Impact of Land Husbandry Technologies on the Improvement of Soil Erosion Control in Rwanda

A Case of Land husbandry Water harvesting and Hillside irrigation (LWH) project site, Nyanza 23.

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In the College of Science and Technology

Supervisor:
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Declaration

I declare that this Dissertation contains my own work except where specifically acknowledged

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Date……/…..……/2016

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MAY GOD BLESS YOU ALL EXCEEDINGLY

Jean Pierre MUNYANTARAMA

Abstract

Erosion has significant effects on the economic, environment, agronomic productivity, food security, and the quality of life of resource-poor farmers in Rwanda. Unsustainable land-use, coupled with Rwanda's steep topography, fragile soils, and climate, is the driving cause of soil erosion. Hence, Land Husbandry Technologies (LHT) was adopted as measures to mitigate soil erosion impact in Nyanza, Southern Province, Rwanda

The main objective of this research was to assess the impact of land husbandry technologies on the improvement of soil erosion control. Revised Universal Soil Ross Equation (RUSLE) applied to GIS was used to assess the erosion rate before and after the implementation of land husbandry technologies while focus group discussions were held with various actors to evaluate the adoption and maintenance of land husbandry technologies and investigate the impact of land husbandry technologies on welfare improvement of direct beneficiaries.

Basing on the results from RUSLE equation applied with GIS, it was found out that the acuteness of erosion reduced significantly. The study revealed that farmers have adopted and are maintaining LHTs. Plot size, farmers' capacity to invest, distance travelled from home to the treated plot, off-farm activities and availability of supportive institutions are the main factors that significantly affect the probability of adopting LHTs. The results also indicate that the introduction of LHTs resulted into welfare improvement of farmers in the area.

Based on the mentioned positive results of adoption of LHTs, local authorities should extend land husbandry technologies in areas where they have not yet been introduced. Also, it is imperative that more sensitization mechanisms be put in place to address the challenge of farmers who have not adopted LHTs and encourage the ones who adopted them to maintain them. Lastly in-depth research should be conducted for evaluating farmer's capacity to invest in adoption and maintenance of Land Husbandry Technologies, therefore based on the results, the LHTs can be extended to other regions of the country

Key words: *Nyanza, Land Husbandry Technologies, Soil erosion, Rusle equation, adoption and Maintenance*

Contents

Declaration **1**

Acknowledgements **2**

Abstract **3**

Contents **4**

Table of Figures **7**

List of Tables **8**

List of acronyms and abbreviations **9**

CHAPTER ONE: INTRODUCTION **10**

1.1 Background 10

1.2 Research Problem 13

1.3 Research objectives 14

1.4 Research Questions 15

1.5 Research hypothesis 15

1.6 Significance of the Study 15

1.7 Structure of the thesis 16

CHAPTER TWO: RESEARCH METHODOLOGY **18**

2.1 Description of Study area 18

2.1.1 Location 18

2.1.3 Land use/cover 19

2.1.4 Soil 19

2.1.5 Slope 20

2.1.6 LHTs applied 20

2.2 Data Collection Techniques Applied 21

2.2.1 Library research 21

2.2. 2 Field Observation 21
2.2.3 Soil erosion measurement using GIS technology 22
2.2.4 Focus Group Discussion 26
2.2.5 Interview 27
2.3 Data Analysis and Visualization 28
CHAPTER THREE: LITERATURE REVIEW 29
3.1 Perceptions of Soil erosion 29
3.2 Erosion Process 30
3.3Types of Erosion 31
3.4 Land Husbandry Technologies 32
3.4.1 Grass strips 34
3.4.2 Soil bunds 34
3.4.3 Improved bench terraces 34
3.4.5 Narrow-cut bench terraces 34
3.5 GIS and Soil erosion models 35
3.6 Erosion control in Rwanda 37
3.6.1 The extent of Erosion in different parts of Rwanda 37
3.6.2 Soil conservation and erosion control in Rwanda 38
CHAPTER FOUR: RESULT AND DISCUSSION 41
4.1 Erosion rate before and after the implementation of land husbandry technologies using GIS 41
4.1.1 Erosion rate before implementation of land husbandry technologies using GIS technologies 41
4.1.2 Erosion rate after implementation of land husbandry technologies using GIS technologies 42
4.2 Adoption and maintenance of land husbandry technologies by direct beneficiaries 44
4.2.1Farmers' Perception on Land Husbandry Technologies 44
4.2.1.1 Perception of erosion before land husbandly technologies 44

4.2.1.2 Perception of erosion after land husbandly technologies 45
4.2.1.3 Perception of farmers on causes, effect and best way of erosion control 46
4.2.1.4 Information Access on Soil and Water Conservation Measures 46
4.2.2 Factors affecting Farmers' Adoption and maintenance of land husbandry technologies 47
4.2.2.1 Plot Size and Land maintenance Capacity 48
4.2.2.2 Time implication on adoption and maintenance of land husbandry technologies 50
4.2.2.3 Distance effect on adoption and maintenance 50
4.2.2.4 Implication of On-farm investment and Off-Farm Economic Activities 51
4.2.2.5 Implication of Supportive Institutions on Adoption and Maintenance of LHTs 52
4.2.3 Maintenance of Land Husbandry Technologies 53
4.3 The impact of land husbandry technologies on welfare of farmers 54
4.3.1 LHTs' Impact on Production 54
4.3.2 The impact of LHTs on Farmers' income and saving 55
4.3.3 The Impact of LHTs on creation of farmers' organizations 56
4.3.4 Farmers' perception of the impact of LHTs on their welfare improvement 57
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS 59
5.1 CONCLUSION 59
5.2 RECOMMENDATIONS 61
References 63
APPENDIXES ..... a
Appendix 1: RUSLE PARAMETERS ..... b
Appendix 2: RUSLE PARAMETERS OVERLAYING c
Appendix 3: C AND P FACTORS AFTER LHTS IMPLEMENTATION ..... d
Appendix 4: FGD GUIDE QUESTIONS ..... e
Appendix 5: INTERVIEW GUIDE i

Table of Figures

Figure 1 Location map of Nyanza 23 Site *18*
Figure 2: Slope map *20*
Figure 3: Land Husbandry Technologies *22*
Figure 4: Conceptual framework for RUSLE *23*
Figure 5: During Focus Group Discussions *27*
Figure 6 Soil erosion type and related hazard levels *30*
Figure 7 Flow chart of soil erosion by water *31*
Figure 8: Erosion before implementation of Land Husbandry Technologies *42*
Figure 9: Erosion after implementation of Land Husbandry Technologies *43*
Figure 10: Terraces, checkdams, agroforestry and liming *46*
Figure 11: Some abandoned terraces in N23 Site *49*
Figure 12: LWH Project Staff evaluating the quality of the compost heap *55*
Figure 13: Nyanza water reservoir with people constructing an irrigation canal *56*

List of Tables

Table 1: C values *25*
Table 2: Soil conservation/control measures in Rwanda by specific slope categories *39*
Table 3: Recommended erosion control measures by LWH and RAB *40*
Table 4: Annually sediment load Results *44*

List of acronyms and abbreviations

AEZ: AGRO Ecological Zone

CA: Command Area

CDO: Community Development Officer

CICA: Agricultural Information and Communication Center,

DEM: Digital Elevation Model

EICV: Integrated Household Living Condition Survey

GDP: Gross Domestic Product

GIS: Geographic Information System

GoR: Government of Rwanda

GPS: Global Positioning System

ISAR : Institut des Sciences Agronomiques du Rwanda

LHT: Land Husbandry Technologies

LWH: Land Husbandry Water Harvesting and Hillside Irrigation

MINAGRI: Ministry of Agriculture and Animal Resources

MINECOFIN: Ministry of Finance and Economic Planning

NASA: National Aeronautics and Space Administration

NISR: National Institute of Statistics of Rwanda

REMA: Rwanda Environmental Management Authority

RMS: Rwanda Meteorological Service

RSSP: Rural Sector Support Project

RUSLE: Revised Universal Soil Loss Equation

SWC: Soil and Water Conservation

UNEP: United Nation for Environmental Programme

USAID: United States Agency for International Development

CHAPTER ONE: INTRODUCTION

1.1 Background

Soil degradation is considered to be one of the foremost vulnerability and global threats nowadays not only for agricultural production and food security, but also for the environmental challenges related to watershed protection, disaster management, bio-diversity conservation, sustainable management of natural resources and climate change (Minhaz et al. 2012).

Kanya (2008) stated that soil erosion is considered as one of major land degradation processes. Although soil erosion is often a natural phenomenon or geological process caused by natural events; soil erosion is intensified when the process is influenced by human activities, this kind of erosion is known as human-induced erosion. The same author also highlights that the accelerated erosion can affect agronomic/biomass productivity (on-site effect) and flooding, sedimentation of reservoirs, siltation of agriculture field and decrease of water quality downstream (off-site effects). For instance, each year, 75 billion metric tons of soils are removed from the land by wind and water erosion, with most coming from agricultural land (David, et al. 2004). The same author stated that during the last 40 years, nearly one-third of the world's arable land has been lost by erosion and continues to be lost at a rate of more than 10 million hectares per year.

The losses due to erosion can be also be evaluated in terms of economics, by estimating the value of the damages, cost of restoration and preventions. For instance, in the USA, soil erosion costs the USA economy, particularly the agricultural sector, an estimated amount of $17 billion per year (David, et al. 2004). An additional yearly loss of $27 billion is attributed to reduced soil productivity. If off-site and on-site costs are combined, the total cost of erosion from agriculture in the US is about $44 billion per year, or about $100 per hectare of cropland and pasture. This erosion cost increases production costs by about 25% each year. Of the 75×10^9 tons (David, et al. 2004) of soil eroded worldwide each year, about two-thirds come from agricultural land. If we assume a cost of $3per ton of soil for nutrients ,$2 per ton for water loss, and $3 per ton for off-site impacts, this massive soil loss costs the world about $400 billion per year, or more than $70 per per- son per year.

Various estimates of the economic losses from erosion justify the need for continuous investment in conservation. In east African countries as well, erosion is a tremendous issue and it has direct

impact on economic development. For instance, in Uganda, it was estimated that land degradation resulted in annual losses of up to 12% of GDP. The value of soil lost to erosion alone has been conservatively estimated at US$400 million a year (Government of Uganda 1991). Large areas of Tanzania, especially the drier zones, have suffered a significant degree of land degradation and soil loss. Christianson et al. (1993) estimated that up to 1-2 mm of topsoil is lost each year in the semi-arid areas on slightly sloping land with some vegetation and average grazing pressure. On overgrazed or cultivated land on sloping ground, as much as 10 mm of soil is lost to erosion every year. Such losses are not directly reflected in the national accounts. They, however, have a serious negative effect not only on total GDP and overall economic development, but also on agricultural and food production, family incomes derived from land and natural resources, and poverty in rural areas.

All over the world, different measures have been taken in order to slowdown the extent of erosion, various country introduced soil control measures but still erosion remains the crosscutting issue. Soil and water conservation in the eastern and southern Africa region has a long history going back almost 70 years (Hall, 1929; Beckley 1933). In Uganda, Tanzania and Kenya, the colonial authorities used coercive approaches to introduce new land-use and conservation methods, such as terracing and forced destocking, resulting in peasant's negative attitudes to soil conservation. This in fact led to widespread neglect of conservation work after independence in the early 1960s. By the end of the 1960s, these countries were experiencing increasing land degradation.

In Rwanda like other East African countries, the problem of the soil erosion/land degradation is also a crosscutting issue as well. Erosion has significant effects on the environment, agronomic productivity, food security, and quality of life resource-poor farmers. These farmers can neither afford the much needed off-farm input essential to sustainable use of soil and water resources, nor are they sure of their effectiveness because of the harsh climate, structurally fragile soils and land tenure (REMA, 2010). Stockholm Environment Institute (2009) reports the loss of 1.4 million tons of soil per year, equivalent to an economic loss equivalent to US 34,320,000, or almost 2% of GDP. The magnitude of the soil erosion problem is further illustrated by UNEP

measurements of sedimentation rates in selected lake/reservoir sinks across the country, revealing high soil loss rates. For example, radioactive dating showed that excess of 54 cm of sediment had been deposited in Lake Karago at the sample point in one year. High sediment loads in the country's turbid rivers are another visible sign of the problem that was validated by UNEP sampling (UNEP, 2011).

Unsustainable land-use, coupled with Rwanda's steep topography, fragile soils, and climate, is the driving cause of soil erosion. Unsustainable land-use practices include deforestation, agricultural expansion into fragile ecosystems, overgrazing, and poor road construction. High demands for arable land results in extensive deforestation, reducing the total forest cover. Deforestation is most severe in the northwest of the country, where farming on very steep slopes has resulted in catastrophic erosion and slope failure (REMA, 2010). Rwanda Environmental Management Authority (REMA) also reports that acute land scarcity has led to the over-cultivation of land. Fallow periods have grown much shorter or have become non-existent. In many cases, cultivation periods have been extended, up to two to three times per year, with very limited soil inputs or soil conservation measures.

The effect of soil erosion on the country's agriculture sector is high. REMA (2009) reported that the total arable land in Rwanda is about 1.4 million hectares, which is 52% of the total surface area of the country. Over 80% of the population lives in rural areas where they subsist on smallholder farming (ROR 2008). Currently, agriculture is growing at 5.8 per cent per year and employs 80% of Rwandans of the population and contributes 33% of GDP and 70% of export revenues (EICV III). Given Rwanda's economy which is largely agrarian, it is clear that soil erosion have substantial impact on the economic development of the nation, thus the effectiveness of programs intended to prevent soil erosion would mean a brighter future for the country's economy.

Most of the cultivation area is on hillside with an incline of more than 60% slope. With an average of 415 persons per square km, Rwanda represents the most densely populated country in the continent (NISR and MINICOFIN, 2014). Consequently, high population density has fuelled a shortage of arable land, led to decreasing farm size. Household average land size is 0.3 hectare fragmented amongst several parcels (USAID, 2010), shortage of arable land and the adoption of

intensive agricultural practices on recommended slopes and subjected to severe soil erosion as well as low productivity.

Farmer response to offset low production yields by over-cultivation that only worsens land degradation. A practical way to break out of this cycle is to increase both soil nutrient capital and soil organic matter through the simultaneous application of organic inputs (e.g. animal manure) and chemical fertilizers but also introducing land husbandry activities aiming at stabilizing soil namely: terracing, application of liming and inorganic fertilizers, agro-forestry and progressive ditches at marginal lands having more than 60% of incline.

1.2 Research Problem

To counter soil erosion and to increase agricultural production, a variety of soil and water conservation (SWC) measures have been introduced in developing countries, including Rwanda (Bizoza 2012). Indigenous techniques from the pre- colonial era focused on erosion control in combination with water conservation by ridging, mulching, constructing earth bunds and terraces, multiple cropping, fallowing, and the planting of trees (REMA, 2010). But in spite of all effort made, erosion still is said to be the most environmental challenge Rwanda is facing.
According to the Integrated Household Living Conditions Survey (EICV) 3, the percentage of land that has been reported as protected against soil erosion in Nyanza district is of 83.5%, thus one can say that erosion has diminished to high rate due to protective measures. Nearly 30 % of the total watershed is occupied by two soil types: Humic Acrisols and Dystric cambisols while other types of the soils found in that area occupying 70% (MINAGRI, 2012). According to the same source, naturally Dystric Cambisols are found at greater depths than 50 cm. However, due to the severity of soil erosion in Nyanza site and due to its susceptibility nature to erosion, some of the Dystric Cambisols have less than 50 cm soil depth, this is one of the reasons why land-husbandry in this watershed was crucially essential.

Even though there is a reported protective measure against erosion, there are limitations of current measurement techniques and temporal patterns of soil and water degradation across catchments. In addition to that there is no effective assessment of the impact of applied protective measures on the soil erosion rate, this restrict ability to develop cost-effective land

management strategies. However, the advent of new techniques of erosion assessment and Geographical Information Systems (GIS) to study soil erosion and sediment delivery offer considerable potential for meeting these requirements.

Land husbandry technologies were introduced in Nyanza23 site to fight erosion in that area. The project was started in 2010 when Land Husbandry Water harvesting and Hillside irrigation Project (LWH) has introduced the said technologies in Nyanza 23 on various slope categories. From the slope of 0 to 6%, the project introduced grass strips. Soil bunds were applied for slope categories of 6-16 % slopes while improved bench terraces were constructed in 16 - 40% slope and narrow-cut bench terraces were implemented only in slope categories of 40 - 60 % slopes. Zones with slope above 60% were planted trees /shrubs in pits dug in a staggered fashion. LWH project also introduced water-ways, cut-off-drains, check dams, trash lines, mulch and compost in the land husbandry technologies in order to control water runoff in the area. The impact of all said technologies has not been assessed.

Diverse research done in different parts of the globe including Rwanda revealed that erosion poses a significant threat, thus an immediate need of land husbandry technologies. The quantification of rate of erosion before and after the implementation of erosion control measures is needed as well in order to assess the effectiveness of the applied techniques. As this problem has not been addressed by any research, it is worthy to focus on it in order to contribute to suggesting ways for solving or mitigating it.

1.3 Research objectives

The main objective of this research is to assess the impact of land husbandry technologies (LHTs) on the improvement of soil erosion control.

This study specifically

1. assesses the erosion rate before and after the implementation of land husbandry technologies using GIS technologies
2. evaluates adoption and maintenance of land husbandry technologies by direct beneficiaries
3. investigates the impact of land husbandry technologies on welfare of direct beneficiaries.

1.4 Research Questions

The current study will attempt to answer following questions:

1. What were the erosion rates before the implementation of land husbandry technologies?
2. To what extent land husbandry technologies has contributed to the reduction of soil erosion?
3. Which factors are important in the adoption and maintenance process of land husbandry technologies by direct beneficiaries?
4. Are direct beneficiaries satisfied of land husbandry technologies as soil erosion control measures?
5. Is there a significant change in production after implementation of land husbandry technologies?
6. Will Land husbandry technologies sustain after the project has phased out?

1.5 Research hypothesis

The current study was guided by following hypothesis:

1. There was high erosion rate before the implementation of land husbandry technologies
2. Implementation and maintenance of land husbandry technologies contributed to the decline of erosion rate in Nyanza 23 site
3. Little monitoring, education and awareness of local farmers in soil erosion control practices can lead to the aggravation of erosion in N23 site.

1.6 Significance of the Study

Different individuals and organizations will benefit the findings of this research; the results will anticipate a better understanding of the impact of land husbandry techniques on soil erosion control in N23 Site, Nyanza district and the country as a whole. This is needed against a background of soil erosion that has affected the country and the fact that a rising human population poses a greater threat to the land resource.

The findings of the study will help to review the role of the local community emphasizing on conservation measures and proper land use planning and management to control and reverse the trend of soil erosion or environmental degradation generally which is a direct threat to the future livelihoods in the country. Proper enforcement of proper land husbandry technologies will also assist the government and the local community in seeking alternative means to poverty eradication and to restore their own environment for the better survival for future generations.
In addition, this research will provide an opportunity to further research by individuals and organizations.

1.7 Structure of the thesis

The thesis is divided into five chapters.

The first chapter provides the general introduction to the study. This chapter includes also statement of the research problem, the aim and the objectives of the study. Apart from this, research questions and hypotheses underlying the study, the significance of the study was outlined and discussed.

The second chapter explains how the study was undertaken in order to answer the research problem. This involves methods, techniques, and tools applied in data acquisition, data processing and analysis and data visualization.

The third chapter reviews relevant literature on the problem of soil erosion highlighting entry points for the current research. It clarifies Land husbandry technologies types and how are they applied. Various concepts on soil erosion control, adaptation and management are covered in this chapter. It is mainly inspired from published materials.

The fourth chapter present and discuss findings. It covers the analysis of GIS erosion model and the data from the field; this includes the quantity of the erosion before and after the implementation of land husbandry technologies, adoption and maintenance of the applied technologies and the impact of those technologies on the welfare of the local population.

The fifth chapter concludes the report and formulates some recommendations for a better soil erosion control measures.

CHAPTER TWO: RESEARCH METHODOLOGY

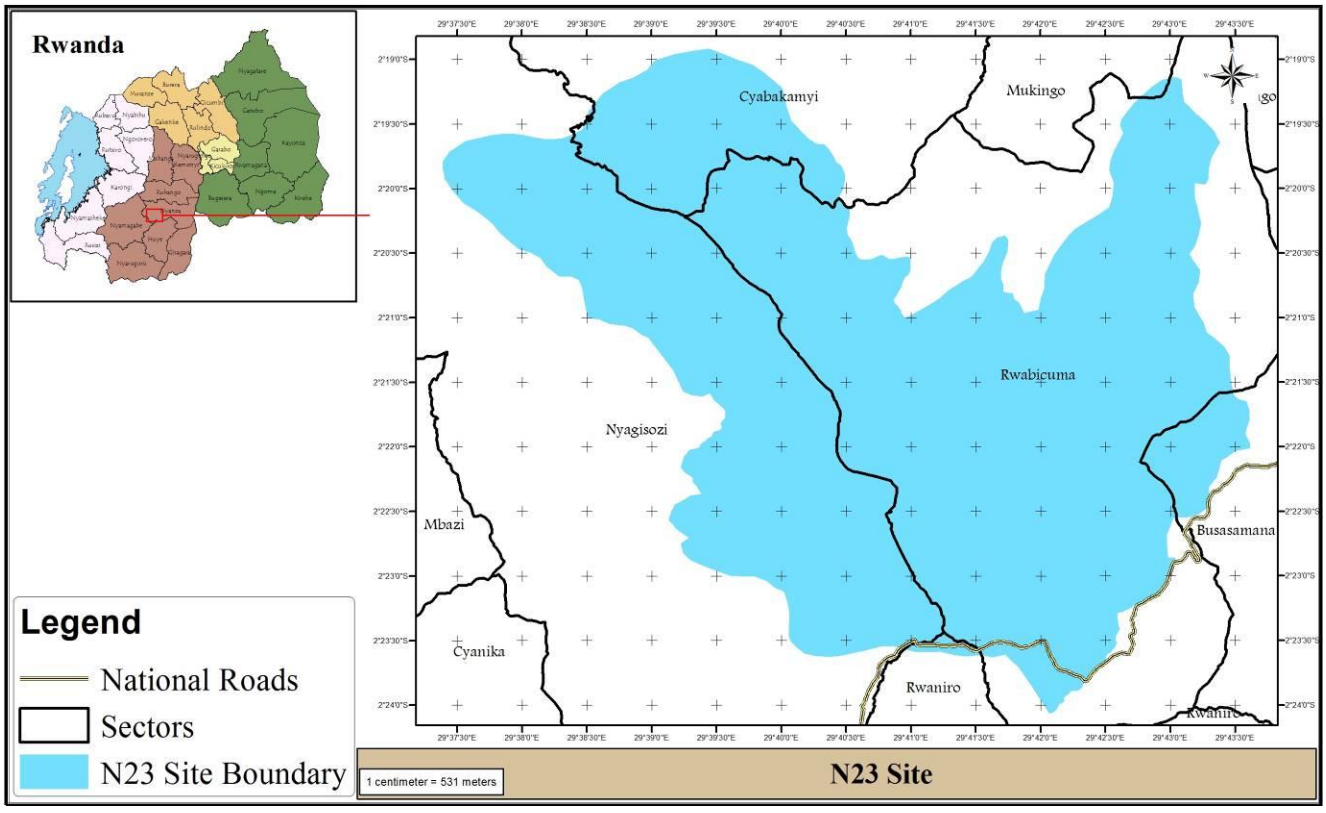
This chapter is mainly describing materials, procedures, techniques, calculations that were used in this research. Limitations and problems that encountered in this research were also said here.

2.1 Description of Study area

2.1.1 Location

Nyanza 23 site is located in Nyanza district, Southern province and it is called Nyanza 23 as a World Bank project code. As it illustrated in Figure 1, Nyanza 23 straddles over Rwabicuma, Busasamana, Cyabakamyi and Nyagisozi sectors, Nyanza District. The project site lies at the right and left bank of the Gisuma River.

Figure 1 Location map of Nyanza 23 Site



Source: MINAGRI/LWH

The project targets to develop 3,050ha with comprehensive land husbandry technologies in the whole watershed out of which 470 Ha will be subjected to hillsides irrigation.

2.1.2 Climate

According to Ministry of Agriculture and Animal Husbandry (MINAGRI, 2012), the site falls in the Moist Mid-Highland agro-climatic zone, which covers 41.65 % of Rwanda with greater potential for agriculture. The annual rainfall of the area is around 1,200 mm. Rainfall maxima around 200 mm/month are usually observed in April, during the main wet season of the year, which lasts from mid March until the beginning of June, but following the climate change, rain stops now mid-May. The second wet annual period from mid September through December, shows monthly rainfall maxima of more than 100 mm. The dry season extends from June to August, with July as the driest month.

2.1.3 Land use/cover

The natural ecosystems in the area have been modified due to human activities especially agriculture and settlement. Those changes caused secondary formations consisting essentially of *graminaceous* plants, numerous seasonal or perennial species alternating with crops (MINAGRI 2012). MINAGRI also reports that cultivated areas have changed from natural ecosystems to agro-ecosystems. *Cyperus latifolius* species are only founded in isolated patches in the dam site. Seasonal crops mainly bean, maize, cassava, rice and perennial crops like banana, as well as scattered Eucalyptus and *Grevillea spp* trees and *Acanthus spp* bushes are the most common vegetation. No endangered plant species were observed in the area.

2.1.4 Soil

Within the respective slope categories, the shallow and deep soils are found across the site. Almost 1/3rd of Nyanza 23 site is covered by deep soils while the other 2/3rd is covered by shallow soils units.

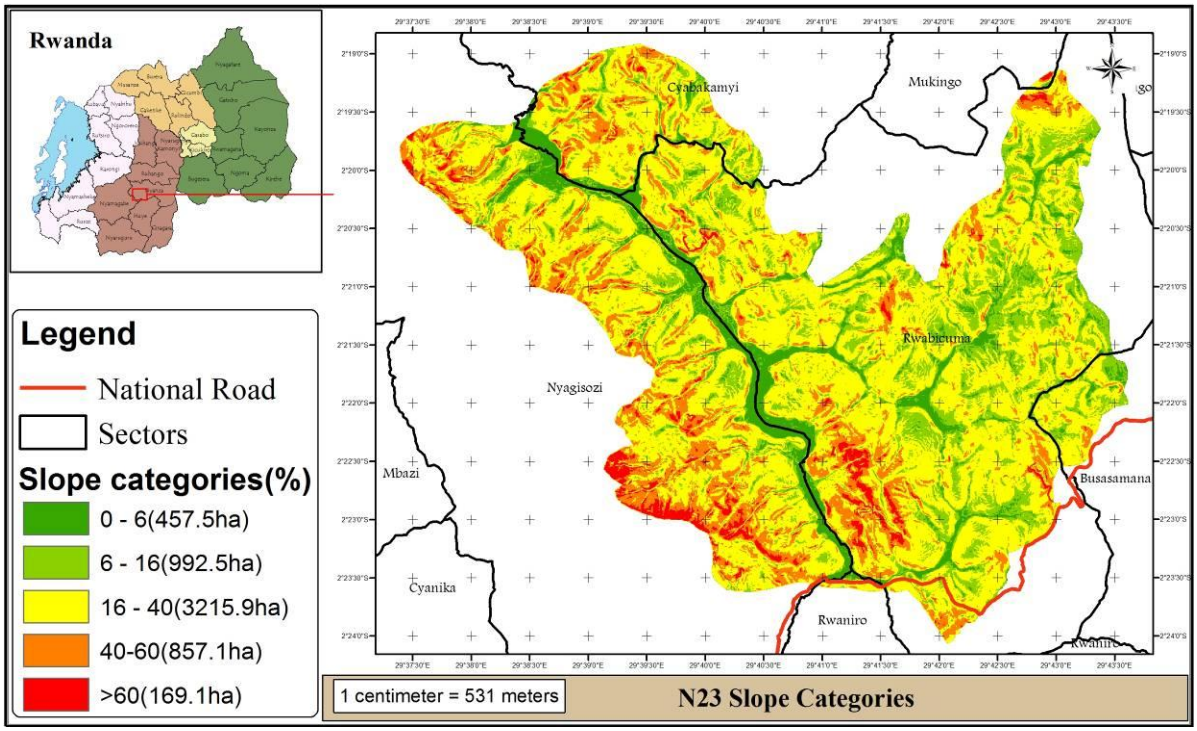
According to MINAGRI (2012), N23 watershed is covered by five soil units namely Dystric Leptosols, Dystric Cambisols, Ferric lixisols and Haplic and Humic Acrisols. The same author

stated that nearly 30 % of the total watershed is occupied by two soil types that are having greater than 50 cm soil depth: Humic Acrisols and Dystric cambisols.

2.1.5 Slope

In terms of topographic configuration, Nyanza-23 watershed shows five distinct slope categories. These are: the undulating plain (0-6%) that covers 8% of the watershed, 6-16% that covers 18% of the watershed, 16-40% slope which covers 56% of the watershed, 40- 60% slope that covers 15% of the watershed and above 60% slope that covers 3 % of the watershed. Due to this topographical characteristic, most of the watershed is vulnerable to severe erosion.

Figure 2: Slope map



2.1.6 LHTs applied

LHTs applied in the site are categorized into three types which include; physical, agronomic and chemical. The physical land husbandry techniques introduced in the area include soil bunds, improved and narrow cut-bench terraces, progressive ditches, check dams and water ways. The agronomical land husbandry technologies introduced include; agroforestry, grass strips, plant

residuals (mulching), and crop management systems. Also the chemical land husbandry technologies that were introduced in the area are fertilizers (both organic and industrial chemical fertilizers) and liming.

2.2 Data Collection Techniques Applied

Data used in this research were collected using the library research for secondary data collection. Soil erosion measurement using GIS technology, field observations and measurement, survey research, and interview were applied to collect primary data on perception of land husbandry technologies, adoption, and maintenance of land husbandry technologies by the direct beneficiaries and the impact of land husbandry technologies on welfare of direct beneficiaries.

As earlier mentioned, Nyanza23 site covers four sectors of Nyanza district namely Rwabicuma, Busasamana, Cyabakamyi and Nyagisozi. The area has a total population of 109,102 persons living in 29,955 households. Those farmers are grouped into different cooperatives. As it is impossible to collect data on all heads of households located in the catchment because of limited financial resources and time, this study was conducted into three sectors namely; Rwabicuma, Cyabakamyi and Nyagisozi.

2.2.1 Library research

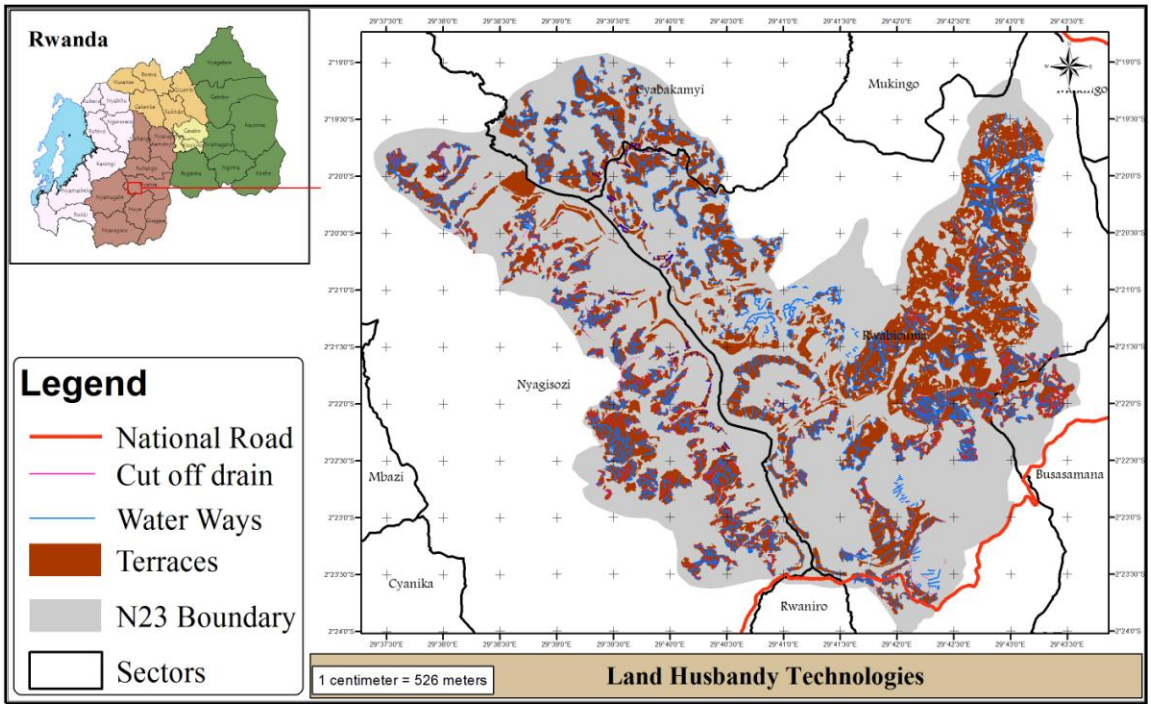
Secondary data was obtained from various published and unpublished sources of the governmental and the non-governmental organizations like Nyanza District Office, GIS Documentation Unity, Ministry of Agriculture and Animal resources (MINAGRI), Agricultural Information and Communication Center (CICA), Rwanda Meteorological Service (RMS), Rwanda Environment Management Authority (REMA) and National Institute of Statistics of Rwanda (NISR). Books, maps, journals, internet sources, research reports, archives and records was employed for acquiring the necessary information for better understand the soil erosion control measures, and getting spatial data of the study area.

2.2. 2 Field Observation

Field observations and measurement was used in this research in order to observe and measure the erosion traces like gullies, sediment deposit, land husbandry technologies and their maintenance.

During field observation, digital camera was used to take photos of areas with interesting phenomena for the study such as LHTs, erosion gullies, ravines, etc. Global Positioning System (GPS Trimble GeoXT with arc pad 10) was used to locate land husbandry technologies, some visible gullies, water ways and cut offs in site as can be seen on the figure 4.

Figure 3: Land Husbandry Technologies



Source: Author

2.2.3 Soil erosion measurement using GIS technology

The Revised Universal Soil Loss Equation (RUSLE) was used to estimate the erosion rates in the study area before and after the implementation of land husbandry technologies. RUSLE is a revised version of the eminent Universal Soil Loss Equation (USLE equation), which was originally developed to predict erosion on croplands in the United States by Wischmeier and Smith (1978). RUSLE is linear model that predict long-term average rates of soil erosion, in which

$$A=R*K*L*S*C*P$$

Where:
A is the calculated average annual soil loss in tons per hector per year (t ha^{-1} yr^{-1})

R is the erosivity factor,

K is the soil erodibility factor,

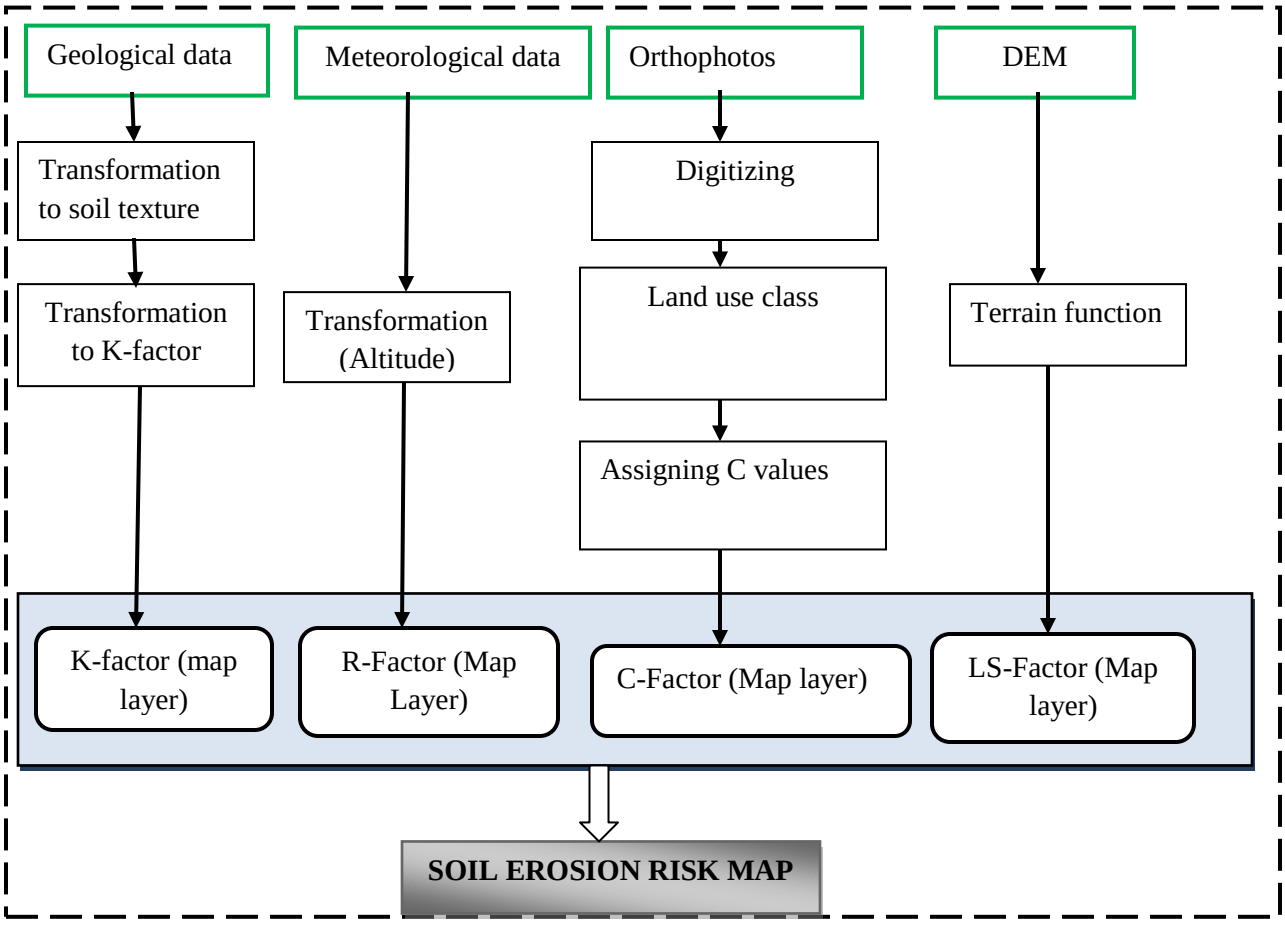
LS is the both the slope length and the slope steepness factors,

C is the cover management factor,

P is the support practice factor

Each parameter was calculated and integrated into GIS software in order to produce soil loss map. To assess the erosion rate before and after the implementation of land husbandry technologies, various data source were used to assess the soil erosion before and after the modern practices. To assess the erosivity-R (rainfall pattern), erodibility-**K** (susceptibility of soil to be eroded depending on the structure and type of soil), steepness and length of slope-**LS**, crop system-**C** and human management practices-**P,** data such as rainfall pattern, soil type, topography, cover management and support practice were utilized for soil modeling using RUSLE and ArcGIS.

Figure 4: Conceptual framework for RUSLE



Source: from Gitas, et al., 2009

Here is the estimation of each parameter:

- **Rainfall-Runoff Erosivity Factor (R)**

As it is common to many areas within the developing world, it is hard to find data on daily basis; we cannot find the rain gauge data (mm/day) in this area that is suitable for deriving precipitation intensity (mm/hr). Therefore, in this research the erosivity factor was analyzed on an annual basis. Using a second order regression equation it is possible to estimate erosivity values using the value for annual precipitation. The R value is in MJ*mm/ha*h*yr (mm=rainfal, h=hour, ha= hectare, and yr=year).

R = - 0.0334 (P annual) + 0.006661 (P annual) Squared (Hudson 2005).

After computing the R factor from above formula, its value was added in the new column of the R-factor table. Here geostatistical method was used with ordinary criging as kriging type. The input dataset was meteo- station and datasource was erosivity. The result was rasterized and fitted to the boundary of the study area as it is described in Appendix 1.

- **Soil Erodibility Factor (K)**

The soil erodibility factor (K) represents the average long-term soil and soil-profile response to the erosive power associated with rainfall and runoff (Hudson 2005). The soil map of Rwanda provides information on soil erodibility. Each soil type has a distinct K-value associated with it.

From the available data, soil erodibility of the study area was extracted. The K-factor shapefile was converted to raster by highlighting on the K-factor shapefile in the table of contents and going to conversion tool, go to polygon to raster and the input in the value field is K-factor. The output was named K_factor as it is described in Appendix 1.

- **Slope Length and Steepness Factor (LS)**

In executing the RUSLE, the L and S factors are combined into the LS factor. The LS factor can be measured directly in the field or from USGS quadrangle maps. Here LS factor was generated

from the DEM. Here the DEM was extracted by mask in order to have the only portion within the study area (Nyanza 23 site).

Afterwards, the LS factor was computed for using the Dem and ArcGIS. From Spatial Analyst tool and surface Analysis toolset the slope tool was used to calculate a slope surface for the area. The output was named Nyanza 23 Site slope. In the computation of LS factor, flow accumulation was required. From Arc Hydro tool flow accumulation (Fac) was calculated from DEM, I made a mask of this using Nyanza 23 Site boundary as the mask for Fac. This generated the flow accumulation for the actual watershed. The new theme was named flow_acc and it was described in Appendix 1. All themes necessary to generate the LS factor using the DEM have been generated, thus using the Raster calculator the following expression to compute for the LS factor:

LS= **Power ("flow_acc" * cell resolution / 22.1, 0.4) * Power (Sin("slope" * 0.01745) / 0.09, 1.4)**

- ## Cover Management Factor (C)

To calculate land cover factor, in this project the land use map shapefile was generated by digitizing them from Rwanda orthophotos for before terraces information. For after LHTs implementation, Google earth has been used and the C factor map is in Appendix 1.

Each class was assigned a C-value according to their effects on soil erosion. C-values were assigned using information from studies done in Malaysia (Teh, 2011). Following values has been assigned to each class.

Table 1: C values

Type	**C- value**
Built-up area	0.25
Closed agriculture	0.30
Forest plantation	0.15
Irrigation	0.10
Natural forest	0.03
Open agriculture	0.50
Open land	0.90
Water bodies	0.01

- **Support Practice Factor (P)**

The support practice factor *P* represents the effects of those practices that help prevent soil from eroding by reducing the rate of water runoff (Hudson 2005). According to the same author, the values of P are calculated as rates of soil loss caused by a specific support practice divided by the soil loss caused by row farming up and down the slope. In this work, however, the *P*-factor was estimated regarding the different practices on the land of the study area. Since the Government of Rwanda (GoR) has implemented modern agricultural practices at different sites with the implementation of land husbandry technologies, their susceptibility to soil erosion should be lower than the remaining areas. The modern agricultural practices yield a P-value equal to 0.5, meaning that there is a lower susceptibility to soil erosion. Areas that do not belong to the land with land husbandry technologies have a P-value of 1, which indicates that there are more likely to be affected by soil erosion as it was illustrated on the map in appendix1.

Once all factors necessary for executing the RUSLE are be available, map calculator was used to execute the following expression:

A=[R-factor]*[LS]*[K-factor]*[C-factor]*[P-factor]

The result was named Soil_Loss. This is the annual soil loss (tons/ha) for the Nyanza 23 site as it can be seen in appendix 2.

It is clear that this method will help in detecting the impact of land husbandry technologies on soil erosion. Note that the R, LS and K factors remain the same before and after land husbandry technologies while C and P factors will be differ in the before and after scenarios.

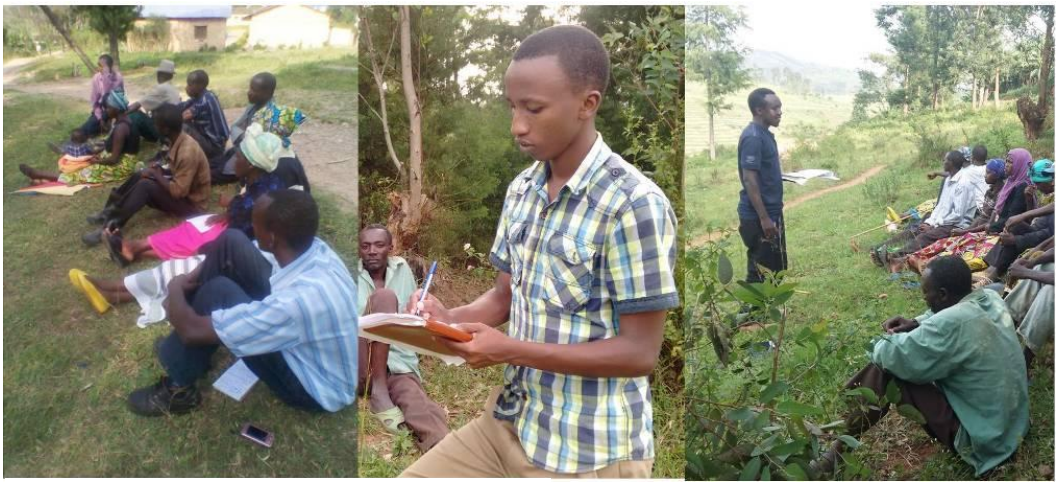
2.2.4 Focus Group Discussion

This technique was applied to search the level of population's awareness of the land husbandry techniques and its acceptability among the ground population. It also helped in evaluating qualitatively the impact of this technique on crop production. FGD helped to discuss community livelihood improvement, constraints and opportunities in the introduction of LHT; gain in-depth knowledge on the importance of LHT; get insight into farmer perceptions of soil erosion, erosion control strategies and get information on common adaptive and coping strategies of LHT. An assistant was recruited to help in conducting FGDs.

In order to make geographic representation at the site-level and inclusion of multiple members of farmer groups within the site, 9 FGDs were organized in the 3 sectors namely Rwabicuma with 1 site namely Dam site near Dam, Cyabakamyi with 1 site namely Cyabakamyi primary school and Nyagisozi with 1 site namely Rurangazi football ground near Rurangazi center. Each group presented its views in an open environment.

The discussants consisted of adult males, females and different age groups to capture information from different categories. Each FGD included 7 discussants. In total 63 farmers participated in the FGDs. Discussants were selected randomly; the community development officer (CDO) of the project asked people on my behalf to come in a regular meeting but with an invitation to participate in a discussion. People were given different dates in different sites and discussants were selected from there.

Figure 5: During Focus Group Discussions



Source: Author

2.2.5 Interview

Face-to-face interview was held key informants in order to know their viewpoints on the adoption and impact of LHTs in the study area. These include construction, maintenance, problems and benefits of land husbandry technologies. The key informants interviewed are sectors agronomists, N23 Site Project Coordinator, agronomist and Community development

officer, Cooperative managers of KOABINYA, INGENZI and ABADATEZUKA cooperatives were interviewed.

In identifying suitable methodological approach for conducting this research, FGDs and Interview was selected for various reasons. One of the reasons was to ensure better data quality, validity and reliability as this approach is inductive or "bottom-up". This approach helps to examine the breadth and depth of phenomenon to learn more about them. In this research, it was also found to be a useful approach for the same purpose. Furthermore the methods help to get in-depth understanding of respondent's viewpoint and this helped to obtain a variety of information on the issue of LHTs; adoption, maintenance and its impact on welfare of farmers

2.3 Data Analysis and Visualization

In this research GIS concepts and Techniques was necessary to complete the research objectives as well as to test set hypotheses. Modeling physical processes with GIS; Raster analysis; local operations and neighborhood operations, Map algebra and Boolean operators was used. Raster techniques for creating data subsets from large data sets, use of the ArcHydro extension to model watersheds and flow accumulation, Spatial Analyst and Raster calculator and on screen digitizing were also used. Statistical analyses of the data were conducted using software namely Microsoft Excel. After collecting, processing and analyzing various data, the end results were visualized using different scientific illustrations such as diagrams, charts and tables for statistical data, maps for spatial data.

For qualitative data, the researcher noticed, collected and thought about things that were of relevance and hence made valuable judgments.

Particularly for the FGDs, each participant quote was assigned a separate line on the page as well as each new thought or idea therein in excel. Each group was assigned its specific spreadsheet and within each spreadsheet, one sheet per question was created. In each sheet, 3 columns were formed; one column for coding another for the participant ID and finally a column for responses was created. From that database, it was possible to arrange categories or responses from those with the largest number of entries to those with the smallest and then analyzed.

CHAPTER THREE: LITERATURE REVIEW

The literature that the researcher reviews was based on the objectives of the study with much attention on the erosion concepts, Perceptions of Soil erosion, Erosion Process, Types of Erosion, Land Husbandry Technologies, GIS and Soil erosion models, Erosion control in Rwanda

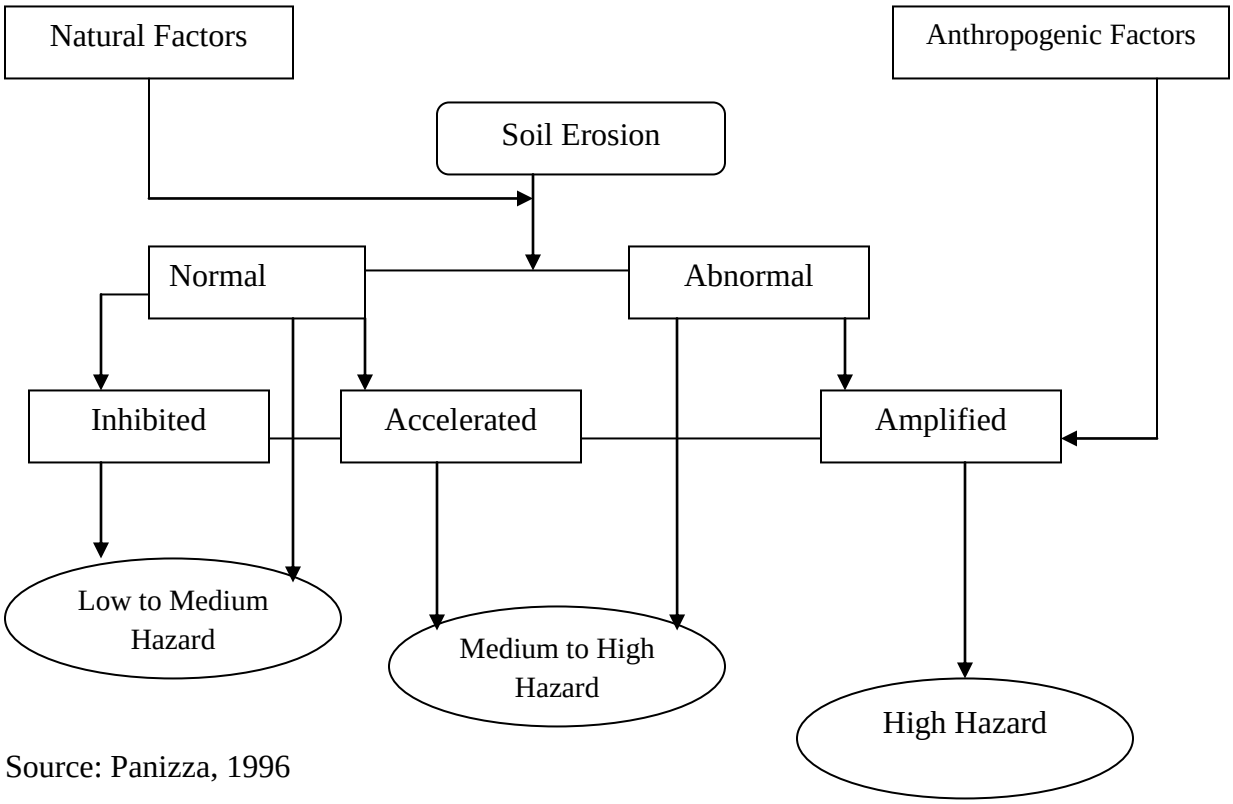
3.1 Perceptions of Soil erosion

The world "erosion" initially comes from Latin word "erodere" which means to eat away, and to excavate. Later, the term erosion is used to describe all form of destruction of earth's surface due to water (Zachar, 1982). Figure 3 shows factors of erosion and the relationship between soil erosion type and related hazard levels.

Panizza (1996) stated that soil erosion is the result of detachment, transport and deposition process of soil particles by erosive agents. Raindrops segregate the soil particles from the earth's mass. With the water flow, the segregated soil particles move following the flow and then finally sediment. Sedimentation is the process whereby the detached particles generated by erosion, are deposited elsewhere on the land, in lakes or in rivers. Together, the two processes; erosion and sedimentation, result in soil being detached, carried away and eventually deposited elsewhere (Kunta. K, 2009).Morgan (2005) pointed out that erosion is a hazard traditionally associated with agriculture in tropical and semi arid areas and it influences the productivity and the sustainability of agriculture in long terms.

Zachar (1982) differentiated the kind of erosion into two groups, natural process and anthropogenic process. In natural condition where there are not any anthropogenic activities, the soil productivity remains constant and the erosion is in equilibrium (acceptable limit). If anthropogenic activities interfere with practice of agriculture but it is done by applying conservation technique, the effect on soil erosion can still be zero (nil hazard). However, the equilibrium can be altered if exceptional natural events occur, such as rainfall; long period of drought, earthquake, landslide, and etc abnormal erosion can be triggered. And when the abnormal conditions runs into anthropogenic activities (deforestation, on conservative farming, earth-moving, etc) soil erosion will be accelerated (Panizza, 1996).

Figure 6 Soil erosion type and related hazard levels

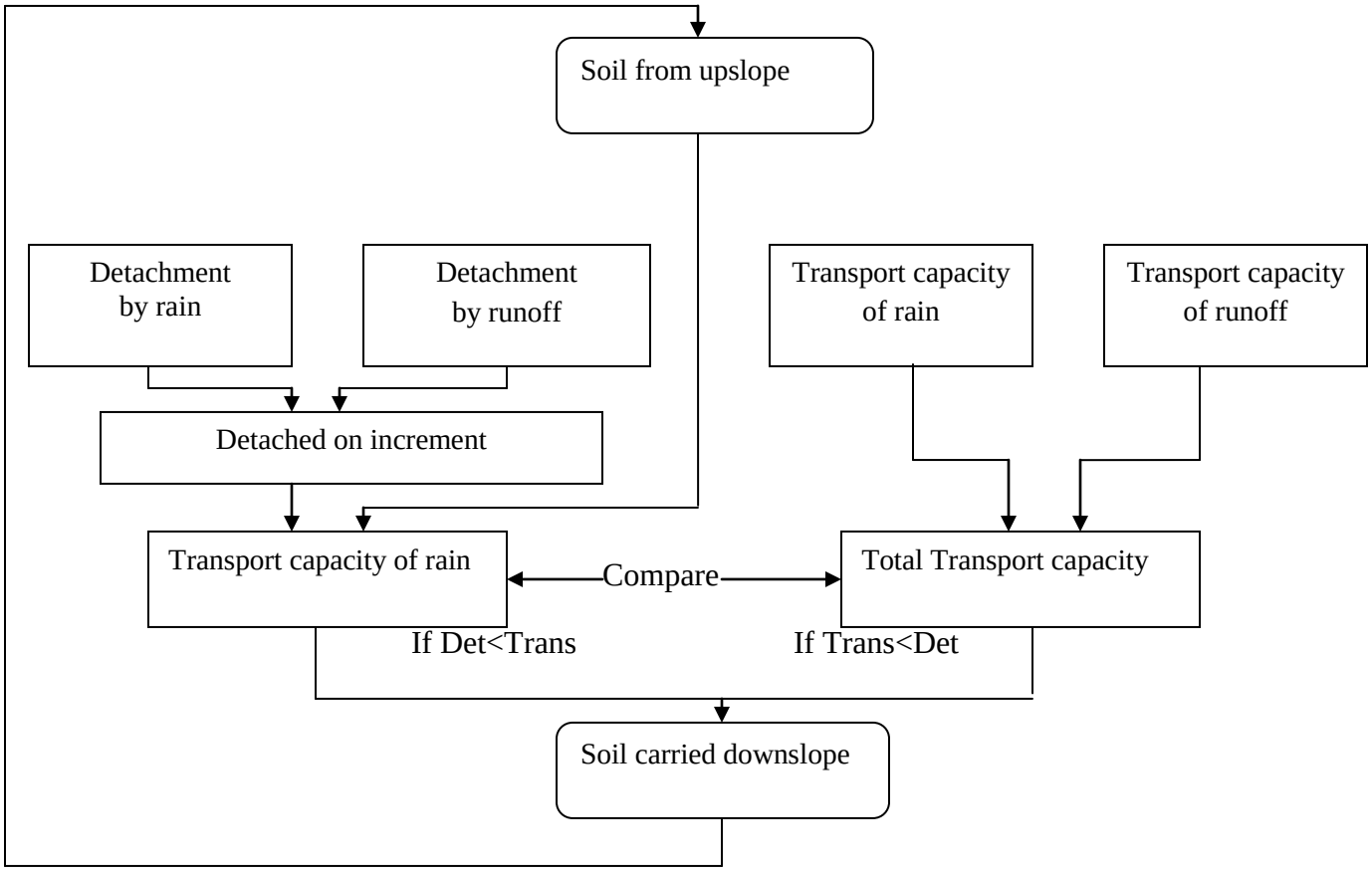


Source: Panizza, 1996

3.2 Erosion Process

During a rain storm, either because there is no vegetation or because it passes through gaps in the plant canopy, part of the water falls directly on the land. Part of the rain is intercepted by the canopy m and returns to the atmosphere by evaporation or finds its way to the ground by dropping from the leaves, or by running down the plant stem as stemflow. The action of direct through-fall and leaf drainage produces rain-splash erosion. The rain that reaches the ground may be stored in small depression or hollows on the surface or it may infiltrate the soil, contributing to soil moisture storage. When the soil is unable to take in more water, the excess contributes to runoff on the surface, resulting in erosion by overland flow or by rills and gullies (Morgan, 2005).

Figure 7 Flow chart of soil erosion by water



Source: Morgan (2005)

3.3Types of Erosion

According to Kunta (2009), the major types of water erosion are: splash erosion, sheet erosion, rill erosion, gully erosion, and channel erosion.

The first stage of the water erosion processes when raindrop impact occurs, commonly termed splash erosion. Splash erosion occurs when the soil is directly exposed by raindrop impact and the soil aggregates are broken up. Fine particles and organic matters are separated from heavier soil particles. In the main, splash erosion is closely correlated directly to raindrop size.

When rainfall intensity becomes greater than the infiltration rate of the soil, sheet erosion will take place. This erosion type is caused by shallow sheets of water flowing over the soil surface

(Goldman et al., 1986). Thin layers of the topsoil are moved by the force of the runoff water, leaving the surface uniformly eroded. This erosion type accounts for great volumes of soil.

Later on, at low areas since the velocity and turbulence of water flow increases, the flowing water concentrates deeper into soil surfaces. The energy of this concentrated flow is able to both detach and transport soil particles. The soil surface is cut to small channels or rills which results in rill erosion. Both sheet and rill erosion occur on overland-flow areas and when erosion becomes increasingly severe, rill erosion is assumed to begin. In addition, rill erosion can often progress to gully erosion.

Gully erosion occurs when water flows in narrow channels during or immediately after heavy rains or melting snow. A gully is sufficiently deep that it would not be routinely recovered by tillage operations whereas rill erosion can be smoothed by ordinary farm tillage. The gully formation is a complex process that is not fully understood (Goldman, et al., 1986). Not always does the gully erosion develop from rill erosion. Some gullies are formed when runoff cuts rills deeper and wider or when the flows from several rills come together and form a large channel. Gullies can enlarge in both uphill and downhill directions. Once it is established, gully erosion can be difficult to stop it from growing, and repair is costly.

Besides these four erosion types, channel erosion happens when the cover material or vegetation is disturbed or when the volume or velocity of flow in a stream increases. The equilibrium of a stream changes and it causes streambank erosion, known as channel erosion (Goldman, et al., 1986). Common points where channel erosion occurs are at stream bends and at construction points, for instance where a bridge crosses the river. Once more, eroded streambank is not easy to recover from and is expensive

3.4 Land Husbandry Technologies

According to Shaxson et al. (1987), the concept of husbandry is widely understood when applied to crops and animals. The same author continue saying that as a concept signifying active understanding, management, and improvement, it is equally applicable to land. Crop husbandry, animal husbandry and land husbandry all imply the following:

- Understanding the characteristics, potentials, and limitations of different types of plants, animals, and land.
- Predicting the likely positive or negative effects on their productivity resulting from a given change in management, or of severe but rare events, such as disease or severe rainfall.
- Working out how they can be strengthened to resist the negative effects of such events.
- Adopting systems of management that maintain their productivity and usefulness.
- Improving their productivity in terms of quality and quantity of output in a given time.
- The active and central role of the farmer as steward of the land.

Good land husbandry is the active process of implementing and managing preferred systems of land use and production in such ways that there will be increase or at worst, no loss of productivity, of stability or of usefulness for the chosen purpose; also, in particular situations: existing uses or management may need to be changed so as to halt rapid degradation and to return the land to a condition where good husbandry can have fullest effect" (Shaxson, Douglas and Downes, 2005). It involves the active management primarily of rainwater, vegetation, slopes and soils, with regard to the technical aspects. This management takes place at a variety of scales, from the field to the landscape, and embraces land under planted crops, pastures and plantations, and under native vegetation of every sort (Shaxson F., et al., 1997). Normally there are three main types of soil-water management practice: (i) physical (Bench terraces, soil bunds, narrow cuts), (ii) agronomic (agroforestry, grass strips, plant residuals (mulching), crop management system, etc) and (iii) chemical measures (fertilizers both organic and industrial chemical fertilizers, liming).

For better land husbandry practices, some techniques either biological or physical are applied. Here below are some techniques applied for different slope categories developed by Azene Bekele-Tesemma /PhD in 2011. These include Grass strips, Soil bunds, Improved bench terraces, and Narrow-cut bench terraces.

3.4.1 Grass strips

Grass strips are applied on the average in 5 m spacing to each other in 4 - 6% slopes. They are not effective in higher slope categories. Note that one grass strip is spaced next to other grass strip on the average by 10 meters. For slopes of 0 – 4% may, only contour plowing and raw planting along the contour may suffice. With frequent cutting and harvesting, the grass strip develops naturally into bund enough to effectively obstruct the sheet erosion that may occur in this flat to gentle slope.

3.4.2 Soil bunds

Soil bunds are applied for slope categories of 6-16 % slopes but not in other higher slope categories. They are less effective in higher slopes than 16%. Though the range is given as 6 – 16% slope, the spacing needs to be calculated for each slope that the land is exhibiting. For instance, for 8% slope, at 1 m vertical interval, the spacing of the bunds will be 100/8 = 12.5 meters while the spacing of the bunds for 16% slope would be 100/16 = 6.25 meters. It may be required to use vertical interval of less than one meter if the soil depth cannot allow cutting at least 50 cm before reaching the "C" soil horizon.

3.4.3 Improved bench terraces

Improved bench terraces are constructed in 16 - 40% slope categories but not in higher slope categories than 40%. This is average slope range. Their effectiveness varies in the way we space the bench terraces for each slope category. For 20% slope, at 1.5 m vertical interval, the spacing will be every (100/20) x 1.5 = 7.5 meters while the spacing for 39% slope would be (100/39) x 1.5 = 3.85 meters. Please note that you may use a vertical interval of 1.5 meters only if the soil depth allows you to cut at least 75 cm soil depth before reaching the C horizon.

3.4.5 Narrow-cut bench terraces

Narrow-cut bench terraces are implemented only in slope categories of 40 - 60 % slopes but not any other slope class. The vertical interval would be as high as 2 meters provided that there is deep soil depth that can allow one cut a depth of at least 1 meter. In such a case, the spacing for narrow-cut bench terraces, for instance, for a slope of 45 % would be (100/45) x 2 = 4.44m. Likewise, the spacing for 60% slope would be (100/60) x 2 = 3.33 m. If the soil depth is shallower, consider 1.5 m vertical interval and consider your spacing accordingly. In places

where one cannot have soil depth of greater than 75 cm depth to cut before reaching the “C” horizon in this sloe range for instance for 45% slope, the spacing would be 2.2 m. When one uses a riser slope ratio of 2:1 V: H, the terrace width will be 2.2-1 = 1.2 m which is too narrow to grow even a single line of perennial crops. Therefore, if the soil depth is not allowing use 1.5 m vertical interval in this slope range, considering not to terrace and using it for forestry landuse is preferred. In such a case only pitting and planting is the option for the land-husbandry. And For the slope greater than 60%, they plant forest

The said physical land husbandry techniques are mixed with agronomic; agroforestry, grass strips, plant residuals (mulching), crop management system and chemical measures namely fertilizers (both organic and industrial chemical fertilizers, liming).

3.5 GIS and Soil erosion models

In the 1930s and 1940s with the need to evaluate different soil conservation practices, the stimulation for developing soil erosion models has begun (Kunta 2009). The same author stated that different models based on knowledge of local conditions of climate, soils, topography, and land cover have been applied to measure long-term soil erosion control, as described in section 2.2. Nevertheless, to complete the models, meaningful data is required for the models.

Presently, soil erosion models differ remarkably from model to model. According to Merritt et al. (2003), who reviewed the different soil erosion models and postulates that determining the appropriate model for an application requires consideration of the suitability of the model to local catchment conditions, model complexity, the accuracy and validity of the model, model assumptions, spatial and temporal variation, components of the model and the objectives of the model user(s). In general, there is no 'best' model for all applications. Every model obtains shortcomings and benefits in various aspects. The most appropriate model to each case must be chosen by the users.

Generally, the model can be considered in two main categories; empirical model and physics based model. Harmon et al. (2001) stated that empirical soil erosion models were developed to answer relatively simple questions about mean rate of soil loss from the fields, in comparison to physics-based models. Parameter values in empirical models may be obtained by calibration, but

are more often transferred from calibration at experimental sites, for instance Universal Soil Loss Equation, USLE (Wischmeier and Smith, 1978) and Revised Universal Soil Loss Equation, RUSLE (Renard et al., 1997).

Physics-based models are derived from mathematical equations to describe the process involved in the model, taking into account the laws of conservation of mass and energy (Morgan, 2005). The examples of physics-based models are Water Erosion Prediction Project WEPP (Flanagan and Nearing, 1995), European Soil Erosion Model, EUSOREM (Morgan et al., 1998), etc.

The USLE and RUSLE are empirical models which are frequently used in preference to more complex models as they can be implemented in situations with limited data and parameter inputs. In regional scales, limited inputs are the main problem. Hence, prediction of sediment delivery at regional scales is commonly based on empirical methods (Meritt at al., 2003).

When combined a with GIS platform, soil models can be a significantly simpler and less time consuming method for estimating soil loss (Kunta and Carosio, 2007). At present, most soil erosion studies have applied GIS to integrate, analyze and visualize the data and the results to identify relationships, patterns and trends. With these services of GIS, the soil erosion can be treated with different GIS tools.

In the current study, GIS is the main tool for examining the soil erosion problem. With the recent increases in computing power, there has been a rapid increase in the exploration of catchment erosion and sediment transport through the use of computer models. GIS has been a widely known tool for spatial analysis for decades. GIS is a tool to create, store, organize, demonstrate and analyze spatial phenomena, such as soil erosion. All relevant erosion factors can be converted in different GIS data formats as they are spatial information. As a result, GIS is universally applied to soil erosion analysis as well as to other environmental problems (Kunta, 2009).

3.6 Erosion control in Rwanda

Lying on the east African plateau at elevations of mostly over 1,000 m, Rwanda's landscape has been shaped by intense tectonic action as well as rain and river erosion (UNEP 2011). The same author sated that Rwanda's population is projected to grow from approximately 10 million in 2008 to 16 million by 2030. Both rapid population growth and poverty have increased pressures on scarce resources most notably land, water and fuelwood in rural and urban areas. In rural areas, high population pressures and acute land scarcity have resulted in land fragmentation, which in turn have led to overcultivation and overgrazing, exacerbating Rwanda's chronic soil erosion problem.

Olson (1994) stated that erosion and land degradation have long been assumed to be severe and a major reason for the poverty and food insecurity in the country. The same author stated that the colonial administration and the post-independent government responses included large, countrywide programs to dig erosion prevention ditches on the hillslopes using mandatory, communal labor. Nevertheless, researchers and farmers perceived soil fertility to be declining rapidly in the 1980's and 1990's throughout the country but especially in the Southwest, and the low productivity undoubtedly contributes to the country's poverty.

3.6.1 The extent of Erosion in different parts of Rwanda

Every single part of the country is experiencing the soil erosion but with different rates and degree of impacts. Olson (1994) found that soil fertility was declining in all parts of the country with only one region, former Gisenyi, showing a lower degree of impact. It was found also that the area of the country that was experiencing the worst poverty and social problems was also the region experiencing the worst land degradation: the Southwestern part of the country of Gikongoro and Kibuye former prefectures.

Land degradation is most severe in the Southwest of the country, especially Gikongoro, Kibuye, and the higher zones of Cyangugu, Butare and Gitarama former prefectures. In these areas, the soil is ferrallitic and the slopes of the hillsides are often very steep. After many years of intensive seasonal cropping, the soils have become highly acidic (less than 4.5), are deficient in P and N, and suffer from aluminum toxicity (König, 1994; Roose and Barthès, 2001).The Northwest of

the country (Ruhengeri, Byumba, Gisenyi) experiences some land degradation and about one third of farmers identify declining productivity but this area has not experienced as severe land degradation, despite even higher population densities, because of its volcanic soil, a more economically productive farming system and critically the availability of non-farm income sources (Olson et al. 2003). Nevertheless, the region's steep slopes and continuous cultivation threaten greater erosion levels and loss of productivity if erosion control measures are not maintained. Farm sizes are extremely small and returns to labor in the current system are probably much less than one.

The East of the which is relatively dry and covered with gently rolling hills, came under widespread cultivation only since the 1970's, yet over a third of farmers complain of visibly declining fertility. Indeed, land that had been cattle ranches, wetlands and a national park has come under cultivation since the resettlement program following the 1994 civil war (Olson et al. 2003). The same author compared the erosion in East and West and found that the soil in the East is not badly eroded and still relatively fertile compared to the West, because it has been cultivated for less time and the gentle slopes do not lead to the same degree of erosion.

3.6.2 Soil conservation and erosion control in Rwanda

A vast campaign for soil conservation initiated by Institut National des Etudes Agronomiques au Congo (INEAC) later known as the *Institut des Sciences Agronomiques du Rwanda* (ISAR) since 1937 first in research stations, before extending it to the whole country (REMA, 2015). Kabiligi (1985) reported that in 1947, the program was widened to the whole country and many extensionists (mostly known as "MONAGRIS: *moniteurs agricoles* i.e. agriculturalist instructor)"). At that time the colonial administrative "resident" made the creation of ditches and the planting of grass and trees obligatory for all land holders. After Independence (1962), erosion control was abandoned and many erosion infrastructures were even deliberately destroyed. In 1966, the GoR revived a national program of soil erosion control and after this, several compulsory five-year programs (1966-1970; 1977-1981; 1982-1986) were implemented.

In 2005, as the country was recovering from the 1990-1994 civil war and genocide, the erosion control program was re-started with the same approach. Since then, many bench terraces have been constructed. As a result, in many regions of the country, the landscape has changed remarkably. At the same time, the old infiltration ditches were renewed (Rushemuka et al. 2013). The same author stated that one of the most ancient and common examples of erosion control infrastructure in Rwanda is in the use of infiltration ditches (*imingoti*) stabilized by grass verges parallel to contour lines. In addition to being labor-intensive and lacking positive impacts on crop yields, the method is inefficient in controlling soil erosion on steep slopes. In fact, the ditches do not have any impact on tillage practices (the root cause of human-induced erosion) or on physical soil properties (*e.g.* improvement of water infiltration rate).

Another important soil and water conservation technique applied in Rwanda from 1970s are bench terraces. They were introduced in Rwanda in 1973 in the mountainous region of Buberuka at Kisaro hill. In this region, terraces have been greatly appreciated as effective way of controlling soil erosion and maintaining or progressively improving soil fertility. Since 1992, the use of bench terraces has been expanded to the unproductive soils of the topographically similar mountainous region of the Congo-Nile watershed divide AEZ, at Kigeme hill. In this region, in contrast, bench terraces have not been adopted, and the terraced terrains have remained unused (Rushemuka et al. 2013).

Norén (2009) reported that other techniques like, mulching, tree planting, crop selection and crop management are added to terraces and ditches in order to control soil erosion in Rwanda. Soil conservations are done on different slope classes and each class is suitable to the specific soil conservation technique. RAB (2014) set up guidelines for relevant soil conservation/control measures in Rwanda and the specific slope categories to be applied on as showed in table 2

Table 2: Soil conservation/control measures in Rwanda by specific slope categories

Slope (%)	**Minimum erosion control measures**
< 5	No minimum control measures needed
5-30	a) contour grass strips with double rows of *Setaria* b) contour strips with two rows of banana (alternate planting stations)
30-100	Infiltration ditches with double rows of *Setaria* on the upslope ridges
> 100	No cultivation

Source: RAB, 2014

With more details, RAB and LWH have identified more technologies to be applied on specific slope categories. The table 3 highlights the technologies to be applied on the slope from less than 6% up to the slope greater than 60%.

Table 3: Recommended erosion control measures by LWH and RAB

LWH (Azene, 2011)		**RAB (2012)**	
Slope (%)	**Technology**	**Slope (%)**	**Technology**
0 – 6	**Grass strips**/trash lines Agroforestry interventions Intercropping and green manuring	0 - 5	Hedgerows
		5 - 12	Trenches
6 – 16	**Soil bunds** Trees/shrubs along lower side for support bunds Intercropping and green manure		
		12 - 55	Bench terraces Grass on risers
16 – 40	**Improved bench terraces** Trees/shrubs along lower side for support terrace Intercropping and green manuring		
40 – 60	**Narrow-cut bench terraces** Intercropping and green manuring		
> 60	Micro-basins with tree planting pits		

Source: RAB, 2014

CHAPTER FOUR: RESULT AND DISCUSSION

This chapter deals with the application and results of the RUSLE; with the estimation of the total amount of soil loss in tones per unit of hector per year. It discusses the adoption and maintenance of the LHTs by farmers and how the LHTs have had the impact on the improvement of welfare of farmers.

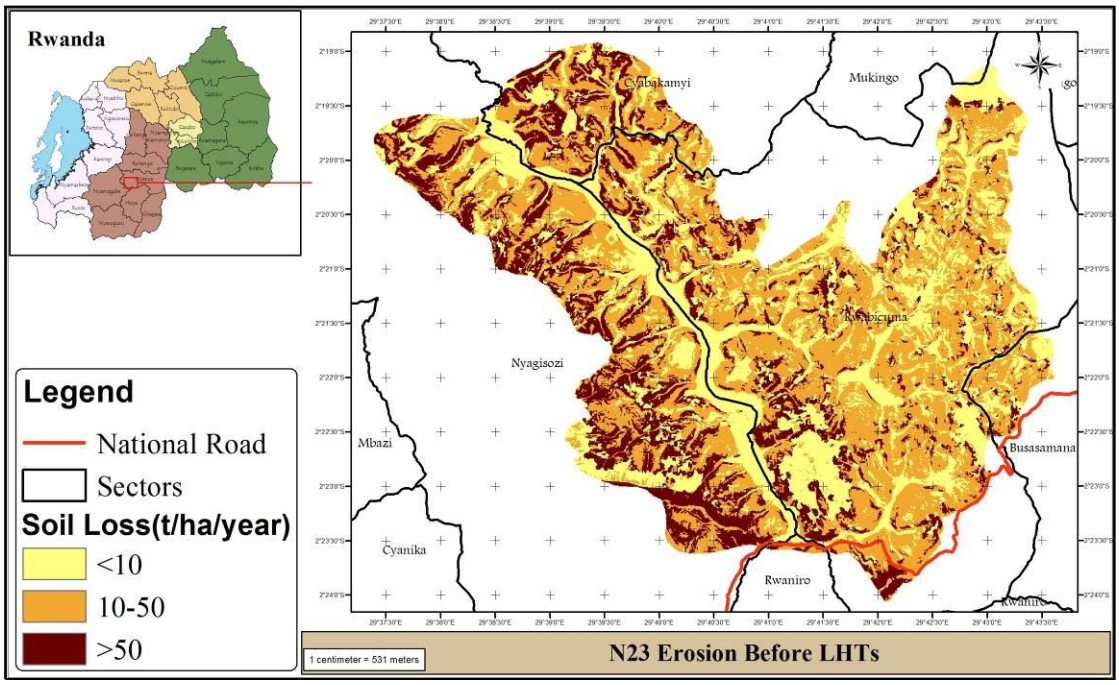
4.1 Erosion rate before and after the implementation of land husbandry technologies using GIS

4.1.1 Erosion rate before implementation of land husbandry technologies using GIS technologies

In order to predict the annual average soil loss rate in the N23 site, six parameters of the RUSLE model were multiplied using the raster calculator function tool of the ARC GIS. Figure 8 shows the annual average soil loss rate map of N23 Site. The findings indicate that at N23 site, erosion rate was high: the annual soil loss was estimated above 50 tonnes/ha/ year around 9% of the total area, between 10 and 50 tonnes over around 36% of the total area, and less than 10 tonnes/ha/year over 54%. This last category is made of valleys and rare flat terrain. Soil loss is very high even in flat terrain. The risk was that, without any corrective measure, all agricultural land would be lost in some years with dramatic consequences. This was due to the topography of the area which is characterized by steep and undulating terrain which is dominated by Humic Acrisols and Dystric cambisols. Due to the fact that the area receives an annual rainfall that is around 1,200 mm, as it falls in the moist mid-highland agro-climatic zone, and that the natural ecosystems in the area have been modified due to human activities especially agriculture and settlement, the area is highly susceptible to soil erosion.

The erosion found in the study area is also explained by the fact that 56% of the site has the slope between 16-40%, and 15% of the site has the slope ranging from 40% to 60%. It was found out also that 3% of the site is covered by the slope above 60%. Due to this topographical characteristic, most of the site is vulnerable to severe erosion

Figure 8: Erosion before implementation of Land Husbandry Technologies



Source: Author

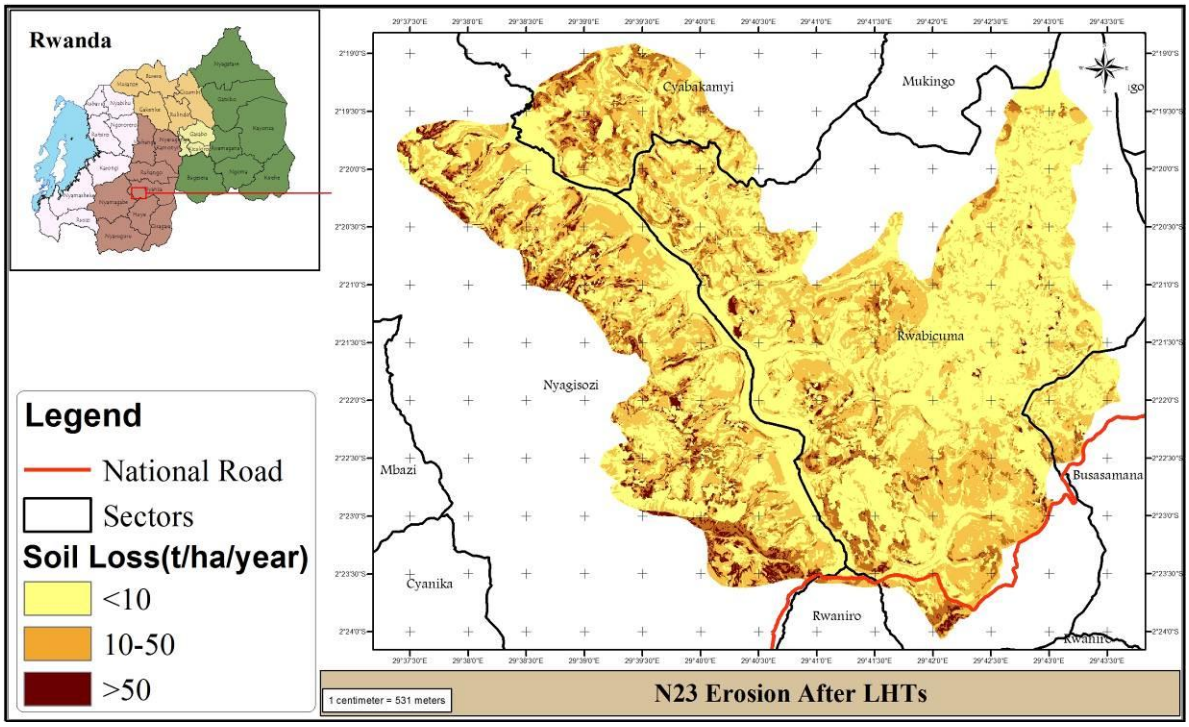
4.1.2 Erosion rate after implementation of land husbandry technologies using GIS technologies

To fight again the acuteness of erosion in Nyanza site 23, LHTs have been applied since 2010. Using RUSLE, results indicate that Land Husbandry Technologies have contributed to the reduction of soil loss and sedimentation in the study area. Figure 9 shows the annual average soil loss rate map of N23 Site; the annual soil loss was estimated above 50 tonnes/ha/ year around 3% of the total area, between 10 and 50 tonnes over around 21% of the total area, and less than 10 tonnes/ha/year over 74%.

The reduction of soil loss and sedimentation was explained by the increase of vegetation cover which increases the interception of the raindrops, infiltration rate and the increase of soil roughness and therefore reduces the soil erosion. It was also resulted from the decrease of the slope length and breaks up of one long slope into a number of short ones with the presence of grasses along the bench which slow down the stream power of the flow and reduces the erosion.

This is in alignment with the study conducted in Byabagabo-Jabana catchment in Gasabo District by Uwase (2016), which found out that ecosystem based approaches are efficient in reducing soil loss through erosion.

Figure 9: Erosion after implementation of Land Husbandry Technologies



Source: Author

The efficiency of LHTs on erosion reduction was also noted by Widomski (2011) who stated that terracing is successful in limiting the soil erosion by water. The author stated that the efficiency of terraces in limiting soil erosion rate is connected to reducing the volume and speed of rain surface runoff because the amount of lost soil is directly related to surface water flow.

The efficiency of LHTs on the erosion reduction was also reported by LWH, 2015. The report says that the sediment was reduced from 2012 after LHTs were implemented in different project sites. The findings of the report are summarized in the table 4. The trend in the decrease of soil loss measured in Nyanza 23 is also happening in other sites where there was the implementation of LHTs. These results indicate that LHTs are contributing to soil protection.

Table 4: Annually sediment load Results

Site Name	Sediment load (t/ha/yr)				Soil Erosion Reduction from 2011* (%)	Soil Erosion Reduction from Baseline** (%)
	2011*	2012	2013	2014		
Gatsibo-8	38	7	4	1.2	97%	90%
Karongi-12	68	35	18	8.7	77%	31%
Karongi-13	57	23	18	9.2	76%	27%
Nyanza-23	53	15	13	7.5	80%	40%
Average	**54**	**20**	**13**	**7**	**83%**	**47%**

Source: LWH Report 2015

* Sediment load during construction of terraces
****** Baseline taken from Phase 1B sites above

4.2 Adoption and maintenance of land husbandry technologies by direct beneficiaries

4.2.1Farmers' Perception on Land Husbandry Technologies

4.2.1.1 Perception of erosion before land husbandly technologies

Farmers (both male and females), perceived that there was soil erosion in their cultivated land before the implementation of land husbandry technologies. Most of them stated in FGDs that it was almost impossible to find cultivated land without erosion. One of the farmers alleged; *"I found traces of erosion in my farmland due to the fact that my land is on steep slopes. Consequently, there is a big gully passing through my land and it has been expanding as years went-by"*. This is an agreement with the findings of other studies made in different part of the country.

Clay and Lewis (1996) found that farmers themselves perceived erosion as a problem as one of the causes the productivity decline of their land over the years. This is not the particular case of Rwanda. Gebre and Weldemariam (2013) found that in Ethiopia, the majority of farmers (62.5%) acknowledged soil erosion as a problem in at least one of their own farmlands.

Perception of erosion as a risk to crop production and sustainable agriculture is the most important determinant in the adoption of conservation measures. When farmers do not acknowledge soil erosion as a problem, they cannot expect benefits from controlling the erosion

process; and it is highly likely that they will decide against adopting any conservation technologies (Gebremedhin and Swinton, 2003).

The perception of farmers about the degree of soil erosion is different among respondents. Most of the farmers rated the degree of erosion to be high before the introduction of land husbandry technologies. This was due to the fact that their land was with no or insufficient soil and water conservation measures by then. However, some farmers in FGDs said that the rate of erosion was low and interestingly, some of them did not notice the erosion in their cultivated land.

The difference in perception about the degree of the negative impacts of soil erosion is believed to be due to a number of reasons. Firstly, the steepness of their land might be very low to the extent that soil erosion effects are very negligible or insignificant. Secondly, some of these farmers might be against the soil erosion conservative technologies due to their belief that they reduce the size of their land. Such farmers also think the soil erosion conservative measures would cost them too much effort in putting them in place and for their maintenance. Furthermore; due to land consolidation and crop intensification programs, farmers are obliged to cultivate one crop in the terraces. They therefore resist to implement those programs since they are used to mixing crops.

4.2.1.2 Perception of erosion after land husbandly technologies

According to the farmers, there was no erosion after the introduction of LHTs and the most frequent answer from FGDs was that there is no erosion in the area covered with LHTs. Still, where it is noticed; its degree is very low in that; the water that would erode the soil is now retained in the soil and other portion of it goes in stabilized waterways, cuts offs and gullies. In justification of the responses from the farmers, LWH Project's coordinator confirms that;

> *"It is clear that erosion has been diminished at a considerable rate. Immediately after the introduction of LWH terraces, soil erosion was very high just because land cover was perturbed and the soils were still less strong to resist. As of yet, the terraces are stabilized and erosion has declined".*

The farmers' and the Coordinator's perceptions are in agreement with those of the sectors agronomists.

This shows the impact of LHTs on the significant reduction of soil erosion. This was also observed in the study conducted in Byabagabo-Jabana (catchment in Gasabo district) by Uwase (2016) which found out that terraces are efficient in reducing soil loss through erosion.

4.2.1.3 Perception of farmers on causes, effect and best way of erosion control

Regarding the causes of soil erosion in the area; during the FGDs, it was found out that, the main cause of erosion is the steepness of the slope cultivated without soil and water conservation measures. In addition to this; runoff from the upland, soil erodibility and erosive rainfall respectively were also found to be the major causes of erosion. With regards to the effects of erosion, the findings indicate that farmers are aware of the effects of soil erosion. Basing on these findings, it is evident that farmers were in need of these soil conservative technologies.

Figure 10: Terraces, checkdams, agroforestry and liming



Source: Author

As in regard to the control of soil erosion, the research findings indicated that farmers knew the best way of erosion control. Most of them testified that they knew progressive terraces, waterways, cut of drain check dams and progressive ditches. Most of the farmers got to know these technologies just after LWH project introduced them in their farmland

4.2.1.4 Information Access on Soil and Water Conservation Measures

From FGDs, farmers indicated that before LWH Project was introduced, the information about soil and water conservation measures was obtained from local authorities. However, after the project was introduced in 2010, the project staff disseminated information about the various ways of erosion control technologies trough meetings. Currently, the most important source of information on soil and water conservation measures is LWH project.

These findings confirm the LWH Project agronomist statements who stressed that; the common way that the information is given is through meetings by LWH staff. In addition to that, radio broadcasts (Radio Huguka 105.9FM) was used to disseminate this information. Here, the information given to farmers basically focused on the best use of inputs and how to maintain the LHTs.

Moreover, the research found out that most of the farmer attended the training related to soil and water conservation just in the beginning of the work of LWH project this was discovered from FGDs but also confirmed by the project coordinator and project CDO. This was backed by the fact that farmers were the ones to work in those land husbandry activities and could be trained before starting work. On the other hand, farmers who didn't work in the construction of terraces and other land husbandry technologies did not receive trainings on the soil and water conservation.

From these findings, it is evident that farmers who did attend trainings on soil conservation are more likely to retain conservation structures than their counterparts that did not. This is in agreement with the findings of the study conducted in Ethiopia by Traoré et al. (1998); which indicated that farmers that are more informed assess the impact of soil erosion better than their counterparts that are not.

4.2.2 Factors affecting Farmers' Adoption and maintenance of land husbandry technologies

The response of farmers as in regard to adoption and maintenance of the introduced land husbandry technologies in this study was categorized into two categories. The first category was of those farmers who maintained these land husbandry technologies in their original state by maintaining the conservation structures. The second category was of those farmers who selectively removed the conservation structures. The findings of this study from FGDs indicated that most of the farmers retained structures in their original state. Most of them said

> "*LWH constructed terraces in our land from 2010 up to now, the constructed terraces are stable, we can't demolish them as we know how important and how expensive they are, the problem we are having is how to make them more productive*"

However, there are other farmers who indicated that they selectively removed the conservation structures. One of the farmers' leaders elaborated as in the following quote:

> *"It is almost impossible to find check dam in my farmland as it was at the time of terraces construction because I used them for firewood. Other technologies like trees for agroforestry and notches were removed at the time of land preparation".*

The findings of this study differ from those conducted in other areas. For instance, Bekele (1998) found that in Ethiopia 53% of farmers interviewed removed introduced conservation measures completely, 31% removed selectively and only 16% maintained conservation measures in their original state. Moreover, other research done in other part of Ethiopia by Ertiro H. (2006) found that the most common response of farmers to the introduced conservation measures was complete removal followed by the selective removal of structures introduced to their cultivation field in Ethiopia. Ertiro argues that, about 53% of farmers interviewed removed conservation structures completely, 26% removed selectively and the remaining 21% of interviewees retained structures in their original state.

The low number of people removing the conservation structure in their farmland in Nyanza 23 site as presented in the findings of this study compared to the other studies conducted elsewhere could be due to LWH project's approach of working hand in hand with local authorities and farmers. It has been noticed that the approach of extension agents working with local authorities and farmers has a positive impact on adoption. The study conducted in Ethiopia indicated that if a farmer receives better information (advice) from extension agents, the farmer will be willing to construct new conservation measures and to maintain the existing ones (Wagayehu and Lars, 2003).

4.2.2.1 Plot Size and Land maintenance Capacity

From the FGDs, it was indicated that the size of the farmer's plot has an impact on adoption and maintenance of land husbandry technologies. Farmers with big plots of land are highly willing to maintain land husbandry technologies compared to those with small plots. It was also found out that most of the farmers are not able to cultivate their entire plots because they considered it to be costly at all dimensions of; land preparation, planting (Selected seeds) and harvesting. All

these activities require time, labor, money and some farmers are not able to afford this hence some plots remain uncultivated as it can be seen on *figure 12*. The discussants' statements were corroborated by one of the community development officers in Nyanza who said:

> *''It is very evident that there are plots of land that are not well maintained here due to the fact that plot owners are not able to meet all the costs needed to fully maintain them…some farmers can't afford to buy all inputs and prepare land in time during season implementation''* (Rukundo Robert, CDO).

Clay and Lewis (1990 as cited in Bizoza 2012) also have reached similar results. The two authors noted that farmers' low level of adoption and maintenance of terraces is not due to their ignorance of soil erosion problems and their effects on production. Instead, the limited ability to secure complementary inputs required by the technology could the major reason. Bouma et al. (2007) found out that this situation can be explained partly by a lack of sufficient transitional measures such as maintenance funds that would allow farmers to better maintain and continue using terraces already established under various SWC interventions. Therefore limited financial capacity can be a cause of poor maintenance of LHTs, and later their abandonment.

Figure 11: Some abandoned terraces in N23 Site



Source: Author

4.2.2.2 Time implication on adoption and maintenance of land husbandry technologies

The findings of this research indicate that it takes farmers much time to make land over which LHTs have been applied more productive. Discussants said that most of the farmers spend more than three days in land preparation, planting, mulching and harvesting. Women spend more time in farmland compared to their male counterparts as one female discussant said:

> *"Most of the time farming activities is our priority; we spend more than three days even five working in terraces. Sometimes we work with our husbands or other family members in the morning hours but afternoon we (women) come back for other activities like planting, manuring." (Women in Nyanza Site).*

These findings imply that LHTs are time consuming but also as farmers are willing to spend more time on land husbandry technologies, this imply the more they have adopted these technologies and consequently; the more they are highly likely to maintain them. Additionally, women are more likely to adopt and maintain these technologies since they spend more time I them than their male counterparts.

However, spending much time on these technologies is likely to have a negative impact on future adoption and maintenance. This is because it consumes much of the time that would otherwise be used to do other income generating activities.

4.2.2.3 Distance effect on adoption and maintenance

Discussants in FGDs declared that farmers who make long distances to their fields do not frequently visit them except during planting and harvesting periods. In this case, if any of these technologies need urgent repair, they are not repaired in due time because it takes them time to reach there. The relatively long distance between the field and the plot owner's residence results in poor maintenance of LHTs. This implies that farmlands situated far from residence suffer from destruction of conservation structures and enhanced erosion.

The same situation was observed by Kessler (2006) and Wagayehu & Lars (2003) who found out that cultivation fields that are far from residence do not get attention from owners as they visit such land usually during planting and harvesting seasons. The relatively long distance between home and the fields' farmers may have a negative impact as Long (2003) found out that frequent

visit to cultivated land influences decision to adopt conservation structures positively. Bizoza (2012) also noted that plot size and distance between the plot and the homestead, are important in the design and adoption of soil conservation measures such as bench terraces. Bizoza argues that, farmers prefer to cultivate plots that are close to their homes since transportation of fertilizers such as manure and household residues is easier. It is therefore evident that, if new technology is introduced, the plots close to the homestead are the most targeted by farmers and hence well maintained.

4.2.2.4 Implication of On-farm investment and Off-Farm Economic Activities

Regarding the investment in LHTs, discussants declared that most of the farmers invested money in land preparation, buying inputs, harvesting and transport of harvest to the storage. Other investments reported by the discussants include time and the opportunity cost of replacing the previously cultivated crops with those that must be planted in terraces. The capacity of every farmer especially financial capacity to invest in LHTs was not assessed, but it is clear that farmers do invest in LHTs. If farmers make some investment in LHTs, their future adoption of these LHTs is highly likely. This was also discovered by Bizoza (2012) who argues that the investment in LHTs affects future adoption. He further pointed-out that; the future adoption of bench terraces is conditional upon both current adoption and farmers' ability to invest in complementary inputs for sustained soil conservation and agricultural production.

Concerning the source of money farmers invested in LHTs, discussants said that such money is secured from different sources. Some farmers have off farm activities whereas others got it from LWH project activities and finally invested it in LHTs. Indeed LWH project employs many local farmers in its various activities. These include among others terraces construction, tree nurseries, construction of storage, compost making and etc. other farmers get money from the selling of their produce.

Studies conducted by; Holden et al., (2002); Bekele (1998) and Gould et al (1989) found negative association between adoption of conservation measures and involvement in off-farm activities. When farmers are very much involved in off-farm activities, there is limited time left to look after these LHTs and hence, poor maintenance.

Apart from the sources of income mentioned above, it was discovered that people having the land in area with irrigation system part (Command Area) receive money for the lease of their land from investors. Farmers are given 100,000 Rwf /ha per year and; the money received is invested in these LHT activities elsewhere in case they have other plots treated with LHTs. Others farmers reported that they got money from working on activities in investor's plots in the Command Area part.

4.2.2.5 Implication of Supportive Institutions on Adoption and Maintenance of LHTs

Farmers receive assistance from different institutions that support them to make and maintain these LHTs. One of the farmers declared:

> *"We receive assistance from the LWH project staff. They teach us techniques of making LHTs. They also gave us the compost and lime for free for the first season after the the construction of terraces. We were also linked to TUBURA (One Acre Fund) project which gives us fertilizers and selected seeds. Payment is done after the harvest. Furthermore, the LWH project staff train us on the use of inputs, land consolidation program, making compost, and working in cooperatives. We also receive trainings on money saving and how to get access to credit so that we can do agriculture in a modern way".*

The above statement was confirmed by the local LWH Project's Community Development officer. He said that farmers have had extensive trainings on cooperative management, use of improved farming methods, marketing and financial literacy. As a result of these trainings, farmers are able to organize themselves into strong producer organizations that can maintain the LHTs in their plots.

It is evident that hand in hand collaboration between supportive institutions and farmers has a positive impact on adoption and maintenance of Land Husbandry Technologies. This is in alignment with the study conducted in Ethiopia by Wagayehu and Lars (2003) who found out; that if a farmer receives better information (advice) from extension agents, the farmer will be willing to construct new conservation measures and to maintain the existing ones.

4.2.3 Maintenance of Land Husbandry Technologies

The FGDs revealed that most of the farmers are able to repair their LHTs in case they are damaged or even demolished since most of them have skills in their construction. In any special case that would require more skills that farmers do not possess, the LWH project staff and local authorities are ready to help. This was stated by one of discussant during the FGD:

> *"For now, most of the LHTs are stable. But when there is a case that requires repair, we can do it ourselves since most of us worked in terraces construction phase, we have skills on how to make them. So, if any terrace, is demolished we repair them easily and for those who are unable to repair LHTs installed in their field due to age or lack of skills, they asks assistance from neighbors, self help groups or any project staff".*

The FDGs and interview revealed that for the people having plot with irrigation system, they report to the project for any demolition. This might be due to the fact that farmers are not familiar with this kind of technology. Furthermore, due to the lease program, farmers think that they do not have full access to these plots and hence they take less effort to repair them in case they need repair.

The research findings indicated that for those farmers who do not maintain LHTs, there are a number of factors that contribute to their not doing so. Discussant said that most of the farmers who do not maintain their LHTs are discouraged by the high maintenance cost involved. The second main reason is an inadequate household labor to maintain these plots of land treated with LHTs. The work involved is also very tiresome. There are also some farmers who believe that they do not have full access to their land and they think that their plots will at the end be given to other people especially for those farmers having plots in the area with irrigation system.

The reasons put forward and the fear above mentioned are similar the ones found by Winter-Nelson and Amegbeto (1998). In their research they found out that terracing entails substantial construction costs in terms of labour and complementary inputs, especially at the early stage, thus; few farmers have the means to construct terraces, unless support is provided by SWC programmes.

4.3 The impact of land husbandry technologies on welfare of farmers

4.3.1 LHTs' Impact on Production

The discussants acknowledge that the introduction of LHTs did have a great impact on the quantity of production. They reported that the production has been increasing over the last 6 years. All FGDs agreed that the before the implementation of LHTs, they used to mix crops and could not even use fertilizers. They also said they even know the quantity of what was harvested. They admitted that after the introduction of LHTs, most of the farmers do no longer mix crop, they use selected seeds and other inputs like fertilizers and lime on consolidated land. Although the first production after the introduction of terraces was not so good; the yield has been increasing exponentially in for the following seasons.

Those observations were confirmed by one cooperative manager who pointed out that he noticed that the yield increased after the introduction of LHTs in Nyanza23. The increase of yield and consequently the production was also observed by MINAGRI (2015). MINAGRI 2015 annual report claims that the increases of yields of different crops have tripled and in some areas like Karongi the crop yield increased 5 fold after the land treatment. The yield and production increase are also acknowledged by the RSSP-LWH report (2015) which states that as of to-date; production of beans increased from 0.6 tons/ha to 2 tons/ha and climbing beans to 3.6 tons/ha. Also, maize increased from 0.8 tons/ha to 2.5 tons/ha while Irish potatoes which were not cropped in the site before LWH interventions reached 9 tons/ha on average. This complements the government's initiative on improving the welfare of the farmers within the project site, through provision of required nutrients at household level and income that may be used to purchase essential goods and services.

The increase in the quantity of produce resulted into food security and increased income of farmers as noted by in LWH-RSSP report (2015) which states that the farmers' net income from sales has tripled as farmers now market 74% of their produce from 30% before the project. The report also claims that post-harvest infrastructures were constructed to minimize post-harvest losses and improve the quality of produce.

4.3.2 The impact of LHTs on Farmers' income and saving

The findings of this study indicated that the introduction of LHTs did have a positive impact on farmers' income and instilled into them a habit of saving. Discussants agreed that the most of them, especially the ones who work for LWH in installing LHTs, earn an average of 20,000Rwf to 40,000Rwf per month. The second group of vulnerable group especially old women and men above 50 years of age and other people with disabilities roughly earn average amount ranging from 10,000 Rwf to 25,000 Rwf per month for their work in LWH's tree nurseries.

The third group of people earned an income from making compost; and their income earnings depended on the quantity of compost supplied. An example of these people is someone who invested in compost making who got more than 12,000,000 Rwf per season after supplying 447,700 kgs of compost (27Rwf per kg). The fourth and last group is made of farmers, who grouped themselves in self help groups (SHG), invest in composting making, and share the profit from that activity. One live example is KANGUKADUKORE A, a SHG working in Nyagisozi sector, which got more than 5,000,000 Rwf after supplying 19,500kgs of compost (27Rwf/kg).

Figure 12: LWH Project Staff evaluating the quality of the compost heap



The research findings also indicated that some farmers earn money from other project activities like the construction of post-harvest and irrigation infrastructures as it can be seen on the figure 14.

Figure 13: Nyanza water reservoir with people constructing an irrigation canal



This study also disclosed that the introduction of LHTs instilled a habit of saving and working with financial institutions. This is confirmed by one farmer who said:

> *"Yes, we have been working in terraces construction works and we were instructed to open-up bank accounts through which we were paid. Apart from this, we are also members of a cooperative, if they sell our harvest the money from the sales is given to us through bank accounts so to have a bank account is a must. Our SHGs also have bank accounts for savings and we are able to get credit as SHGs".*

This was also observed by LWH-RSSP 2015 report which claims that to increase formal financial services; farmers in the site have been linked to five financial institutions (SACCOs). The report further states that; more than 84.4% of individual farmers have accounts, while 100% of SHG have got their accounts through which they get credit to finance the agricultural value chain.

These findings indicate that the farmers' welfare state improved significantly since they can work with financial institutions. If farmers can by themselves conduct internal saving and lending and access credit from other financial institutions, it shows that they can invest in other income generating activities and hence improve their livelihoods.

4.3.3 The Impact of LHTs on creation of farmers' organizations

From the interview with the project CDO, this study found out that the introduction of LHTs led farmers to join different groups and associations. Through these, farmers can easily access credit, technical advice, farm equipment, socio-networking and conflict resolution. This is confirmed by farmers during focused group discussions as the following quote justifies;

"As farmers working in LHTs area, we are all grouped in SHGs which are in turn grouped into cooperatives. We benefit from technical knowledge on LHTs implementation and maintenance, we work together to prepare compost. We also receive inputs together; we do savings and have access to credit as a group. Apart from this, farmers in area with irrigation system are grouped in Water users associations (WUAs) for better use of water from reservoir".

These claims are also confirmed by the project staff and local authorities who authenticate that; farmers have been trained on different modules aiming at creating strong farmers organizations. As a result, after a period of one year, SHG have formed three cooperatives; KOABINYA, INGENZI and ABADATEZUKA. They further affirm that these trainings have been specifically aiming at improving skills in a number of aspects including modern agricultural and marketing practices.

These results are confirmed by the MINAGRI's 2015 report that pointed out that through the implementation of LHTs, strong farmer groups were formed in different sites. The report further confirms that farmers were trained on the subjects of agricultural technologies, post-harvest handling and marketing, business planning, compost making, tree nursery maintenance and saving.

4.3.4 Farmers' perception of the impact of LHTs on their welfare improvement

Most of the discussants in FGDs indicated that farmers recognize the impact of LHTs on the improvement of their welfare. They acknowledge that their access to money increased especially at the time of LHTs construction and many of them have constructed new houses, bought cows, goats and other livestock. Others have motorcycles and bicycles from wages paid by LHW project. Most of them continue with the development by making terraces more productive.

However there are some farmers who allege that there is a very small improvement on their welfare since the implementation of LHTs. From my side, this kind of perception may be due two main reasons among others. First these farmers may have small plots of land treated with LHTs where the impact of these technologies on their farmers' livelihoods is insignificant.

Secondly, such farmers may still have adaptation issues on land consolidation programs and they still believe that traditional farming methods are better.

4.3.5 Future maintenance of Land Husbandry Technologies

From the declarations in the FGDs, it is evident that farmers are highly likely to continue maintaining LHTs after the project will have phased out. Some farmers said: *"Yes, this is our land and we depend on agriculture. We will continue to maintain them as long as they are our main source of our income"*. This statement is a strong proof of farmers' commitments to maintain installed LHTs.

However, there are some farmers who said not to be keen to maintain LHTs installed in their farmland except if they were allowed to cultivate crops of their own choice. This finding shows that some farmers still have not adapted the land consolidation and crop intensification programs. Such farmers still need government 'and project's support in case of low harvest due to weather events. They claimed that they incur losses on seeds and other inputs and there are no insurance measures to cater for these kinds of issues.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

This chapter concludes the report and formulates some recommendations for a better use of Land Husbandry Technologies.

5.1 CONCLUSION

Erosion has significant effects on the environment, agronomic productivity, food security, and quality of life resource-poor farmers in Rwanda. Unsustainable land-use, coupled with Rwanda's steep topography, fragile soils, and climate, is the driving cause of soil erosion. This is why the GoR has initiated the LHTs to fight against erosion. Those techniques are implemented in many parts of the country including Nyanza23 Site. In this regard, in the study area wide range of land husbandry technologies were introduced with the objective of conserving, developing and rehabilitating degraded agricultural lands and increasing food security and social welfare through increased food productivity.

These technologies have been categorized into three types which include; physical, agronomic and chemical. The physical land husbandry techniques introduced in the area include soil bunds, improved and narrow cut-bench terraces, progressive ditches, check dams and water ways. The agronomical land husbandry technologies introduced include; agroforestry, grass strips, plant residuals (mulching), and crop management systems. Also the chemical land husbandry technologies that were introduced in the area are Fertilizers (both organic and industrial chemical fertilizers) and liming.

Due to lots of effort that have been put in place to conserve soil the success is very significantly comparable with the effort made. Erosion have reduced significantly, farmers also confirm that there is a significant change in soil loss if one compares the current situation with the one before the introduction of these LHTs. The results from this analysis indicated that farmers have adopted and are maintaining these introduced land husbandry technologies. It was discovered that before the introduction of LHTs, farmers perceived soil erosion as a significant problem that had catastrophic effects on their agricultural production. The study also unveiled that soil erosion was significantly eradicated.

Based on the result of this study, it was discovered that plot size, farmers' capacity to invest, distance travelled from home to the treated plot, off-farm activities and availability of supportive institutions were the main factors that significantly affect the probability of adopting LHTs. Farmers with big plots of land are highly willing to maintain land husbandry technologies compared to those with small plots. The results also indicated that the plot size was directly proportional to the willingness of farmers to invest, but hindered by the capacity of some of the farmers to do so.

The outcome of this research indicated that as the distance traveled from home to the treated plot increases, the likelihood of farmers to adopt and maintain these LHTs decreases. This is to say; distance has a negative effect on farmers' adoption and maintenance Land Husbandry Technologies. It was discovered that most farmers invested in maintenance of LHTs and the on-farm and off-farm activities were the main sources of the investment. The more the farmers did concentrate on off-farm activities, the less likely those farmers will adopt and maintain Land Husbandry Technologies. It was discovered that farmers in the study area receive support from concerned institutions and the more farmers are supported, the more likely that those farmers will adopt and maintain LHTs.

It was discovered that, though some of the farmers still have beliefs that would prevent them from maintaining these LHTs in future, most of the farmers in the study area are highly likely to continue maintaining them.

The study indicated that the introduction of land husbandry technologies resulted into welfare improvement of farmers in the area. LHTs increased the income earnings and instilled a culture of saving and working with financial institutions amongst farmers. The study also indicated that the introduction of these LHTs resulted into an improved willingness of farmers to join farmers' organizations like Self Help Groups and Cooperatives. These results imply that farmers now have an easy access to credit, technical advice, farm equipment, socio-networking and conflict resolution mechanisms.

It has been noticed that what is observed that the problem of that have been identified as the crosscutting issue at national level in Rwanda can be also observed at micro level as the case in Nyanza23 site. Erosion is a significant problem from a small scale up to the country level.

All hypotheses were verified; there was high erosion rate before the implementation of land husbandry technologies in the study area. The rate of erosion declined due to the Implementation and maintenance of land husbandry technologies in Nyanza 23 site. But, little monitoring, education and awareness of local farmers in soil erosion control practices can lead to the aggravation of erosion in N23 site.

5.2 RECOMMENDATIONS

Based on the findings of this research, the following recommendations are formulated to help a better comprehension of LHTs, their large dissemination and maintenance in the area under consideration

1. Although, RUSLE and GIS model is a valuable tool for the quantifications and mapping of an estimated value of soil loss at various locations, further studies in limited spatial scale using high resolution data is recommended to monitor and mitigate the areas appropriately. Better prediction of RUSLE parameters should be complemented by accumulating more accurate input data. For example, the accurate R value should be more predicted by measuring precisely the quantity of the rain falling in the site. LWH project and local authorities can make this possible by putting micro stations through the site and record the rain quantity at time basis.

2. Because of their positive impacts on soil conservation, crop production and the population's livelihood in general, local authorities should encourage the adoption of land husbandry technologies in areas where they have not yet been introduced.

3. Local authorities and the Project should continue the coaching and training offered to the community to avoid damages or destruction of LHTs in place. Here, the information about ineffectiveness of traditional farming system has to be disseminated and should

also be made part of training programs offered especially focusing on the young people as future adopters.

4. Local authorities should improve the effective way of using energy resources by increasing the use of improved cooking stoves in order to avoid destruction of some soil and water conservation technologies like chekdams, agroforestry trees by farmers in need of energy for cooking.

5. For a sustainable maintenance of LHTs, the projects and other departments should help farmers in acquiring bank loans that would enable them to pay fertilizers and input required so the farmers can cultivate all their plots and therefore make more benefit and maintain the LHTs in place.
6. As the study was conducted in three out of 4 sectors where the projects operates, it would be very interesting to conduct a thoroughly study in the all study area with focus on farmers capacity to invest in adoption and maintenance of Land Husbandry Technologies, therefore based on the results, the LHTs can be extended to other regions of the country.
7. The project should put continuous effort in sensitizing farmers to adopt and maintain the LHTs because they are effective against soil erosion.

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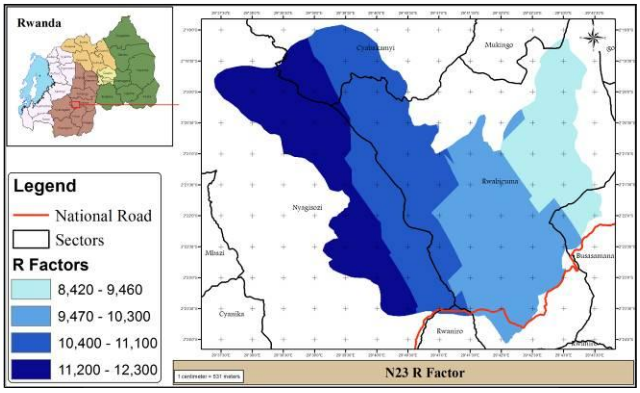
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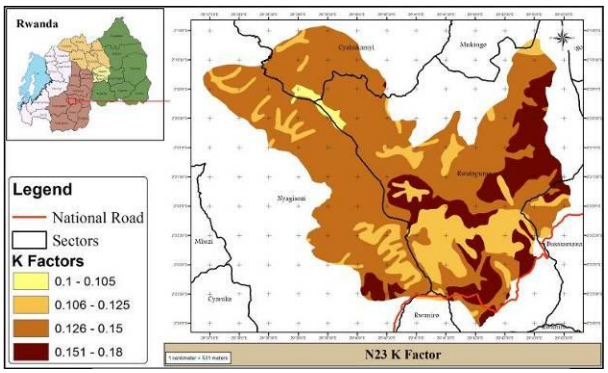
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APPENDIXES

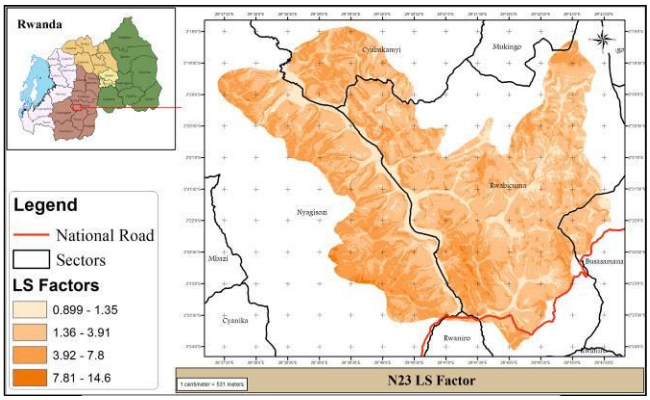
Appendix 1: RUSLE PARAMETERS



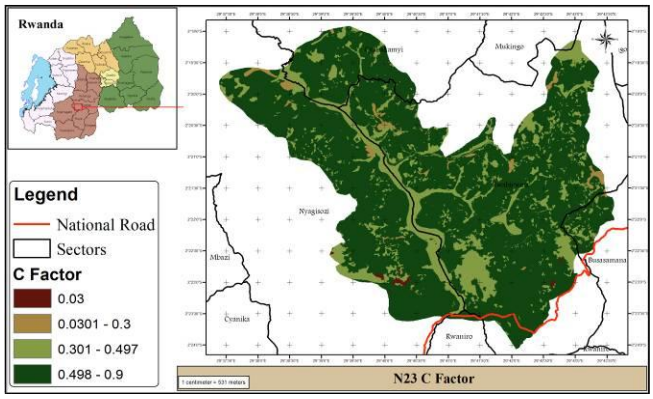
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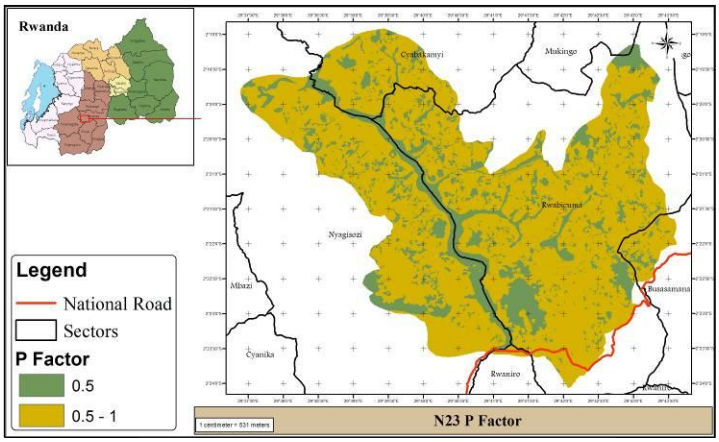
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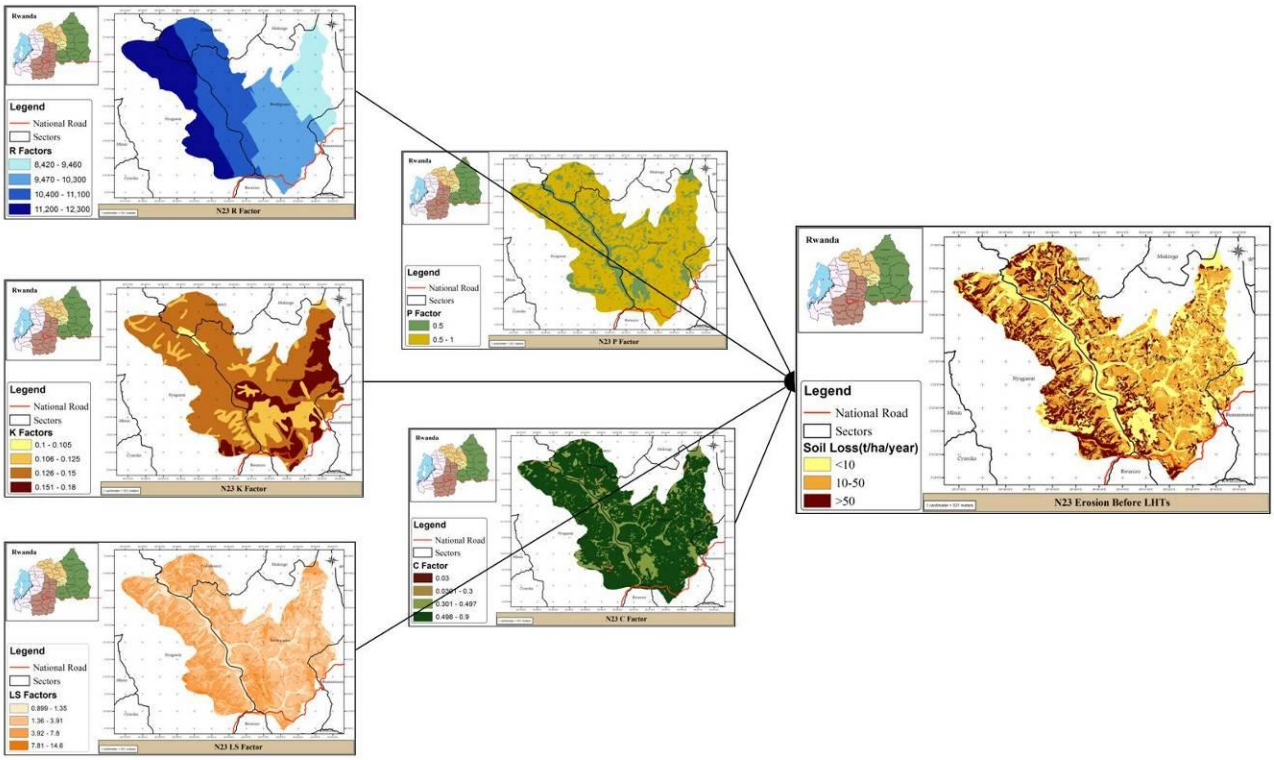


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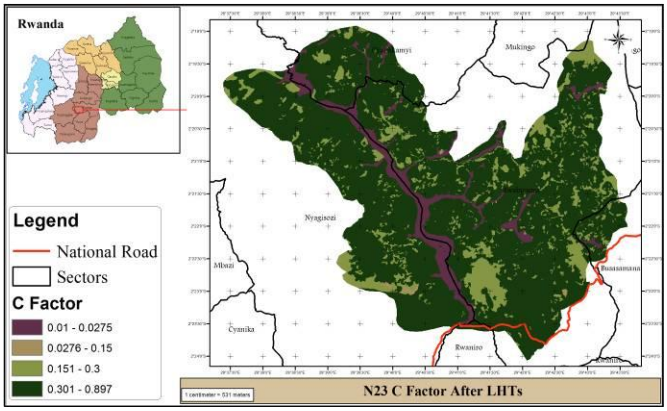


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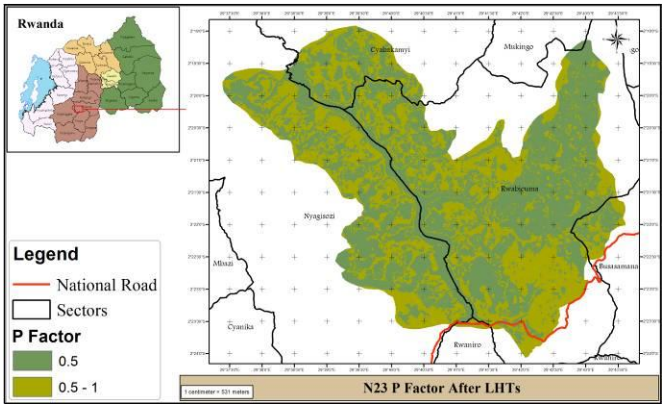
Appendix 2: RUSLE PARAMETERS OVERLAYING



Appendix 3: C AND P FACTORS AFTER LHTS IMPLEMENTATION



C factor



P factor

d

Appendix 4: FGD GUIDE QUESTIONS

Site: Moderator:

Number of participants: Note-taker:

Date:

Start: End:

A. QUESTION ON LH TECHNOLOGIES

1. Did you notice erosion in your area before the implementation of land husbandry technologies?

2. How do you describe the degree of soil erosion in your farmland at that time?

    a. Severe risk of soil erosion
    b. Moderate risk of soil erosion
    c. Minor risk of soil erosion
    d. No risk of erosion problem at all

3. How do you rate the erosion after the implementation of LH Technologies in your area?

    a. Severe
    b. Moderate
    c. Low
    d. No erosion

4. In your opinion what are the causes of land degradation in your village?

5. Which are the best ways of erosion control do you know?

6. Where did you get information about the soil and water conservation measures (rank them according to their importance if they are more than one, giving one to the most important source)?

7. Have you ever attended trainings related to soil and water conservation?

B. INFORMATION ON THE ADOPTION AND MAINTENANCE OF LAND HUSBANDRY TECHNOLOGIES

8. What are soil and water conservation measures introduced to the area?

9. What have you done with the soil and water conservation technologies introduced to the area?
   a. Applied but removed them completely
   b. Applied but removed them selectively
   c. Applied and maintained the conservation measures introduced

10. In season preparation, are your entire plots with land husbandry technologies cultivated? Explain why

11. How many total days in a week do you spend on land preparation and planting for your plot during Season time? This includes preparing fields for planting and planting.

    a) One day b) Two days c) Three days d) More

12. Do you work alone as household members or with cooperative or SHG members?

    Specify……
    …….

13. How far do you travel to access your plot with land husbandry technology?

    a)< 50M b) 50M-100M c) 100M-500M d)>500M

14. What did you invest in land husbandry technologies practices after being constructed in your farmland?

15. Where have you got money for land husbandry technologies practices?

16. Have you ever received assistance and advice from the authorities on best practice method?

If the answer is yes, what kind of help and advice were you given?

i. …….
ii. ……
iii. ……..

iv. ……..

17. What do you do when any land husbandry technology demolished?

    .....……

    …….

18. If you are not maintaining terraces constructed in your farmland, what are factors that discourage you from maintaining

19. At your own, do you plan to construct at your own any land husbandry technology in your land where there are not? Yes/No

Explain why……

20. Is there anything else you would like to say about why you do or do not adopt and maintain land husbandry technologies?

C. IMPACT OF LAND HUSBANDRY TECHNOLOGIES ON FARMERS' WELFARE

21. What changes have occurred in the quantity of harvest (Increased, No change or Decreased) over the last 10 years? (Explain reasons for the change)
    ……
    ……
    ……
    ……

22. Does your HH currently have a bank account (at a bank/SACCO/COOPEC)?

    a) Yes ☐ b) No ☐

23. Did you get some savings from land husbandry technologies? Yes/No

If yes where was the source of income?

a. Land husbandry technology for LWH construction (RWF):

b. Nurseries for LWH (RWF):

c. Composting for LWH (RWF):

d. Other, Specify……

24. Membership of associations and benefits

Associations	**Yes/No**	**Direct Benefits**[1]
Self Help Group (SHG)		
Women's' groups		
Social/religious groups		
Water committee/users association		
Other:		

[1] *Examples of benefits: Access to credit/borrowing money; Technical advice; borrowing farm equipment, social networking, conflict resolution*

25. Do you see any impact of land husbandry technologies on the improvement of your welfare?

Explain……
……
……

26. Do you have a plan to continue to maintain and sustain Land Husbandry Technologies after the project has phased out?

Explain why…….

27. Is there anything else you would like to say about what will happen on land husbandry technologies after the project phase out?

Appendix 5: INTERVIEW GUIDE

Kindly provide the following information

i. Name :

ii. Position :

1. What strategies use/ used to facilitate the practice of soil and water conservation?

a) Field training/seminars of farmers ☐ b) Use of media ☐ c) others ☐

2. How do you explain the erosion before and after the land husbandry practices in the study area?

3. What is your message to farmers about land husbandry technologies practices?

4. How do you evaluate the performance of the project with regard to controlling soil erosion and social welfare?

5. Do you have a plan to continue to maintain and sustain Land Husbandry Technologies after the project has phased out?

Explain