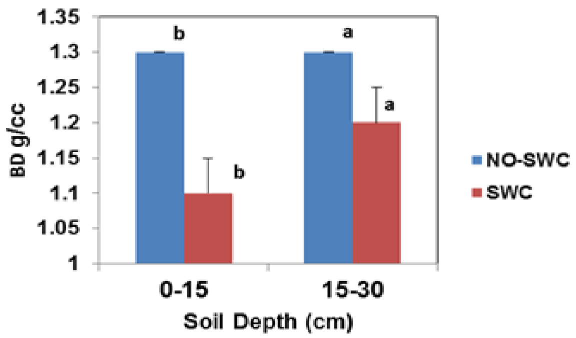


Fig6 Average BD as affected by land management at the CRD plots [means with the same letter are not significantly different at *P* ≤ *0.05* *Error Bars are SE*

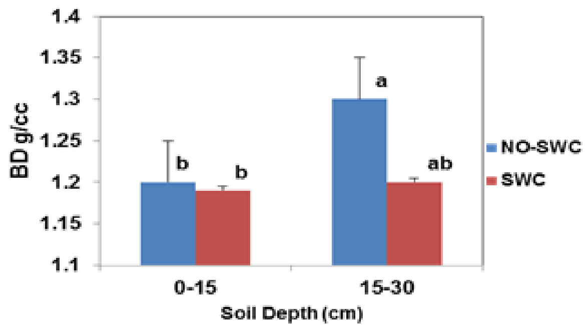


Fig7: **Figure – Average BD as affected by land management at the TAMP Sites [means with the same letter are not significantly different at *P* ≤ *0.05***

Bulk density (BD) CRD: bulk density is very important in crop productivity as it is an indicator of soil physical fertility, it influences infiltration, root penetration and nutrient uptake. Baseline conditions ((non-conserved plots) show a high bulk density at these sites mostly at the 0-15cm soil depth, and it does not change much as we move done the soil profile.

BD in the conserved sites is seen to be decreasing in the top layer compared to the sub layer which although has reduced compared to the non-conserved sites remains high. The one way analysis of variance revealed that there was no significant mean difference in bulk density between the conserved and non-conserved sites (P=0.0689). there was however a significant mean difference in BD on sites with conservation between the 0-15cm and 15-30cm compared to non-conserved sites where there was no significant difference between the 2 depths. The decrease in BD of the conserved sites could be attributed to the presence of relatively higher organic matter as a result of

SWC. However a significant difference was revealed in terms of depth (Fig 3), the bulk density of the top soil (0-15) was significantly lower (1.12 g/cm) than the bulk density of the sub layer (15-30) 1.23 g/cm(Fig 2). The topsoil bulk densities of the sampled soils are in line with the ranges described by Rai (1998); Landon (1984) that is, between 0.92 to 1.17 g cm-3. Findings are also in line with Bayu et al 2006 who found that bulk density increased with depth there by making root penetration difficult and also signified a decline in organic carbon.

Bulk Density (TAMP) There was no significant difference in mean values (P= 0.0680) of bulk density between the non-conserved and conserved sites of TAMP. At the 0-15cm depth bulk density is more less the same in both the conserved and non-conserved sites the top soil bulk densities are above the ones recommended by Rai (1998). However a significant difference between mean values of bulk density was seen (P=0.0020) at the 15-30cm depth. Comparing the non-conserved and conserved sites bulk density is decreasing in the conserved sites this could be attributed to higher organic matter in the conserved sites, therefore more plant roots, litter are accumulating in these sites. Also, application of SWC led to a reduction of bulk density Fig, a reduction in BD is a sign of increased soil porosity caused by an increase in organic matter, this finding is in line with Islam et al(2006), Marthur (1997) whose findings showed an increase in OM content which influences bulk density after addition of organic manure.

4.4.4 Effects of calliandra and organic manure on other chemical properties (CRD)

Table 2: effects of SWC on other Chemical properties at CRD

Land Management	Layer (cm)	P (ppm)	CA (ppm)	MG (ppm)	K (ppm)
No SWC	0-15	30.9a	1583.6b	565.3b	239b
	15-30	10.59a	980.2c	402c	97.57c
SWC	0-15	87.12a	2098.0a	705a	346.9a
	15-30	76.6a	2547.7a	787a	398.8a

P=available phosphorus, CA=Calcium, MG= Magnesium, K = Potassium , (a,b,c,ab)

Figures in the same column having the same letter are significantly not different from each other

Effects of SWC on other chemical properties (CRD).

There was a significant mean difference in P, Ca, Mg, and K between the conserved and non-conserved sites of the CRD, nutrient values rose to significant levels in sites with SWC compared to the non- conserved. P increased from medium levels (30.9) where medium ranges from 23-35.5 in the top layer, to high levels (87.12) where high values range from 36-68.5 in the top layer, Mg, K, and Ca increased to significant levels (Table 2) although they were well above critical levels even in the non-conserved sites. However there was a significant difference in P, Ca, Mg, and K between the 0-15 and 15-30cm soil depth, with the top layer having more of these nutrients than the sub layer. In the conserved sites however, there was no significant difference in nutrients between the 2 soil depth.

Table3: Effects of SWC on other chemical properties at TAMP sites.

Land Management	Layer (cm)	P (ppm)	CA (ppm)	MG (ppm)	K (ppm)
No SWC	0-15	4.3b	1017.9b	474.7a	116.8ab
	15-30	5.08b	1187.7ab	517.9a	101.03b
SWC	0-15	10.2a	1293.6a	546.5a	153.93a
	15-30	11.2a	1359.5a	574a	156.87a

P=available phosphorus, CA=Calcium, MG= Magnesium, K = Potassium , (a,b,c,ab)

Figures in the same column having the same letter are significantly not different from each other

Other chemical properties (TAMP), The non-conserved sites had very low to low P and OC levels with P values going below critical levels of 12ppm in the top layer. Mg and K levels were very high. Significant differences were registered between non-conserved and conserved sites. Where significant nutrient increases were registered in conserved sites. analyses showed conserved sites having the highest amounts of K , and Mg, while Ca and P were at very Low to medium levels (Table 3)

Table 4: Pearson correlation between organic carbon and other soil properties

	pH %	OC %	P(ppm)	CA (ppm)	MG (ppm)	K (ppm)	BD g/cc
OC%	0.2794						
P (ppm)	0.6533	0.2669					
CA (ppm)	0.8660	0.2161	0.6338				
MG (ppm)	0.8316	0.1489	0.5727	0.8958			
K (ppm)	0.9098	0.2190	0.6700	0.8713	0.7881		
BD (ppm)	0.2270	-0.1437	-0.0363	0.2828	0.2265	0.1604	
Sand (%)	-0.7322	-0.3895	-0.4200	-0.4976 -	0.4692	-0.5997	-0.0778
Silt (%)	0.5273	0.3417	0.5925	0.3814	0.2978	0.4835	0.0070
Clay (%)	0.2307	0.0601	-0.1428	0.0942	0.1478	0.0897	0.1471

Pearsons correlation coefficient at r=0.5

The output analysis above shows that all the nutrients variables are significant at 5% level of significance due to the fact their p-values are greater than 5%. The correlation coefficients of potassium content and those of Mg are positives which implies that there is a weak positive correlation between Organic carbon contents with potassium and Mg contents mean that a unit increase of Organic carbon to the soil leads to a slight unit increase of potassium and Mg contents

The study showed a slight positive correlation between organic carbon and pH r= 0.1596, Clay r=0.523,. it revealed that there was a weak negative correlation between OC and bulk density BD r=-0.423, sand r=-0.2571 , these results are in line with studies carried out by E sakin who showed that as OM increased Bulk density decreased. P,K,Ca and Mg concetrations were lower in soils without SWC than in soils with SWC

The coefficient of soil PH is positive (0.227) shows that a unit increase in the organic carbon content in the soil pair sample would lead on average increase 0.050 in the soil PH. In other words as more and more contents 0f organic carbon increase in the soil leads to the reduction in the soil PH. An increase in pH leads to an increase in cations (p,k,Ca,and Mg)5 implying that the PH and Bulk density of the three soil pair samples site depended on the organic carbon content.

Similarly, The coefficient of soil bulk density is negative (-0.2449) shows that a unit increase in the organic carbon content in the soil pair sample would lead on average to 0.245 decrease in the soil bulk density.

Soils of TAMP were acidic and low in p with values below critical levels even after SWC,, however OC values are high this is because the study was carried out in Kabale, a District with low temperatures, where SOC accumulates more than it decomposes.

Soil analysis revealed that at values ranging between 4.8% (top soil) and 4.2% (sub soil) SOC stocks were relatively high at the CRD, pH values of 5.2 % (top soil), 4.7% (sub soil) were at critical levels and BD at 1.2 g/cm^{-3} soils were compact before and after application of SWC measures

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter presents a summary of key findings, conclusion and recommendations of the study on assessing the impact of soil conservation measures on soil carbon a case study of villages under the Center for Rural Development (CRD) and the Trans-boundary Agro-ecosystem Management Project (TAMP), Kabale district as evidenced from the study as detailed below.

5.1 SUMMARY OF KEY FINDINGS

The overall objective of the study was to assess the impacts of soil conservation measures on soil organic carbon stocks. Specific objectives were to understand land management practices and to assess the impact of calliandra hedge rows and organic manure on soil organic carbon stocks.

The study findings revealed that there is no statistical significant mean difference in soil organic carbon between plots with and without soil conservation after a period of 2 years of practice with the significant mean difference at SOC($P=0.43 >0.05$) . This is due to the fact that in as much as calliandra fixes Nitrogen in the soil it matures between 6 months- 2 years. In soils that are acidic like those of Kabale it takes much longer meaning that within 2 year the hedges are not thick enough to reduce nutrient loss through soil erosion and leaching. Also the high level of polyphenols in calliandra restrict soil microbial organic matter breakdown (Gutteridge,1992) to enable accumulation of soil organic carbon after the given period . The slight changes realized could be because of application of organic manure, findings are supported by Habtamu(2015) who registered an increase of soil organic carbon 2 years after application of organic manure in maize.

The study revealed a significant mean difference (p-value (.001) $<.05$) between plots with and without soil conservation at a depth of 0-15 cm after a period of 5 years. This is due to the continuous input of organic manure (10t ha) and crop residues in the top layer of the soil. These results are in consistence with that of Lie et al. (2010) and Xueli et al. (2012) who reported that the application of OM in combination with inorganic fertilizers exerted greater influence and linearly increased soil OC levels. Gentile et al. (2010) also observed an increase in soil OC content after three years of OM application in Kenya. Findings are similar to those by Lee et al. (2009) who realized a significant increase in SOC organic manure additions.

Similarly calliandra calothyrsus lives in symbiosis with rhizobium, forming nodules on roots to fix nitrogen from the atmosphere, which is transferred to the Calliandra plant. This helps the Calliandra to grow fast, Through litter production and dense foliage, Calliandra also provides ground cover and improves soil quality and productivity, making it suitable for rejuvenating degraded soils, as found in the Kabale highlands (ICRAF 2001a). Findings are supported by Nakakaawa 2002's study in Kabale district where soil organic carbon increased by 78% compared to the baseline after establishment of calliandra fallows

The 2 sites compared, there was no significant mean difference between soil organic carbon between plots with and without soil conservation measures at the depth of 15-30 cm this is probably because organic matter decomposition and accumulation occurs at the 0-15cm soil depth. Soil organic carbon ideally decreases down the soil profile.

On running analysis on the degree of dependency between organic carbon content and other nutrients, the results showed that after a period of 5 years SOC content had a positive relationship with soil PH and other nutrients like Mg, Ca,P and K , whereas SOC had a negative relationship with soil bulk density this implies that soil conservation measures have positively impacted on agricultural productivity of the conserved areas.

5.2 CONCLUSION

The use of soil conservation measures is very important in Kabale District, farmers have prior knowledge to the causes of soil erosion and declining soil fertility and the dire consequences of unsustainable land use practices, they have knowledge on the characteristics of both a good and poor quality soil. However adoption of calliandra and organic manure application on farms depends on farmer's perception of the soil fertility problem. Factors such as plots proximity to homesteads (calliandra and manure are applied to plots close to homesteads where management is easy), importance attached to crops grown on the plot(management differs from crops grown for home consumption and those grown for commercial purposes)and benefits received from development organisations for practicing SC were some of the reasons given for adoption or disadoption of SWC.

The results showed that it is therefore possible to recover abandoned and /or degraded areas, resulting from a number of causes such as deforestation, shifting cultivation, overgrazing, swamp reclamation and or over cultivation of ecologically sensitive areas in Kabale District through the introduction of Calliandra thereby making it an effective agroforestry system that is most adequate for Kabale District and other areas of Uganda. Calliandra agro-forested areas allow for SOC conservation in the ecosystem is therefore making it a good plant especially for problem sites which are common in Uganda.

It adapts well on steep hillslopes and poor soils, establishes easily by direct seeding or planting seedlings, its extensive and deep root system, makes it suitable for erosion control on slopes and stabilization of soil and water conservation structures thereby making it a prime candidate for restoring slopes and grass lands removed through shifting cultivation, deforestation among others and above restoring Soil Organic Carbon and carbon sequestration.

These findings reinforce the facts that in order to sustain use and adoption of SC measures of calliandra hedgerows and organic manure should be given a strong priority for long term SC use and soil organic carbon increases.

Use of organic manure makes it possible to improve soil physical and chemical properties due to its composition of organic matter ensuring a sustainable management of soil fertility. Organic manure plays an important role in improving soil organic carbon most especially on the top layer of soils. Therefore, policy makers should encourage farmers to use soil conservation approaches such as calliandra that stops soil erosion and soil nutrients loss, and organic manure that increase organic matter input into the soil so as to reduce carbon dioxide fluxes into the atmosphere and store carbon in soil organic matter.

5.3 RECOMMENDATIONS

The rural households in the study area poor, living on very meager annual incomes. Land degradation, particularly soil erosion by water, is a threat to their agricultural production. SWC measures are very helpful in reducing surface runoff thereby increasing land productivity. Thus, all stakeholders need to encourage farmers and the community at large in the facilitation, adoption and implementation of SWC measures at farmland level in high land Districts. The management of soil nutrients using farm yard manure, crop rotation, weed control and crop residue incorporation practices such as over grazing, over cultivation; crop residue burning should also be discouraged, for they reduce on biomass that could eventually turn into organic matter.

Attention should be given to the bio-physical SWC measures. Biological SWC measures have the capacity to make the ecology more stable and economically viable. Moreover, most of the biological conservation practices are linked to the normal agricultural practices and are not too difficult to be learnt by farmers.

More work is yet needed to be done on Calliandra in many fields of soil science, botany, forestry, ecology, microbiology among others. The recommendations therefore proposed are intended to increase the scaling up of use of Calliandra and organic manure, not only in the study area but also in the whole country.

More promotion of Calliandra use as a better way of restoring Soil Organic Carbon, reforestation and carbon sequestration in general, in view of the clear benefits demonstrated should be encouraged by government in its Plan for the Modernisation of Agriculture and by extension service providers through the National Agricultural Advisory Services and NGOs.

5.4 AREAS FOR FURTHER RESEARCH

More research should be done to find out the diseases that affect Caliandra so as to clear constraints that may affect its adoption.

An assessment on impacts of calliandra and organic manure on both the physical and chemical soil properties is required

More research on socio-bio-physical SWC approach is required to get a comprehensive idea on effects of SWC measures on key soil properties, socio-economic development, environmental impacts, cropping and tillage systems, etc. to have a better understanding in an integrated way.59

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APPENDIX 1

1: QUESTIONANAIRE FOR FARMERS

Farmer Interview- Survey of Land Management Practices

Survey information

Date

Time

Enumerator Name

Random Sample No

Introduction

I am are researcher studying at Uganda matyrs university Nkozi ,supported by the Carbon Foundation of East Africa in Kampala, and the University of Aberdeen in the UK. With permission from the National and District governments our research is studying the relationships between livelihoods, poverty and organic soils. We would like to ask you some questions about how you benefit from the soils, in particular how you use them for farming. It should take no more than 45 minutes of your time. All responses will be kept confidential and your name will not appear in any data that is made publicly available. The information you provide will be used purely for research purposes. These questions form part of a survey to help us better understand the benefits that people receive from soil. The results from this will be used to understand how people can benefit from improving their soils, and how people can be helped to manage their soil better. These results will be shared with your cooperative for feedback and further discussion.

Do you consent to being part of this survey: Yes No

Farmer information

Name of farmer	
Farmer phone number	
How long have you cultivated in this area (years)?	
Location of farmer household	Sub county: Parish: Village:
How many plots do you cultivate on the upland slopes?	

What is the ownership status of your plots?	Private Communal Rented Government Other- specify
Location of plots	Village:
What is the size of your biggest plot? Units	
What is the size of your smallest plot? Units	
What is the main use/crops grown on your plots in areas?	
Do you rent any of your plots to others?	

Upland conditions and use

	Upland plots		
From your own experience and expertise as a farmer, what are the 3 signs of good soil quality (e. g. soil moisture, dark soil, etc)	1.	2	3
How many of your plots show these?	1. All/ most/ some/ none	3. All/ most/ some/ none	2. All/ most/ some/ none
How would you describe the soil quality in your plots?	Very good Good Satisfactory Poor I don't know		
How would describe any problems related to soil quality in your plots?	Very bad Bad Significant Mild None Can't tell		
Additional comments on soil quality			
How would you describe any problems with pests and diseases in your plots?	Very bad Bad		

	Significant Mild None Can’t tell	
Additional comments on pests and diseases		
During the past 12 months, which of these techniques have you used for soil management in your plots?	Trenches Grass bunds Planting of calliandra/ grevellia Applying farmyard manures Applying compost Burning of crop residues or vegetation from clearing Chemical fertiliser Fallow periods Mixed cropping (intercropping) Weeding Pre-emptive use of pesticides Treatment with pesticides Planting eucalyptus trees Planting natural trees Others- specify	

Comparison/ contrast of plots

Which plots do you get most of your household food needs from?	Upland/ valley bottom
Which plots do you get most of your crops for market from?	Upland/ valley bottom

Information about the study plot

What is the size of this plot?	
What is the position of the plot on the slope?	Upper Middle

	lower
What crops do you grow on this plot?	
What is the current crop growing on the plot today?	
When exactly do you expect to harvest this crop?	

Timeline of land use over the year of the study plot

Crop 1 (main crop):	Crop name	
Do you plant this crop on this plant more than once in a year? If so, how many times?	Yes No	
Preparation and planting	Time of year (month)	
	Time spent in the plot	
	Number of paid labourers	
Weeding	Time of year (month)	
	Number of times	
Spraying pesticide	Time of year (month)	
	Number of times	
Name of pesticides	Time of year (month)	
	Number of times	
Name of fertiliser applied?	Time of year (month)	
Harvest	Time of year (month)	
	Time spent in the plot	
	Number of paid labourers	

Crop 2:	Crop name	
Do you plant this crop on this plant more than once in a year? If so, how many times?	Yes No	
Preparation and planting	Time of year (month)	
	Time spent in the plot	

	Number of paid labourers	
Weeding	Time of year (month)	
	Number of times	
Spraying	Time of year (month)	
	Number of times	
Name of pesticides	Time of year (month)	
	Number of times	
Fertiliser applied?	Time of year (month)	
Harvest	Time of year (month)	
	Time spent in the plot	
	Number of paid labourers	
Crop 3:	Crop name	
Do you plant this crop on this plant more than once in a year? If so, how many times?	Yes No	
Preparation and planting	Time of year (month)	
	Time spent in the plot	
	Number of paid labourers	
Weeding	Time of year (month)	
	Number of times	
Spraying	Time of year (month)	
	Number of times	
Name of pesticides	Time of year (month)	
	Number of times	
Fertiliser applied?	Time of year (month)	
Harvest	Time of year (month)	
	Time spent in the plot	
	Number of paid labourers	

Crop 4:	Crop name	
Do you plant this crop on this plant more than once in a year? If so, how many times?	Yes No	
Preparation and planting	Time of year (month)	
	Time spent in the plot	
	Number of paid labourers	
Weeding	Time of year (month)	
	Number of times	
Spraying	Time of year (month)	
	Number of times	
Name of pesticides	Time of year (month)	
	Number of times	
Fertiliser applied?	Time of year (month)	
Harvest	Time of year (month)	
	Time spent in the plot	
	Number of paid labourers	

Additional activities

When was this plot last left to fallow?	How long for (months)?	
Grazing	You or others?	
	Months	

Land Preparation on the study plot

Prior to planting your main crop, what is the state of vegetation cover?	None Other crop Wetland grasses Papyrus Fallow weeds Other- specify	
Do you carry out any of these activities on this plot?	Burning of crop residues or vegetation from clearing	

	Fertiliser	How much? Name?
	Chemical weeding/ use of herbicides	When? How much?
	Pesticides	
	Others specify SWC?	

History of study plot

When did you first cultivate this plot?	
Were you the first to cultivate this plot?	
If no, then when was the first cultivation ever on this plot?	
What were your main crops when cultivation began and associated yields?	
What was the total yield of the main crop at the last harvest?	
Has there been a change in yields of this crop over time? If yes, please describe the change and your reasons for the changes.	
Has there been a change in quality of produce over time? If yes please describe and your reasons for the changes.	

Pests, weeds and diseases in the study plot

How would described the impact of weeds on the growth of your crop in your main plot?	Very bad Bad Significant Mild No affect Can’t tell
Any addition comments about weeds in your main plot	

How would you describe the impacts of soil nutrient depletion in your soils?	Very bad Bad Significant Mild No affect Can't tell
Any addition comments about soil nutrient depletion in your main plot?	

Disease/pests	During which periods do the attacks occur 1 = Germination 2 = Growth period 3 = Harvesting	Severity of attack 1 = Not severe 2 = Severe 3 = Very severe	Parts affected 1 = Leaves 2 = Stems 3 = Tubers 4 = Others (describe)	Ability to identify the problem by looking at symptoms 1 = Not at all 2 = Quite able 3 = Completely able	What % of your crop is affected by this problem	Please indicate the treatment used *(e. g chemicals, fertilizers, herbicides)*	What is the average cost of treatment (***UGX***)
Have you observed diseases in this plot in the last 12 months? **Yes/ No/Don't know**							
Diseases							
1.							
2.							
3.							
Did you experience pest problems in this plot in the last 12 months? **Yes/ No/ Don't know**							
Pests							
1.							
2.							
3.							

APPENDIX 11

2: PROCEDURE FOR USING THE SOIL AUGER

The following are the procedures used to collect soil samples with a soil auger

1. Attach the auger bit to a drill extension rod, then attach the “T” handle to the drill extension rod.
2. Clear the area to be sampled of any surface debris.
3. Begin auguring, periodically removing any accumulated soil from the auger bucket.
4. After reaching the desired depth, slowly and carefully remove the auger from boring. (When sampling directly from the auger, collect sample after the auger is removed from boring and proceed to Step 10.)
5. Remove auger tip from drill rods and replace with a pre-cleaned thin-wall tube sampler. Install proper cutting tip.
6. Carefully lower tube sampler down borehole. Gradually force tube sampler into soil. Care should be taken to avoid scraping the borehole sides. Also **avoid hammering** of the drill rods to facilitate coring, since the vibrations may cause the boring walls to collapse.
7. Remove tube sampler and unscrew drill rods.
8. Remove cutting tip and remove core from device.
9. Discard top of core (approximately 1 inch), as this represents material collected by the tube sampler before penetration of the layer of concern.
10. Transfer sample into an appropriate sample or homogenization container. Transfer soil from the sample collection device to an appropriate sample container using a stainless steel or plastic scoop or equivalent.