USING GIS TECHNIQUES TO DETERMINE RUSLE’S ‘R’ AND ‘LS’ FACTORS FOR KAPINGAZI RIVER CATCHMENT

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Master of Science Research Project Report

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December 2009

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Declaration
The following Master of Science project report was prepared by me without any additional help. All used sources of literature are listed at the end of the report. I hereby grant to Jomo Kenyatta University of Agriculture and Technology permission to reproduce and to distribute publicly copies of this document in whole and in part.

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

Mbugua W. Esther
EN 382-0069/2008
Dedication

This report is dedicated to my Daughters Tabby and Ruth who never complained even after sacrificing their precious parental time for the learning. It is my sincere hope that this study/learning contributes to improving their well-being. I pray that they grow in knowledge and continue from where I have left
Acknowledgement

I owe much to all who have contributed to the success of this project. Firstly, I would like to thank God whose grace has been sufficient throughout the study period.

Secondly, it is important to note that a research project such as this is never accomplished without the collaboration and cooperation of many people and organizations. To begin with I would like to thank Jomo Kenyatta University of Agriculture and Technology (JCUAT) and World Agroforestry Centre (ICRAF) for their support in this research project. I am also grateful to all the JKUAT lecturers and PRESA team from ICRAF for their unlimited support and cooperation during the research period.

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Last but not least, many thanks to my dear husband Jacob M. Gacheru who has always stood by my side throughout the learning period. His support both morally and financially have made this research work a success.
Abbreviations and Acronyms

A: RUSLEs Equation average annual soil loss in tons per acre;
C: RUSLEs Equation cover-management factor
DEM: Digital Elevation Model
GIS: Geographic Information Systems
IDW: Inverse Distance Weighted
IFAD: International Fund for Agricultural Development
ILWIS: Integrated Land and Water Information System
K: RUSLEs Equation soil erodibility factor;
KENGEN: Kenya Electricity Generation Company
L: RUSLEs Equation slope length factor;
MAR: Mean Annual Rainfall
MFI: Modified Fournier Index
MKEPP: Mt Kenya East Pilot Project
P: Support Practice Factor
PRESA: Pro-Poor Rewards for Environmental Services for Africa
R: RUSLEs Equation Rainfall-runoff erosivity factor;
RUSLE: Revised Universal Soil Loss Equation
S: RUSLEs Equation slope steepness factor;
SWAT: Soil and Water Assessment Tool
UCA: Upslope Contributing Area
USLE: Universal Soil Loss Equation
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ABSTRACT

The purpose of this study was to use GIS techniques to determine some of the soil erosion factors including rainfall runoff erosivity (R) and slope length/steepness factor (LS). This was done successfully and thematic maps of these parameters were generated. In order to establish the effects of these factors especially topography, a preliminary assessment of potential soil erosion was carried out.

The factors were calculated using the local data that was collected specifically for Kapingazi River Catchment. The results show that R value ranges between 492 and 857 MJ/ha.mm/h with the highest values being in the upper part of the catchment and the lowest values in the lower part of the catchment. Slopes in the catchment varied between 0 and 88° or 0 and 2,676% with steep slopes having higher values of slope length/steepness factor (LS) of more than the mean value. The mean LS factor is 8 with a standard deviation of 15.2. The minimum value is 0 and the maximum value is 395.8.

The results of the preliminary soil erosion assessment indicate that the average annual soil loss within the catchment ranges from 0 to 449 tons/acre with zero erosion occurring along the channels. On the other hand the highest soil loss was found to occur along the river banks with steep slopes.

Based on the results of this study, it is recommended that ground survey be undertaken on areas showing high risk of soil erosion. Depending on the outcome of the survey immediate action should be taken to curb acceleration of land degradation in the areas with high risk. It is also important to note that the steepest slopes show high risk of soil erosion, it is therefore recommended that further study be undertaken to establish the suitable soil and water conservation measures that should be implemented in these areas as well as the whole catchment.
CHAPTER ONE: INTRODUCTION

Recent assessments suggest that about 80% of the world’s agricultural land suffers from moderate to severe erosion (Ritchie et al., 2003). Because of this erosion-induced loss of productivity and population growth, the global per capita food supply is currently declining. In many areas of the world, on-site impacts of increased soil loss are frequently coupled with serious off-site impacts related to the increased mobilization of sediment and its delivery to rivers. These off-site impacts include water pollution, reservoir sedimentation, the degradation of aquatic habitats and the increased cost of water treatment.

1.1 Background
The limitations of current measurement techniques and models to provide information on the spatial and temporal patterns of soil and water degradation across catchments restrict ability to develop cost-effective land management strategies. However, the advent of new techniques of erosion assessment and recent developments in the application of remote sensing and geographic information systems (GIS) to the study of erosion and sediment delivery offer considerable potential for meeting these requirements.

Since disturbed lands in watersheds are significant source of sediment, a systematic rating of their potential for erosion would be useful in soil conservation planning. Most importantly mapping and assessment of erosion prone areas enhances soil conservation and watershed management. Maps showing the spatial distribution of natural and management related erosion factors are of great value in the early stages of land management plans, allowing identification of preferential areas where action against soil erosion is more urgent or where the remediation effort will have highest revenue.

1.2 Problem Statement
Tana River is the biggest River in Kenya and it originates from Mount Kenya one of the five critical fresh water sources in Kenya. The rivers emanating from the mountain (including Kapingazi River) make up almost 49% of the Tana River (Website 1). It is important to note that hydro-power constitutes around 60 per cent of the total electricity generated in Kenya. According to Kenya Electricity Overview (Website 2), the bulk of this electricity is tapped from five generating plants along the River Tana. These stations are Kindaruma, Kamburu,
Gitaru, Masinga and Kiambere. It also supports irrigated agriculture, fisheries, livestock production and biodiversity conservation especially in the lower parts of its basin which are dryer than the highlands. This makes it a critical natural asset in Kenya’s economic developments.

Currently, economic pressure is intensifying the conversion of land from forest to farming. As a result, people cultivate along the riparian as shown on figure 1.1. This has resulted in land degradation on the upper Tana basin hence inflicting heavy costs to downstream areas through the siltation of reservoirs (figure 1.2), damage to infrastructure and reduced flows during dry seasons (figure 1.3). There is therefore a concern by PRESA (Pro-Poor Rewards for Environmental Services for Africa) project and partners that Tana River is steadily losing its life supporting functions due to ecosystem degradation caused by human activities at the upper and middle catchment areas. The human activities are a clear indication that local communities are a component of the ecosystem and their decisions on land-use affects the amount of water and sediments flowing into the Tana River.

Figure 1.1: Cultivation along Kapingazi River
In order to curb the vice it is envisaged that a rewards based approach that incorporates these resident communities would have potential to reverse the degradation. PRESA has identified
the potential sellers of environmental services as land owners and users at the upper Tana basin and middle catchment areas. On the other hand the potential buyers would include the Kenya Electricity Generation Company (KENGEN), and irrigation projects at the lower Tana River. For instance KENGEN is interested in reducing sediments that threaten to clog its dams, thereby shutting down electricity production. Also farmers irrigating the lower basin wish to see consistent flows of the Tana through out the year.

To achieve this, PRESA is working along Kapingazi area to facilitate fair and effective agreements between stewards and beneficiaries of environmental services. This is being done in partnership with Mt Kenya East Pilot Project for natural resource management MKEPP and the World Soil Information Centre. The World Soil Information Centre plans to implement a reward for environmental services scheme called Green Water Credits in cooperation with International Fund for Agricultural Development (IFAD) and the Swiss Agency for Development Cooperation.

In the implementation of the reward for environmental scheme, the environmental buyers and sellers would work together and agree on the soil conservation measures that should be put in place in the upper Tana River basin. For an effective and efficient implementation of the scheme, it is important to spatially identify the areas that are prone to soil erosion leading to heavy loads of sediments downstream that have resulted to siltation of the reservoirs, damage to infrastructure and reduced flows.

Since Kapingazi River is one of the rivers on the upper Tana River Basin with intensive human activities, the objective of the research is therefore to use GIS techniques to determine RUSLE’s rainfall-runoff erosivity factor (R) a combined slope length factor (L) and the slope steepness factor (S) LS along the Kapingazi river catchment. The results will be used in the soil erosion risk assessment which will in turn culminate to identification and mapping of soil erosion hot spots along this catchment where immediate attention is required.
1.3 Objectives

Overall Objective
The overall objective of this study is to determine RUSLE’s rainfall-runoff erosivity factor (R) and slope length/steepness factor LS.

Specific Objectives of the Study
More specifically the study will be guided by the following specific objectives
1. To generate a map of the catchment area
2. To generate a Digital Elevation Model (DEM) for the catchment area
3. To use the DEM to generate the slope length and slope maps for Kapingazi River catchment
4. To generate maps of themes that are important to soil erosion in Kapingazi catchment including rainfall-runoff erosivity (R) and slope length/steepness factor LS and establish their effect especially topography on soil erosion.
CHAPTER TWO: LITERATURE REVIEW

The subject of soil erosion has been a global concern and numerous research works have been undertaken. In this chapter, soil erosion has been discussed briefly including the model that has been preferred in its assessment including the importance of application of GIS.

2.1 Introduction

Water erosion is a serious and continuous environmental problem in many parts of the world (Deniz et al., 2008). The need to quantify the amount of erosion and sediment delivery in a spatially distributed form has become essential at the watershed scale and in the implementation of conservation efforts. Sediment yield from a watershed is an integrated result of all water erosion and transport processes occurring in the entire contributing area. The total sediment yield thus depends on both erosion at the various sediment sources such as crop, range and forest lands and the efficiency of the system to transport the eroded material out of watershed (Renard, K.G 1972). The potential for soil erosion varies from watershed to watershed depending on the configuration of the watershed (topography, shape), the soil characteristics, the local climatic conditions and the land use and management practices implemented on the watershed.

The adverse influences of widespread soil erosion on soil degradation, agricultural production, water quality, hydrological systems, and environments, have long been recognized as severe problems for human sustainability. However, estimation of soil erosion loss is often difficult due to the complex interplay of many factors, such as climate, land cover, soil, topography, and human activities. Accurate and timely estimation of soil erosion loss or evaluation of soil erosion risk has become an urgent task.

In many situations, land managers and policy makers are more interested in the spatial distribution of soil erosion risk than in absolute values of soil erosion loss. To address this need the combined use of Geographic Information System (GIS) and erosion models has been shown to be an effective approach to estimating the magnitude and distribution of erosion (Mitasova et al., 1996; Yitayew et al., 1999).
RUSLE, which is greatly accepted and has wide use, is simple and easy to parameterize and requires less data and time to run than most other models dealing with rill and interrill erosion. GIS on the other hand facilitates efficient manipulation and display of a large amount of geo-referenced data. More importantly, it allows easy definition of spatial subunits of relatively uniform properties. Hence, with the aid of GIS, erosion and sediment yield modeling can be performed on the individual subunits. The identification of the spatially distributed sediment sources makes possible the implementation of special conservation efforts on these areas.

2.2 Soil Erosion Models

For a long time, the Universal Soil Loss Equation (USLE) and later the Revised Universal Soil Loss Equation (RUSLE) has been the most widely used model in predicting soil erosion loss. The USLE was originally developed for soil erosion estimation in croplands on gently sloping topography (Wischmeier et al. 1978). With the advent of the revised USLE, it has broadened its application to different situations, including forest, rangeland, and disturbed areas (Renard et al., 1997). Traditionally, these models were used for local conservation planning at an individual property level. The factors used in these models were usually estimated or calculated from field measurements. The methods of quantifying soil loss based on erosion plots possess many limitations in terms of cost, representativeness, and reliability of the resulting data. They cannot provide spatial distribution of soil erosion loss due to the constraint of limited samples in complex environments. So, mapping soil erosion in large areas is often very difficult using these traditional methods.

The use of remote sensing and geographical information system (GIS) techniques makes soil erosion estimation and its spatial distribution feasible with reasonable costs and better accuracy in larger areas (Millward et al., 1999; Wang et al., 2003). For example, a combination of remote sensing, GIS, and RUSLE provides the potential to estimate soil erosion loss on a cell-by-cell basis (Millward et al., 1999).

The RUSLE represents how climate, soil, topography, and land use affect rill and interrill soil erosion caused by raindrop impact and surface runoff (Renard et al., 1997). It has been extensively used to estimate soil erosion loss, to assess soil erosion risk, and to guide development and conservation plans in order to control erosion under different land-cover conditions, such as croplands, rangelands, and disturbed forest lands (Millward et al., 1999).
In addition, the steep slopes of mountainous watersheds are prone to accelerated soil erosion following man – induced or natural disturbances. Gauging their contribution to in-stream suspended sediment and bed-loads is of interest to soil conservation planners and water quality management. The RUSLE (Renald et al., 1997) has been used successfully in this way for agricultural and reclaimed lands. RUSLE is designed to compute long term average annual soil loss for ground slopes where flow convergence/divergence can be neglected i.e. planar slopes, common in agricultural lands. The RUSLE is expressed as:

\[
A = R \times K \times L \times S \times C \times P; \quad (1)
\]

where

- \( A \) is the average annual soil loss in tons per acre;
- \( R \) is the rainfall-runoff erosivity factor;
- \( K \) is the soil erodibility factor;
- \( L \) is the slope length factor;
- \( S \) is the slope steepness factor;
- \( C \) is the cover-management factor; and
- \( P \) is the support practice factor

RUSLE equation has six factors as indicated above. In this study the \( R \), \( L \), and \( S \) factors are of interest and have been determined for Kapingazi River Catchment. In this regard the following section gives more details on these factors.

2.2.1 Rainfall-Runoff Erosivity (R) Factor

Rainfall and runoff play an important role in the process of soil erosion, which is usually expressed as the \( R \) factor. To calculate the \( R \) factor, long-term precipitation data are needed with high temporal resolution, typically available for only few locations. The RUSLE rainfall-runoff erosivity factor (\( R \)) for any given period is obtained by summing for each rainstorm the product of total storm energy (\( E \)) and the maximum 30-minute intensity (\( I_{30} \)). Unfortunately, these figures are rarely available at standard meteorological stations. Fortunately, long-term average \( R \)-values are often correlated with more readily available rainfall figures like annual rainfall or the modified Fournier’s index (Arnoldus, 1978). The models used to determine this factor are described in chapter 3.
2.2.2 Slope and Slope Length (LS) Factors

The slope and slope length factors (S and L, respectively) account for the effect of topography on soil erosion. It can be estimated through field measurement or from a digital elevation model (DEM). The slope length factor L is defined as the distance from the source of runoff to the point where deposition begins, or runoff becomes focused into a defined channel. The interaction of angle and length of slope has an effect on the magnitude of erosion. For example, soil losses from plots on irregular slopes may be dependent on the slope immediately above the point of measurement. As a result of this interaction, the effect of slope length and degree of slope should always be considered together (Edwards, 1987).

With the incorporation of Digital Elevation Models (DEM) into GIS, the slope gradient (S) and slope length (L) may be determined accurately and combined to form a single factor known as the topographic factor LS. The precision with which it can be estimated depends on the resolution of the digital elevation model (DEM). The process of deriving the same is described in chapter 3.

2.2.3 The Effects of Topography on Soil Erosion

The effect of topography on erosion is accounted for by the LS factor in RUSLE, which combines the effects of a hillslope-length factor, L, and a hillslope-gradient factor, S. As hillslope length and/or hillslope gradient increase, soil loss increases. As hillslope length increases, total soil loss and soil loss per unit area increase due to the progressive accumulation of runoff in the downslope direction. As the hillslope gradient increases, the velocity and erosivity of runoff increases i.e. the longer the slope length the higher amount of cumulative runoff and the steeper the slope the higher the runoff velocity which contributes to erosion.

The hillslope length factor, L, reflects the effect of hillslope length on soil loss. When soil loss estimates are used for conservation planning and the protection of a soil resource, hillslope length is defined as the distance from the origin of the overland flow to a point along the hillslope profile where either the gradient decreases to the extent that soil deposition occurs, or where the overland flow becomes concentrated in a well-defined channel (Renard et al., 1997). However, in the field this distance can be difficult to determine due to insufficient evidence to identify the place where overland flow begins upslope and insufficient evidence of the place where deposition begins downslope.
On the other hand, the hillslope-gradient factor, $S$, reflects the effect of hillslope-profile gradient on soil loss. Soil losses increase more rapidly as gradient increases than as length increases. The gradient of a hillslope profile is defined as the change in elevation per change in horizontal distance, expressed in percent or in degrees.

### 2.2.4 Overland Flow Length

Application of RUSLE to mountain watersheds has been marred by difficulties in adapting the slope length factor ($L$) to a complex topography. By definition the slope length factor $L$ is given as a function of slope length $\lambda$, i.e. $L = f(\lambda)$, where $\lambda$ is the plan view distance from the point of initiation of overland flow to the point where overland flow is collected in a channel or where deposition begins (Renard et al., 1997). To take advantage of DEM and GIS procedures, it has been proposed (e.g. Desmet, 1996) to replace $\lambda$ by upslope contributing area (UCA) which is approximated easily using flow accumulation. The upslope contributing area (UCA) of a cell is the number of other cells from which it receives overland flow multiplied by the cell area. According to (Moore and Wilson, 1992), a theoretical test was performed that showed agreement between the RUSLE $L$ and UCA based $L$ for surfaces of negligible tangential curvatures, slope lengths less that 100m, and surface gradients lower that 14 degrees. Most mountain watersheds however, fall outside the test conditions. (Yitayew et al., 1999) found out that LS values compared by the upstream contributing area appear to be systematically higher than those obtained by the RUSLE method.

Upstream contributing area infringe RUSLE rules in two significant aspects (Mitasova et al., 1997)

1. Overland flow lines extend from the upstream to downstream margin of the DEM without consideration of intermediate derivation channels or areas of deposition. This omission may have caused large LS values reported by (Yitayew et al., 1999)
2. The other problem is that upstream contributing area involves flow convergence and thus includes channels as part of the overland flow system which RUSLE excludes.

In light of the above, in this study the slope length has been computed as defined in RUSLE. To begin with, it is important to note that there is a difference between the USLE and RUSLE slope length. The USLE slope length definition is that deposition ends at the slope length. However, if the overland flow continues across the depositional area, the slope length for the lower portion of the hillslope does not begin where deposition end but begins at the top of the
hillslope where runoff began. The following figure 2 is an illustration of slope length as defined in both USLE and RUSLE.

According to (George et al, 2005) Revised Universal Soil Loss Equation Version 2 (RUSLE2), rather than use the traditional USLE slope-length definition, RUSLE2 uses an overland-flow path-length definition. The RUSLE2 overland flow path length is the distance from the origin of overland flow to where the flow enters a concentrated flow area like a gully, waterway, diversion, or stream as shown in figure 2.1b. This slope length is used when the analysis requires that the entire slope length be considered especially on complex slopes.

The slope length to where deposition begins can be used to compute soil loss on the upper eroding portion of a slope. However, the slope length for the lower eroding portion does not begin where deposition ends but starts where runoff originates which flows across the lower portion. Therefore the entire slope length must be used to compute soil loss on the lower portion of slope.
Figure 2.1b: RUSLE Slope Length

(Adopted from George et al, 2005)
CHAPTER THREE: METHODOLOGY

Determining the intensity, amount and distribution of erosion has a big importance. This is because it helps the environmental management specialist to make an informed decision on the suitable soil and water conservation measures that should be installed in a given area. The Universal Soil Loss Equation (Wischmeier, 1978) or the Revised Soil Loss Equation (Renald et al., 1997) is often used to predict rainfall erosion in landscapes/watersheds using GIS.

3.1 The Study area

River Kapingazi Catchment with an area of 61.23 km$^2$ is part of the larger Upper Tana River Catchment. The River drains into River Rupingazi at the lower parts of Embu Town. It is located in Embu District of Eastern Province, Kenya. Embu district lies on the South Eastern Slopes of Mount Kenya. The District illustrates a typical agro-ecological profile of Windward of Mt. Kenya with Kapingazi River catchment being cold and wet. The geographical location of the study area is as given in figure 3.1.

The elevation of the catchment ranges between 1230m and 2100m above sea level. The average annual Rainfall ranges between 1220mm and 1800mm on the lower and upper part of the catchment respectively. The area is suitable for agriculture. The dominant crops in the catchment include Tea, Coffee, Maize and Beans. The cropping pattern varies along the catchment with tea zone in the upper part of the catchment, transition zone where both coffee and tea are dominant in the middle part of the catchment and Coffee zone on the lower parts of the catchment. In all the zones, subsistence farming is practiced with dominating crops being beans and maize. In addition zero grazing is a major agricultural practice within the catchment.

Further, it was noted that, some ecological factors vary with variation in altitude. For instance, the plant cover and rainfall amount are high in the upper part of the catchment (Tea Zone) but they are low in the lower part of the catchment (coffee zone). The main soil types are Eutric Astosols, Andosols and Nitisols (Louis, 2002).
Figure 3.1: Kapingazi River Catchment
During the field visits, it was found out that some farmers have installed different soil and water conservation practices which include terracing (fanya juu/chini, cut off drains), Grass strips (Nappier Grass) as shown in figure 3.2, Benches (in the coffee farms), Mulching and River bank protection (River pegging through MKEPP).

Figure 3.2a: A Farmer Standing on a Bench Terrace near a Grass Strip which is on a Fanya Chini
Figure 3.2b: A Farmer Standing Near a Maize Stalk Mulch
3.2 Data Processing /Data Preparation

In this study, data processing was undertaken using ArcGIS 9.3 and ILWIS 3.3 Academic. Contour lines and rivers were digitized based on 1:50000 topographic maps (UTM, WGS84 Zone 37S) from the Survey of Kenya. Thereafter a 10m spatial resolution DEM was generated. From the DEM the catchment was delineated using Soil and Water Assessment Tool (SWAT) model.

On the other hand, while determining the R factor, the Rainfall Data provided by Meteorological Department of Kenya for both Irangi and Embu town (KARI) rain gauges was used. In summary figure 3.3 shows the methodology applied so as to achieve the intended objectives.

3.3 Data Analysis

3.3.1 Generation of Kapingazi Drainage System

The drainage system (Rivers) was digitized on screen from the scanned 1:50,000 topographical maps from the survey of Kenya. Before the digitization, the toposheets that were in UTM arc1960 projection were rectified and the projection was changed to UTM WGS84 Zone 37S. This was followed by digitization and editing which culminated to production of river Kapingazi drainage system as appearing in figure 3.4 and figure 3.5. Also area contours were generated.
Figure 3.3: Overall Methodology for generating RUSLEs R and LS Factor

Toposheet from Survey of Kenya

Digitizing

Editing

Rainfall Data from Meteorological Department (Embu) and Farm Management Handbook Kenya (Eastern Province)

Rainfall Map

Fournier Index

Contours

DEM

Rainfall Erosivity Factor (R) Map

Watershed/Catchment Map

Slope Map

Overland Flow Length Map

LS Factor Map

Rivers Layer
3.3.2 Generation of the DEM and the Watershed/Catchment Area

A 10m resolution DEM was generated from the contours digitized from 1:50000 toposheets. This was done in ArcGIS 9.3 and the results are as shown in figure 3.4. The sinks in the resulting DEM were identified and filled. On the other hand the watershed/catchment was delineated from the larger DEM (figure 3.4) using Soil and Water Assessment Tool (SWAT). The Soil and Water Assessment Tool (SWAT) is a physically-based continuous event hydrologic model developed to predict the impact of land management practices on Water sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time. While generating the watershed the DEM together with the rivers layer was used to segment the watershed into ‘hydrologically’ connected sub-watersheds. As an input, the river layer was used to predict the location of the streams because the DEM is unable to accurately predict location of the streams. Inputting a river layer, improved the hydrographic segmentation and watershed boundary delineation for areas where the relief was so low. The results of this process are shown in figure 3.5. The catchment boundary was then used to clip the catchment specific DEM show in Figure 3.4c.
Figure 3.4a: A Larger 10m DEM
From figure 4.4c it is observed that the elevation of the catchment ranges between 1228m and 2115m above sea level.

Figure 3.4b: Kapingazi River Catchment Shown on a DEM viewed in 3D
Figure 3.4c: Kapingazi River Catchment
Figure 3.5: Kapingazi River Watershed/Catchment
3.3.3 Slope Length (L) Factor and Slope Steepness (S) Factor;
The LS factor accounts for the effect of topography on erosion in RUSLE. The slope length factor (L) represents the effect of slope length on erosion, and the slope steepness factor (S) reflects the influence of slope gradient on erosion.

The combined topographic (LS) factor was computed rather than the individual slope length and slope angle factors. The inputs for the computation include the slope angle and the slope length. In this study, the slope length (overland flow length) was generated using Integrated Land and Water Information System (ILWIS 3.3) academic while as the slope angle was generated using ARCGIS 9.3. The process of generating the slope angle, slope length and LS factor is as follows:

- First the sinks in the DEM were identified and filled
- The filled DEM was used as input to determine the Flow Direction;
- The Flow Direction was used as an input grid to derive the Flow Accumulation.
- The flow accumulation was used as an input grid in the Drainage Network Extraction
- The Extracted Drainage Network was in turn used in Drainage Network Ordering
- The Drainage Network Ordering Map was used to derive the Overland Flow Length
- The slope was then derived from the DEM;
- The overland flow length and the slope maps were used as inputs in derivation of LS factor map.

Calculating Flow Direction
To begin with, the Digital Elevation Model (DEM) was generated and processed including filling the sinks. From the sink-free DEM, the Flow direction calculation was undertaken. The operation determines into which neighbouring pixel any water in a central pixel will flow. It is calculated for every central pixel in input blocks of 3 by 3 pixels, each time comparing the value of the central pixel with the value of its 8 neighbouring pixels. The output map contains flow directions as N (to the North), NE (to the North East).

Generating/Calculating Flow Accumulation
The flow direction was used as an input in calculation of the Flow accumulation. The operation performs a cumulative count of the number of pixels that naturally drain into outlets. The operation can be used to find the drainage pattern of a terrain. The output map
contains cumulative hydrologic flow values that represent the number of input pixels which contribute any water to the outlets (or sinks if these have not been removed). Output cells with a high flow accumulation are areas of concentrated flow and can be used to identify stream channels. Output cells with a flow accumulation of zero are local topographic highs and can be used to identify ridges. Figure 3.6 below shows the flow accumulation map for Kapingazi Catchment.

Generating the Drainage Network
The Drainage Network Extraction operation extracts a basic drainage network (Boolean raster map). The output raster map shows the basic drainage as pixels with value True, while other pixels have value false. Since a concentrated flow would normally develop when a slope becomes long and uninterrupted, a slope length limit should represent the scale at which the interill and rill erosion processes occur (Renald K.G. et al., 1997). Accordingly, in calculating the drainage network, a limit in the number of cells draining into a particular cell is assumed, depending on the spatial resolution of the DEM. In this research, the slope length limit is set to 150m which is considered as being upper bound when concentrated flow would generally occur. For a 10m x 10m cell-size grid, the limit in the number of upslope cells draining into a particular cell is set as 400.

Ordering the Drainage Network
The Drainage network ordering operation examines all drainage lines in the drainage network map, finds the nodes where two or more streams meet, and assigns a unique ID to each stream in between these nodes, as well as to the streams that only have a single node. In this operation a minimum drainage length is specified which is the value for the minimum length (m) that a stream should have to remain in the drainage network. By choosing a larger value, fewer streams will remain in the drainage network; this will speed up the operation. In this study 150m was specified.

Calculating the Overland Flow Length
The overland flow length operation calculates for each pixel the overland distance towards the 'nearest' drainage according to the flow paths available in the Flow Direction map. The output map figure 4.1 was used as an input in calculation of the LS factor.
Figure 3.6: Flow Accumulation Map
3.3.4 Slope

The slope component is a major input in the computation of the LS factor. It was derived from the 10m resolution DEM. For better understanding of the terrain, the slope was computed in degrees and percentage. The spatial distribution for the same is shown figure 4.2.

The slope calculated in percentage was then classified into six classes. This was done because slope-gradients in Kenya are grouped into six classes by the Soil Survey of Kenya. Each mapping unit is assigned to one or a combination of up to three slope classes as shown in table 1 (Kassam, 1992) i.e. Agro-ecological land Resources Assessment for agricultural Development Planning - A case Study of Kenya- Technical Annex 2.

<table>
<thead>
<tr>
<th>Class</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 – 2</td>
</tr>
<tr>
<td>AB</td>
<td>0 – 5</td>
</tr>
<tr>
<td>B</td>
<td>2 – 5</td>
</tr>
<tr>
<td>BC</td>
<td>2 – 8</td>
</tr>
<tr>
<td>C</td>
<td>5 – 8</td>
</tr>
<tr>
<td>BCD</td>
<td>2 – 16</td>
</tr>
<tr>
<td>CD</td>
<td>5 – 16</td>
</tr>
<tr>
<td>D</td>
<td>8 – 16</td>
</tr>
<tr>
<td>DE</td>
<td>8 – 30</td>
</tr>
<tr>
<td>E</td>
<td>16 – 30</td>
</tr>
<tr>
<td>EF</td>
<td>16 – 56</td>
</tr>
<tr>
<td>F</td>
<td><em>30 – 56</em></td>
</tr>
</tbody>
</table>

Source: Kassam, 1992: *56% is taken to be the upper limit of slopes in the steepest slope class.
3.3.5 Calculation of the LS Factor

The effect of topographic factors, namely slope length $L$ and percent slope $S$, on erosion was derived from slope length factor $LS$. The equation used to determine this parameter was that recommended by (Morgan and Davidson, 1991) given in Equation 2:

$$LS = \sqrt{\frac{L}{22}} (0.065 + 0.045 \times S + 0.0065 \times S^2)$$  \hspace{1cm} (2)

Where

$L$ = slope length in m

$S$ = percent slope

The map algebra used to implement the above equation was as follows:

$$LS = \text{pow} \left( \left( \frac{L}{22} \right) \times (0.065 + (0.045 \times S) + (0.0065 \times \text{pow} (S, 2))), 0.5 \right)$$  \hspace{1cm} (2b)

3.3.6 Calculation of the Rainfall–Runoff Erosivity Factor

Rainfall Data

The rainfall data used in this study is from two rainfall stations namely Irangi and KARI-Embu Stations. Irangi Rain gauge is located at the upper part of the catchment while as the Embu-KARI rain gauge is located at the lower part of the catchment. In addition, rainfall data from the farm management handbook Kenya for Eastern Province was used while generating the rainfall-elevation relationship. Figure 3.7 shows the annual rainfall data for both Embu-KARI and Irangi Rain gauges for a period of 29 years.
From the above graphs it is observed that the amount of rainfall vary significantly in both rain gauge stations and through out the year. This is a clear indication that the rainfall runoff
erosivity would also vary significantly from the lower part of the catchment to the upper part of the catchment. The R factor would also vary significantly from the wet months to dry months. Also, it is important to note that the rainfall varies with elevation variation. In this study, the rainfall map was generated using rainfall data from different rain stations at different elevations (table 2).

Table 2: Rainfall Data from Different Rain Gauges

<table>
<thead>
<tr>
<th>No.</th>
<th>Altitude (m)</th>
<th>Name</th>
<th>Average Annual Rainfall</th>
<th>MAR = 1.1009x - 315.09</th>
</tr>
</thead>
<tbody>
<tr>
<td>9037176</td>
<td>792</td>
<td>Kindaruma Fisheries</td>
<td>678</td>
<td>557</td>
</tr>
<tr>
<td>9037146</td>
<td>793</td>
<td>Kindaruma Dam site</td>
<td>576</td>
<td>558</td>
</tr>
<tr>
<td>9037161</td>
<td>840</td>
<td>Ishiara</td>
<td>820</td>
<td>610</td>
</tr>
<tr>
<td>9037039</td>
<td>1143</td>
<td>Kiritiri Chiefs Camp</td>
<td>896</td>
<td>943</td>
</tr>
<tr>
<td>9037177</td>
<td>1160</td>
<td>Kalaba Chiefs Office</td>
<td>998</td>
<td>962</td>
</tr>
<tr>
<td>9037135</td>
<td>1189</td>
<td>Kiambere Market</td>
<td>818</td>
<td>994</td>
</tr>
<tr>
<td>9037164</td>
<td>1230</td>
<td>Ena Tobacco Factory</td>
<td>1040</td>
<td>1039</td>
</tr>
<tr>
<td>9037171</td>
<td>1230</td>
<td>Kambo Kamaus Farm</td>
<td>964</td>
<td>1039</td>
</tr>
<tr>
<td>9037172</td>
<td>1230</td>
<td>Kamrumo Polytechnic</td>
<td>930</td>
<td>1039</td>
</tr>
<tr>
<td>9037133</td>
<td>1265</td>
<td>Kanyambora</td>
<td>1149</td>
<td>1078</td>
</tr>
<tr>
<td>9037169</td>
<td>1296</td>
<td>Ngenge Pry School</td>
<td>886</td>
<td>1112</td>
</tr>
<tr>
<td>9037103</td>
<td>1352</td>
<td>Murinduko Exp farm</td>
<td>1030</td>
<td>1173</td>
</tr>
<tr>
<td>9037008</td>
<td>1433</td>
<td>Embu District Office (-77)</td>
<td>1065</td>
<td>1262</td>
</tr>
<tr>
<td>9037140</td>
<td>1476</td>
<td>Embu Njukiini Forest Station</td>
<td>1229</td>
<td>1310</td>
</tr>
<tr>
<td>9037122</td>
<td>1478</td>
<td>Runyenjes Dos Office</td>
<td>1395</td>
<td>1312</td>
</tr>
<tr>
<td>9037050</td>
<td>1494</td>
<td>Embu Prov.Agr. Tr. College(-80)</td>
<td>1230</td>
<td>1330</td>
</tr>
<tr>
<td>9037144</td>
<td>1500</td>
<td>Kyeni Girls Sec School</td>
<td>1612</td>
<td>1336</td>
</tr>
<tr>
<td>9037202</td>
<td>1508</td>
<td>Embu Met Station</td>
<td>1232</td>
<td>1345</td>
</tr>
<tr>
<td>9037053</td>
<td>1524</td>
<td>Kevote Pry. School (-80)</td>
<td>1561</td>
<td>1363</td>
</tr>
<tr>
<td>9037134</td>
<td>1650</td>
<td>Kairuri Ngandori Loc</td>
<td>1677</td>
<td>1501</td>
</tr>
<tr>
<td>9037077</td>
<td>1936</td>
<td>Embu Forest Station</td>
<td>1894</td>
<td>1816</td>
</tr>
</tbody>
</table>

This data was used to come up with a catchment specific rainfall and elevation relationship as shown in figure 3.7c and equation 3

\[ Y = 1.1009x - 315.09 \text{mm} \]  \hspace{1cm} (3)

Where

\( Y \) is the precipitation (MAR) in mm and \( x \) is the elevation in meters of the point where the rainfall data is being determined.

Rainfall Vs Elevation

\[ y = 1.1009x - 315.09 \]

\[ R^2 = 0.8216 \]

The DEM was used as an input while generating the rainfall map with each grid value being the elevation for each pixel. The result of this operation was a rainfall map shown in figure 3.8 below. Thereafter the R factor map was generated.
Figure 3.8: Rainfall Data Map
Models

The Rainfall erosivity factor $R$ is often determined from rainfall intensity if such data are available. In majority of cases rainfall intensity data are very rare. As such, if there is no station with rainfall intensity data, the $R$ factor is determined using mean annual rainfall. In addition the Rainfall-Runoff erosivity (R) can be defined as an aggregate measure of the amounts and intensities of individual rain storms over the year. It is related to total rainfall (Hudson 1981; Wenner 1981). The need for very specific data often makes the calculation of R according to its definition impossible and has resulted to derivation of simplified methods. These are based either on the total annual precipitation $P$ or Fournier Index $F$ (Anoldus 1980).

Fournier Index is calculated using the following equation:

$$ F = \sum_{j=1}^{12} \frac{P_j^2}{P} $$

(4)

Where $P_j$ is the monthly precipitation for month $j$

In this study the $F$ values were calculated for both Irangi and Embu-KARI rain stations and the values are as follows;

- Irangi Forest rain station $F = 240.8$
- Embu-KARI rain station $F = 195.9$

In order to distribute the values spatially, a relationship between $F$ and elevation was derived. This relationship was used for interpolating the $F$ values across the catchment. The derived equation is shown below:

$$ 0.1051z + 37.35 = F $$

(5)

Where $z$ is the elevation at the point of interest

Different authors have proposed different ways to retrieve $R$ from $P$ or $F$. Each method is optimized for a certain location and there is as usual, no guarantee that it would work if applied elsewhere. To circuit this problem, several but tested relationships were used and the resulting rainfall runoff erosivity indexes averaged. To determine the suitable equations that could be used at Kapingazi catchment, nine equations given in table 3 were tested based on
the R factors (table 4) given by (Kassam, 1992) ie Agro-Ecological Land Resources Assessment for Agricultural Development Planning A Case Study of Kenya Resources Data Base And Land Productivity. Table 3 shows these equations and the reference where they can be found.

**Table 3: R factor models**

<table>
<thead>
<tr>
<th>Case</th>
<th>Reference</th>
<th>R and P or F Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case I</td>
<td>Arnoldous – linear, 1980</td>
<td>( R = \frac{4.17F-152}{17.02} )</td>
</tr>
<tr>
<td>Case II</td>
<td>Arnoldous (1980)</td>
<td>( R = 4.17F - 152 )</td>
</tr>
<tr>
<td>Case III</td>
<td>YU &amp; Rosewell, 1996</td>
<td>( R = 3.82 F^{1.41} )</td>
</tr>
<tr>
<td>Case IV</td>
<td>Arnoldus – Exponential, 1977</td>
<td>( R = 0.302 F^{1.93} )</td>
</tr>
<tr>
<td>Case V</td>
<td>Renald &amp; Freimun – F, 1994</td>
<td>( R = 0.739F^{1.847} )</td>
</tr>
<tr>
<td>Case VI</td>
<td>Renald &amp; Freimun – P, 1994</td>
<td>( R = 0.0483P^{1.61} )</td>
</tr>
<tr>
<td>Case VII</td>
<td>Roose in Morgan and Davidson (1991)</td>
<td>( R = P \times 0.5 )</td>
</tr>
<tr>
<td>Case VIII</td>
<td>Kassam et al.,1992</td>
<td>( R = 117.6 \times (1.00105^{MAR}) ) for (&lt; 2000\text{mm} )</td>
</tr>
<tr>
<td>Case IX</td>
<td>Singh et al., 1981</td>
<td>( R_{\text{factor}} = 79 + 0.363R )</td>
</tr>
</tbody>
</table>

Where

- \( R \) = rainfall erosivity factor (MJ/ha.mm/h)
- \( \text{MAR} \) = mean annual rainfall (mm)
- \( F \) = Fournier index
- \( P \): Mean Annual Precipitation (mm)
### Table 4  
**Relationships between the Mean Annual Rainfall (MAR) and Rainfall Erosivity (R) Given by Kassam et al., 1992**

<table>
<thead>
<tr>
<th>MAR (mm)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>140</td>
</tr>
<tr>
<td>212</td>
<td>146</td>
</tr>
<tr>
<td>256</td>
<td>153</td>
</tr>
<tr>
<td>302</td>
<td>161</td>
</tr>
<tr>
<td>350</td>
<td>170</td>
</tr>
<tr>
<td>400</td>
<td>179</td>
</tr>
<tr>
<td>453</td>
<td>189</td>
</tr>
<tr>
<td>508</td>
<td>200</td>
</tr>
<tr>
<td>566</td>
<td>213</td>
</tr>
<tr>
<td>628</td>
<td>227</td>
</tr>
<tr>
<td>692</td>
<td>243</td>
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<tr>
<td>761</td>
<td>261</td>
</tr>
<tr>
<td>835</td>
<td>282</td>
</tr>
<tr>
<td>913</td>
<td>307</td>
</tr>
<tr>
<td>998</td>
<td>335</td>
</tr>
<tr>
<td>1089</td>
<td>369</td>
</tr>
<tr>
<td>1189</td>
<td>409</td>
</tr>
<tr>
<td>1298</td>
<td>459</td>
</tr>
<tr>
<td>1419</td>
<td>522</td>
</tr>
<tr>
<td>1557</td>
<td>602</td>
</tr>
<tr>
<td>1711</td>
<td>708</td>
</tr>
<tr>
<td>1892</td>
<td>856</td>
</tr>
<tr>
<td>2108</td>
<td>1054</td>
</tr>
<tr>
<td>2376</td>
<td>1,188</td>
</tr>
<tr>
<td>2729</td>
<td>1,364</td>
</tr>
<tr>
<td>2878</td>
<td>1,439</td>
</tr>
</tbody>
</table>

Source: Kassam et al., 1992
After testing the equations, some of the resulting R factors were found to be close to the values given by (Kassam, 1992) and as shown in table 4. Other models gave too high R values and others gave too low values and hence they were not considered for calculation of the R factor. As a result, the equations (table 5) that gave results that were within the range of the values given for Kenya by (Kassan, 1992) were used to determine the R factor for Kapingazi Catchment:

**Table 5  Selected R factor Models**

<table>
<thead>
<tr>
<th>Case</th>
<th>Reference</th>
<th>Equation</th>
<th>R-Irangi</th>
<th>R-KARI-Embu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case II</td>
<td>(Arnoldous, 1980)</td>
<td>( R = 4.17 \text{MF1} - 152 )</td>
<td>852</td>
<td>665</td>
</tr>
<tr>
<td>Case VII</td>
<td>(Roos in Morgan and Davidson, 1991)</td>
<td>( R = \text{P} \times 0.5 )</td>
<td>941</td>
<td>637</td>
</tr>
<tr>
<td>Case VIII</td>
<td>(Kassan, et al., 1992)</td>
<td>( R = 117.6 (1.00105^{\text{MAR}}) ) for (&lt; 2000 \text{mm} )</td>
<td>848</td>
<td>448</td>
</tr>
<tr>
<td>Case IX</td>
<td>(Singh et al., 1981)</td>
<td>( R_{\text{factor}} = 79 + 0.363R )</td>
<td>762</td>
<td>542</td>
</tr>
</tbody>
</table>

Case VII was applied in estimation of potential soil erosion for River Perkerra Catchment in Kenya (Onyando et al., 2004). Onyando reported that the computed values of \( R \) were found to be in agreement with those recommended by (Wenner, 1981) for different agro-climatic zones in Kenya. Further Case IX equation was applied in India in estimation of soil erosion for a Himalayan watershed using GIS technique (Sanjay et al., 2001).
CHAPTER FOUR: RESULTS AND DISCUSSIONS

In this chapter, the results of the operations discussed in chapter three have been discussed.

4.1 LS Factor

4.1.2 The Overland Flow Length

From the resulting overland flow length map, some pixels were assigned zero value. This is because, a cell is considered a channel when the slope length equals zero. The channels collect the flow from numerous rills and they are generally considered to be slope-ending concentrated flow channels. Figure 4.1 shows overland flow length map.

![Overland Flow Length Histogram](image)

Figure 4.1a: Overland Flow Length Histogram

From these results it can be deduced that the dominant overland flow length ranges between 0 and 600m. This is by the fact that there are very few pixels with values that are greater than 600m as is evident from the histogram. The minimum value is zero and the maximum overland flow length is 1,431m as shown on figure 4.1. The mean value is 178m with a standard deviation of 131.
Figure 4.1b: Kapingazi Overland Flow Length Map

Legend
- Towns
- Overland Flow length
  - 0
  - 1 - 150
  - 151 - 300
  - 301 - 450
  - 451 - 600
  - 601 - 1,431

Embu
Kithunguri
Kaiyungoa
Kavutiri
Kianjokom
Manyatta
Irangi Forest District Office
4.1.2 Slope

The slope map were presented in both degrees and percentage. The slope map in percentage was classified into six classes as shown in table 5 and figure 4.2b.

Table 6 Six Slope Classes Used for Mapping

<table>
<thead>
<tr>
<th>Class</th>
<th>%</th>
<th>Gentlest</th>
<th>Lower</th>
<th>Upper</th>
<th>Steepest</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0–2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>2–5</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>5–8</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>D</td>
<td>8–16</td>
<td>8</td>
<td>11</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>E</td>
<td>16–30</td>
<td>16</td>
<td>21</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>F</td>
<td>&gt;30</td>
<td>30</td>
<td>39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From figure 4.2a below it was observed that the slope Ranges from 0° to 88°. Further, from figure 4.2b and figure 4.2c it was deduced that the minimum slope in the catchment is 0% while as the maximum value is 2676%. However, it is evident from the histogram that a large area exhibit slopes of between 0% and 250%. In addition the analysis showed that the mean percentage slope is 49% with a standard deviation of 135
Figure 4.2a: Slope Map in Degrees

Legend
- **Towns**
- **Slope in Degree Value**
  - High: 88
  - Low: 0
Figure 4.2b: Slope Classes Map
4.1.3 LS Factor

The LS factor was generated by running equation 2 in ARCGIS. The spatial distribution of the same is as shown in figure 4.3.

Figure 4.2c: Slopes Histogram

Figure 4.3a: LS Factor Histogram
Figure 4.3b: LS Factor

Legend

LS Factor

- 0
- 0.1 - 1.7
- 1.8 - 3.3
- 3.4 - 8
- 8.1 - 395.8

Kilometers
From figure 4.3 it was observed that the minimum value of LS is 0 and the maximum value is 395.8. However, it is also evident from the histogram that a larger area has LS values raging from 0 to 50. From figure 4.3b it is clear that LS values greater than the mean occur along the valleys with steep slopes. In addition, the analysis revealed that the mean LS factor is 8 with a standard deviation of 15.2.

4.2 Rainfall Runoff Erosivity Factor (R)

The rainfall erosivity was generated using the models discussed in chapter three. The spatial distribution of this factor is as shown in Figure 4.4

The results showed that in Kapingazi River catchment the R value ranges between 492 and 857 MJ/ha.mm/h with the highest values being in the upper part of the catchment and the lower values in the lower part of the catchment.
Figure 4.4: R factor Map
4.3 Soil Erosion Risk Assessment

As discussed earlier, RUSLE is the preferred model for assessing soil erosion risk for Kapingazi River Catchment. As such, in order to establish how topography affects soils erosion, a preliminary soil erosion risk assessment was undertaken by running RUSLE model in ARCGIS. The important factors for this model are as described in chapter two in equation 1. In section 4.1 and 4.2 of this report, factors LS and R have been discussed. According to (Mokua, 2009) the spatial distribution of the combination of KCP factors is as shown in figure 4.6b. All these factors were combined and the results are as shown in figure 4.6a and figure 4.6c.

From the results shown in figure 4.6 it can be deduced that the minimum average annual soil loss is 0 tons/acre and the maximum value is 449 tons/acre with zero erosion occurring along the channels. On the other hand the highest soil loss was found to occur along the river banks with steep slopes. However, it is evident from the histogram that large area of the catchment experiences average annual soil loss of less than 40 tons/acre. The mean value is 5 tons/acre with a standard deviation of 13.

![Figure 4.5a: Erosion Histogram](image)

No. of Pixels per class

Average Annual Soil Loss (tons/acre)
Figure 4.5b: Combination of KCP Factors
Figure 4.5a: Erosion Risk Map
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

The overall objective of this study was to use GIS techniques to determine the RUSLE’s rainfall – runoff erosivity (R) factor and the slope length/steepness (LS) factor. In order to achieve this objective the study was therefore designed with four specific objectives including: first to generate a map of the catchment area followed by generation of a Digital Elevation Model (DEM) of the same area. The other specific objective was to use the DEM to generate the slope length and slope maps for Kapingazi River catchment and finally to generate maps of themes that are important to soil erosion in Kapingazi catchment including rainfall-runoff erosivity (R) and slope length/steepness factor LS and to establish the effects of the same especially topography on soil erosion.

5.1: Conclusions

GIS techniques were successfully used to determine some of the soil erosion factors including rainfall runoff erosivity (R) and slope length/steepness factor (LS). Consequently, thematic maps of these parameters and the estimated potential soil erosion were determined. With this information, management interventions can be precisely focused and priority given to areas with severe erosion along River Kapingazi Catchment. In general, it is clear from the results of this study that Revised USLE coupled with GIS is a powerful model for the qualitative as well as quantitative assessment of soil erosion risk for the conservation management.

The factors were calculated using the local data that was collected specifically for Kapingazi River Catchment. The R value ranges between 492 and 857 MJ/ha.mm/h with the highest values in the upper part of the catchment and the lower values in the lower part of the catchment. Slopes in the catchment varied between 0 and 88° or 0 and 2,676% with steeper slopes having higher values of LS of more than mean. The mean LS factor is 8 with a standard deviation of 15.2. The minimum value is 0 and the maximum value is 395.8.

The results indicate that the average annual soil loss within the catchment ranges from 0 to 449 tons/acre with Zero erosion occurring along the channels. On the other hand the highest soil loss was found to occur along the river banks with steep slopes.
5.2 Recommendations
Based on the results of this study, it is recommended that ground survey be undertaken on areas showing high risk of soil erosion and depending on the outcome of the survey immediate action should be taken to curb acceleration of the soil degradation.

It is important to note that the steepest slopes show high risk of soil erosion, it is therefore recommended that further study be undertaken to establish the suitable soil and water conservation measures that should be implemented in these areas as well as the whole catchment.
References


5. George R. Foster, 2005, Revised Universal Soil Loss Equation Version 2 (RUSLE2)


19. Singh Gurmel, Ram Babu, Subash Chandra (1981), Soil loss prediction research inIndia,


