Kenya's Water Towers Protection and Climate Change Mitigation and Adaptation (WaTER) Programme

Component 4: Science to Inform Design of Community-Level Actions and Policy Decisions

Assessing Erosion, Sedimentation and Pollution in Mt. Elgon and Cherangany Ecosystems

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Table of Contents

List of Figures

List of Tables

List of Pictures

Disclaimer

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We also appreciate the contributions made by the communities of Mt. Elgon and Cherangany Sub-counties for their cooperation during Focus group discussions and Participatory mapping.

Affirmation

We affirm that this baseline survey report consists of the findings of the study that was undertaken through gathering information on the baseline on energy sources in the counties of Bungoma, West Pokot, Elgeyo Marakwet, Trans-Nzoia, Busia and Uasin Gishu which is among the eleven counties in which the project is being implemented.

The development of this report has been guided by the Terms of Reference, provided by KEFRI and contributions of individuals and community through key informant interviews, focus group discussions and Participatory mapping during the study.

This Baseline Survey Report remains the property of KEFRI. Information and data collected must be used only with their consent.

Recommendations

The findings of the study showed that Mt. Elgon and Cherangany Hills are under continuous LULC dynamics and the two ecosystems are prone to soil erosion. The model showed the erosion risk areas of the two ecosystems and the factors which affect soil erosion. During the validation of the erosion results, ground truthing activity together with PGIS approach was emplyed. From the PGIS activity, ththe findings and minimize the gap between the stakeholders' and scientists' understanding. Therefore, stakeholders, responsible bodies, including land managers and others, who have interest in related issues, should incorporate it during land use planning, soil and water resource conservation and management practices. As a result, the following recommendations are made for sustainable land use management, agricultural production and soil erosion management within Mt. Elgon and Cherangany ecosystems:

Land degradation in the steeper slopes is severe which needs urgent land rehabilitation intervention such as forestation programs, terracing and other remedial solutions.

Soil erosion is a potential problem, mainly because of the mountainous nature and high mean annual rainfall, which exposes the soil as a whole and renders it susceptible to erosion. Basically, man cannot modify rainfall erosivity and soil erodibility factors. However, as the slope gradient and slope length factor is dominant in the magnitude of potential soil erosion in the area, it is possible to modify them through soil conservation practices at a small scale on agricultural land using detailed field assessment.

Creating awareness among the communities concerning optimum use of natural resources, conservation systems, driving forces including population pressure and their respective benefits is vital for sustainable land resource management. Therefore, the local managers and responsible sectors in Mt. Elgon and Cherangany should emphasize the importance of participation of the local communities in conservation activities and decision making regarding land use within the ecosystems.

1 CHAPTER ONE: INTRODUCTION

1.1 Introduction

Soil erosion is a complex and dynamic process by which the productive soil surface is detached, transported, and accumulated at downstream places. According to Fistikoglu and Harmancioglu (2002), Soil erosion is major threats to ecosystem functioning in the tropics and is a highly significant spatio-temporal phenomena in many countries. It produces exposed subsurface where the soil has been detached and the detached deposited in low-lying areas of the landscape or in water bodies downstream in a process known as sedimentation. Some of the most agreeable causes of soil erosion include cultivation on steep slopes and fragile soils with inadequate investments in soil conservation or vegetation cover, erratic and erosive rainfall patterns, declining use of fallow, limited recycling of dung and crop residues in the soil, limited application of external sources of plant nutrients, deforestation and overgrazing.

The negative impacts include removal of nutrient rich topsoil in upland areas and subsequent reduction of agricultural productivity in those areas. In irrigation projects, soil erosionand
sedimentation cause reduction of irrigation conveyance capacities and reservoir storage volumes. They also reduce irrigation water quality by increasing water turbidity. In the lowlands, deposition of soil from eroded uplands causes change in river channels and subsequent increase in flood vulnerability of the floodplain farmlands and residential areas. Underlying these proximate causes include population pressure, poverty, high cost and limited access to agricultural inputs and credit, low profitability of agricultural products and many conservation practices, high risks facing farmers, fragmented land holdings and insecure land tenure, short time horizons of farmers, and farmers' lack of information about appropriate alternative technologies (FAO-SWALIM, 2009).

Soil erosion and sedimentation is not also always a negative environmental process. Whenever soil erosion occurs, there may be downstream benefits such as deposition of rich sediments for promotion of agricultural activities. Examples include Nile basin irrigation systems in Egypt, Ahero Irrigation scheme, Budalangi flood plain which produces maize, etc.

Erosion, whether by water, wind or tillage, involves three distinct actions-soil detachment, transportation and deposition. Topsoil, which is high in organic matter, fertility and soil life, is relocated elsewhere "on-site" where it builds up over time or is carried “off-site” filling in drainage channels. Apart from reduction in plant nutrients, soil loss also results in siltation and deposition in streams, wetlands and lakes. Soil erosion can be a slow process that continues relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil. Soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinization and soil acidity problems are other serious soil degradation conditions that can accelerate soil erosion process. Soil erosionis generally associated with agricultural practices and land cover disturbance in tropical and semi-arid countries, leads to decline in soil fertility, bringing on a series of negative impacts and environmental problems, and has become a threat to water quality and sustainable agricultural production in many regions of the world (FAO-SWALIM, 2009).

In Kenya, Mt. Elgon and Cherangany Hills ecosystems are some of the major Water towers, sources of many rivers both in Kenya and Uganda, supplying irrigation water for many agricultural activities in the region. However, over many years and more specifically in the last 20 years, there has been steady decline in water quality and increase in sediment load resulting to high water turbidity. This has negatively affected downstream community through decline in fish species, algal growth as a result of agricultural activity and upland erosion in these two ecosystems. Generally, upland areas with high soil erosion rates tend to contribute more sediment compared to areas with low soil erosion rates.

In order to reduce the sediment plume from Mt. Elgon and Cherangany Hills ecosystems, contributing areas with high soil erosion rates need to be identified and targeted for soil erosion control measures. Many Kenya development partners are currently putting special attention towards reducing soil and forest degradation, rehabilitating of degraded ecosystems as a way of reducing carbon emission hence contributing to climate change mitigation and adaptation. The aim of this activity therefore is to assess soil erosion status, sedimentation and pollution within Cherangany and Mt. Elgon Ecosystems to inform the rehabilitatin.

2 CHAPTER TWO: METHODOLOGY

2.1 Study area

This study is based in two water tower ecosystems, Mount Elgon and Cherangany.

2.1.1 Mt. Elgon

Mt. Elgon's forest ecosystem covers an area of 236,505ha to the Kenyan side and overlaps with Trans-Nzoia and Bungoma counties (KWS 2011). It was gazetted in 1932 (Ongugo et al, 2001) and receives maximum rainfall, designating it as one of the Kenya's five "water towers" (Synnot, 1968), supporting a huge population (van Heist, 1994). It holds a high percentage of forest resources, crucial to local community' livelihoods (van Heist, 1994). Major products contributing to socio-economy are firewood, poles or timber, vines, water and fodder (Scott, 1994). In addition, Mt. Elgon hosts the headwaters of the Nzoia River which provides hydrological services to a range of economic sectors including irrigated agriculture with an estimated watershed population of over 1.5 in Kenya's Western region, but when excessive also threatens the lives and livelihoods of thousands of people due to flooding. Since the early 1990s, forested ecosystems in Africa registered mass degradations amounting to high values (FAO 2010). Mt. Elgon's forest ecosystem has experienced loss in terms of vegetation diversity and density attributed primarily to a combination of encroachment by local communities and large illegally allocated logging concessions (Nield et al, 1999). The recent year's pattern of climate variability and increased frequency and severity of extreme events, such as landslides and flooding are creating additional pressures on local communities, increasing their reliance on forests as part of their climate coping strategies.

2.1.2 Cherangany Ecosystem

On the other hand, Cherangany Hills forest ecosystem is spatially defined by 35^{o} 26'' East and 1^{0}16'' North at an altitude range of 2000-3365m above sea level (CHFESp 2015). It's comprised of a number of forest blocks (12), cutting across three counties, Trans-Nzoia, Elgeyo Marakwet and West Pokot, on the Western ridge of the Great Rift Valley. It covers an area of 120,000 ha, forming the upper catchment of Nzoia, Kerio and Turkwel rivers (KFWG & DRSRS 2004). The watershed not only underpins livelihoods of communities within Lakes Victoria and Turkana Basins, but stretches its significance to national and global capacity. However, this ecosystem has never been an exemption to anthropogenic disturbances of land use pressure, demographic characteristics and even climate change (Cherangani Hills Forest Ecosystem Strategic Management plan 2015). The least affected forests are those on the Cherangani hills with only 174.3 hectares deforested. However this loss is occurring in indigenous forest cover (KFWG & DRSRS 2004).

The project intervention area covers eleven (11) counties. However, biophysical analysis was conducted on generated catchment maps based on upper ridges of the rivers for both Mount Elgon and Cherangany ecosystems where most of the land use land cover tranformation have occurred. In addition, the upper ridges of the ecosystems is experiencing intensive farming with high rainfall. The catchment maps are as shown in figures 1 and 2.

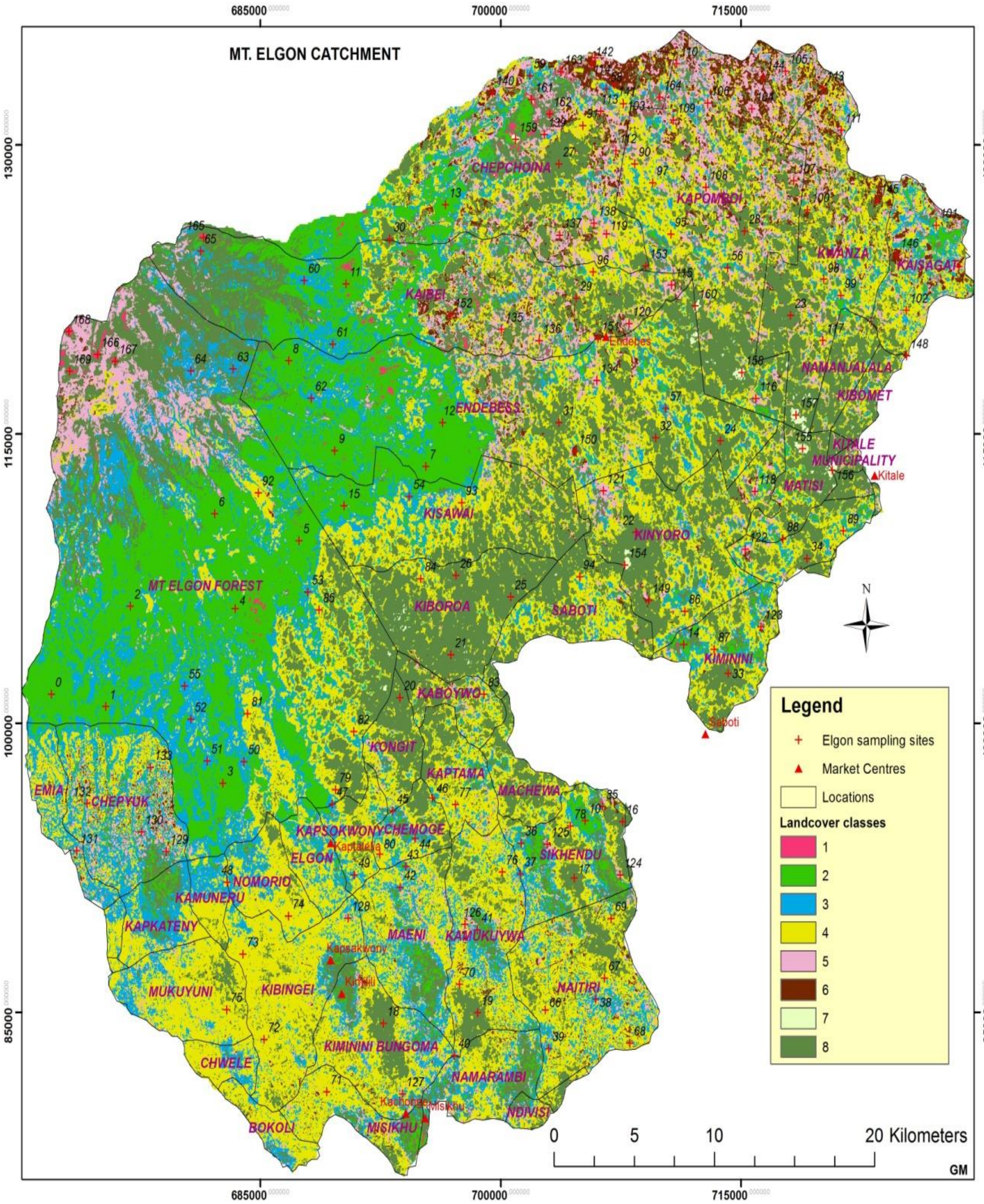


Figure 1: Elgon Catchment

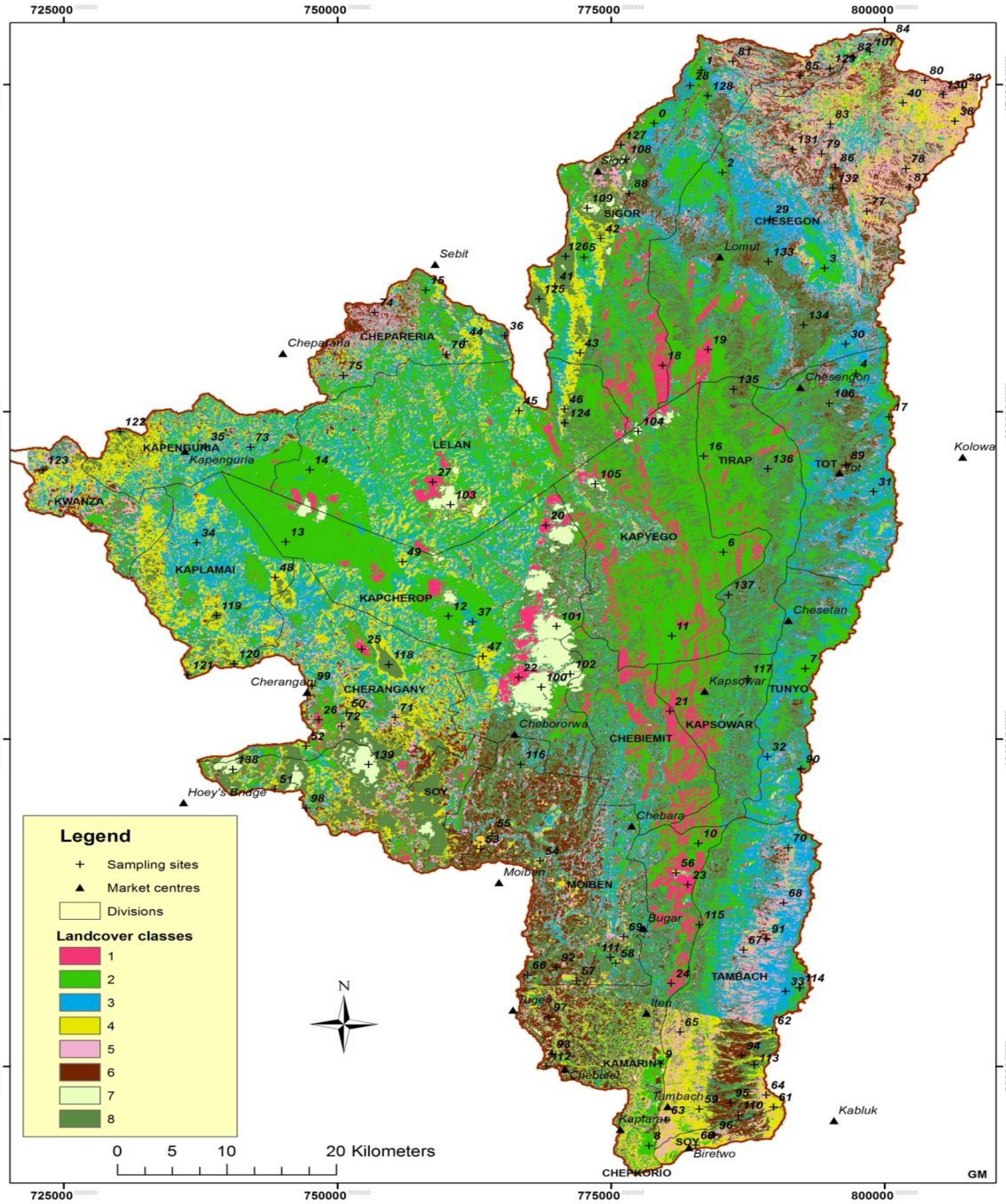


Figure 2: Cherangany Catchment Map

2.2 Terms associated with soil erosion and sedimentation

2.2.1 Soil erosion

It is a complex process which involves detachment, transportation, and deposition of soil particles from one place to another under the influence of wind, water or gravitational forces. In broad sense, soil erosion process can be classified into two categories: geologic and accelerated erosion. Geologic erosion refers to the simultaneous formation and loss of soil which maintain the balance between soil forming processes and soil loss. It is a natural process. Accelerated erosion includes deterioration and loss of soil by human activities. It is called “accelerated” because it speeds up the geologic soil erosion; thus upsetting the balance between soil forming processes and soil loss (FAO-SWALIM, 2009). Accelerated soil erosion occurs in various forms (e.g. splash, sheet, rill, and gullies) depending on the stage of progress in the erosion cycle and the position in the landscape. Some types of accelerated erosion may be used to refer to where the erosion process occurs (e.g. trail erosion, riverbank/riverbed erosion, road slope erosion, cropland erosion).

According to Foster, G.R., (1982) and Saavedra, C. (2005), the main factors influencing soil erosion include climate (rainfall/precipitation or wind), landscape relief, soil and bedrock properties, vegetation cover, and human activity. Of these factors, the climate has been used to further define other forms of soil erosion such as erosion by wind, raindrop, wind etc. Erosion by rainfall is induced by when raindrops strike the surface and overcome the forces holding soil particle together. This is commonly referred to as “rain splash” or “raindrop splash” (Thornes, J.B. 1990). As the rainfall process continue, water infiltrates into the soil at a rate controlled by the intensity of the water hitting the surface and the infiltration capacity of the vertical soil profile. Water that does not infiltrate begins to pond on the surface and then flows along the steepest descent after achieving a sufficient ponding depth.

2.2.2 Sedimentation

The soil materials suspended in water or air is known as sediment. The main sources of sediments are soil erosion of upland areas or river channel, mass movement due to landslides, soil creeps etc, and from mining or dumps lefts as waste material. In Kenya, farming activities in major water towers without proper soil management measures contributes soil erosion which is a major source of sediments into rivers. Sediment transport is a direct function of water or wind movement. With respect to water movement in a river, during sediment transport, sediment particles become separated into three categories: suspended material which includes silt + clay + sand; the coarser, relatively inactive bedload and the saltation load.

Suspended load comprises sand + silt + clay-sized particles that are held in suspension because of the turbulence of the water. The suspended load is further divided into the wash load

which is generally considered to be the silt + clay-sized material (< 62 µm in particle diameter) and is often referred to as “fine-grained sediment”. The wash load is mainly controlled by the supply of this material (usually by means of erosion). The amount of sand (>62 µm in particle size) in the suspended load is directly proportional to the turbulence and mainly originates from erosion of the bed and banks of the river. In many rivers, suspended sediment (i.e. the mineral fraction) forms most of the transported load (FAO?-SWALIM, 2009).

Bedload is stony material, such as gravel and cobbles that moves by rolling along the bed of a river because it is too heavy to be lifted into suspension by the current of the river (FA0-SWALIM, 2009). Bedload is especially important during periods of extremely high discharge and in landscapes of large topographical relief, where the river gradient is steep (such as in mountains).

Saltation load is a term used to describe material that is transitional between bedload and suspended load. Saltation means “bouncing” and refers to particles that are light enough to be picked off the river bed by turbulence but too heavy to remain in suspension and, therefore, sink back to the river bed. Saltation load is never measured in operational hydrology (Lu, X. and Higgitt, D.L. 2001). Sediment transport is facilitated when there is sufficient energy to carry the sediments. The mass rate of transport is known as “sediment discharge”. If at any point during the transport the velocity of the water is reduced, some sediment will be deposited. The process is known as sedimentation. Sediment yield is the amount of eroded soil that is delivered to a point in the catchment (Saavedra, C. 2005).

2.2.3 Soil erosion modeling and sediment flux

Soil erosion and sediment yield can be directly measured in the field. The methods include runoff plots, the use of erosion pins, shrub-mounds, pedestals etc for soil erosion and measurement of sediment quantity in reservoirs, sediment concentration in rivers, etc for sedimentation processes. These direct measurements are reliable for determining soil erosion or sedimentation at a specific point in the landscape. However, they do not give much needed information on spatial distribution of sources of sediments and often integral of many complex phenomena in the landscape. In order to circumvent the problems of direct measurements, many researchers preferred combined application of direct measurements, modeling and the integration of selected model in a GIS framework, which has proved to be accurate at spatial scale. In soil erosion, various models have developed by many researchers worldwide.

2.2.4 Pollution

Pollution can be defined introduction of contaminants into the environment into the natural environment that causes adverse change. The change can be harmful or uncomfortable to organisms in the environment. Contaminants can take the form of gaseous, liquid or solid form and can be natural or man-made. Pollution is often a consequence of human activities that are accelerated in such a way that the naturally existing systems are unable to cope with the changes taking place.

2.2.5 **Participatory Mapping**

Participatory mapping - also called community-based mapping - is a general term used to define a set of approaches and techniques that combines the tools of modern cartography with participatory methods to represent the spatial knowledge of local communities. It is based on the premise that local inhabitants possess expert knowledge of their local environments which can be expressed in a geographical framework which is easily understandable and universally recognised. Participatory maps often represent a socially or culturally distinct understanding of landscape and include information that is excluded from mainstream or official maps. Maps created by local communities represent the place in which they live, showing those elements that communities themselves perceive as important such as customary land boundaries, traditional natural resource management practices, sacred areas, and so on.

2.3 Participatory Soil Erosion Mapping

2.3.1 Introduction to Participatory Mapping

Since the 1970s, development efforts have sought to support and promote community engagement in decision-making through the creation and use of diverse participatory methodologies that gather, analyse and communicate community information. These methods are incorporated into broader development models which have matured from the extractive Rapid Rural Appraisal (RRA) through Participatory Rural Appraisal (PRA), culminating in Participatory Learning and Action (PLA). These are commonly understood as a "growing family of approaches, methods, attitudes and beliefs that enable people to express and analyse the realities of their lives and conditions, to plan themselves what action to take and to monitor and evaluate the results" (Chambers, 1997, p. 102).

Of all the participatory development methods that have been adopted, adapted and applied in a development context, it is "participatory mapping that has been the most widespread" (Chambers, 2006, p.1).

There are a rapidly growing number of participatory mapping initiatives throughout the world. These initiatives are often referred to using different terms including participatory mapping, indigenous mapping, counter mapping and community mapping. Though there are differences among initiatives in their methods, applications and uses, the common theme linking them is that the process of map-making is undertaken by a group of non-experts who are associated with one another based on a shared interest. For the sake of simplicity, this report will refer to these different mapping types generically as participatory mapping.

Participatory mapping is a map-making process that attempts to make visible the association between land and local communities by using the commonly understood and recognized language of cartography.

As with any type of maps, participatory maps present spatial information at various scales. They can depict detailed information of village layout and infrastructure (e.g. rivers, roads, transport or the location of individual houses). They can also be used to depict a large area (e.g. the full extent of a community's traditional use areas, including information related to natural resource distribution and territorial boundaries). Indigenous peoples, forest dwellers and pastoralists often inhabit large areas that until recently have been considered marginal; however, these areas are increasingly being valued for the resources that they contain. Participatory maps are not confined to simply presenting geographic feature information; they can also illustrate important social, cultural and historical knowledge including, for example, information related to land-use occupancy and mythology, demography, ethno-linguistic groups, health patterns and wealth distributions.

Participatory mapping projects have proliferated throughout the world over the past 20 years, from Southeast Asia (i.e. Indonesia and the Philippines) through Central Asia, Africa, Europe, North, South and Central America to Australasia. Many different types of communities have undertaken mapping projects, ranging from relatively prosperous urban groups in northern Europe and America to forest- dwelling indigenous groups in the tropics.

Participatory maps often represent a socially or culturally distinct understanding of landscape and include information that is excluded from mainstream maps, which usually represent the views of the dominant sectors of society. This type of map can pose alternatives to the languages and images of the existing power structures and become a medium of empowerment by allowing local communities to represent themselves spatially. Participatory maps often differ considerably from mainstream maps in content, appearance and methodology.

2.3.2 Criteria used to recognize and denote community maps

Criteria used to recognize and denote community maps include the following:

Participatory mapping is defined by the process of production. Participatory maps are planned around a common goal and strategy for use and are often made with input from an entire community in an open and inclusive process. The higher the level of participation by all members of the community, the more beneficial the outcome because the final map will reflect the collective experience of the group producing the map.

Participatory mapping is defined by a product that represents the agenda of the community. It is map production undertaken by communities to show information that is relevant and important to their needs and is for their use.

Participatory mapping is defined by the content of the maps which depicts local knowledge and information. The maps contain a community's place names, symbols, scales and priority features and represent local knowledge systems.

Participatory mapping is not defined by the level of compliance with formal cartographic conventions. Participatory maps are not confined by formal media; a community map may be a drawing in the sand or may be incorporated into a sophisticated computer-based GIS. Whereas regular maps seek conformity, community maps embrace diversity in presentation and content. That said, to be useful for outside groups, such as state authorities, the closer the maps follow recognized cartographic conventions, the greater the likelihood that they will be seen as effective communication tools.

2.3.3 Application of Participatory mapping to Mt. Elgon and Cherangany community

Although there are many reasons why a community might engage in a participatory mapping process, this soil erosion, sedimentation and pollution activity identified six broad purposes for initiating a participatory mapping activity during field work as:

- To help communities articulate and communicate spatial knowledge of soil erosion, sedimentation and pollution within Mt. Elgon and Cherangany ecosystems to external agencies

Participatory maps have proved to be an effective, legitimate and convincing media to demonstrate to external agencies how a community values, their understanding of soil erosion and sedimentation and interacts with its traditional lands and immediate space. Maps present complex information in a well understood and easily accessible format. This enables groups with language and cultural barriers and differences in land- related values and world views to easily communicate and understand the information presented.

- To allow communities to record and archive local knowledge of erosion and sedimentation within Mt. Elgon and Cherangany ecosystem

Local communities and indigenous groups in particular, are increasingly using participatory maps to record and store important local knowledge and cultural information. Development and rapid removal from traditional land bases have encouraged indigenous groups, and organizations working with them, to use mapping projects to collect and preserve cultural histories and to record their elders' knowledge about their land. This information is being recorded in the fear that it will otherwise be lost as the older generations pass away and traditional ways of life change. Having a clear record of local spatial knowledge will enhance the capabilities of poor and indigenous communities to inform and thus influence a more culturally sensitive approach to development.

- To assist communities in land-use planning and resource management within Mt. Elgon and Cherangany ecosystems

Participatory maps can be a medium to help plan the management of traditional lands within Mt. Elgon and Cherangany ecosystems and make community knowledge about lands and resources visible to outsiders. They have helped communities communicate their long, but often invisible, history of managing resources. This might include identifying and locating specific natural resources such as forest products, medicinal plants, grazing lands, water sources, hunting and fishing grounds, fuel sources and building materials (McCall, 2002). Maps can also be an excellent medium to articulate and communicate desired management plans to regional planners (e.g. for input into bioregional maps) (Aberley, 1993). With the rapid uptake of participatory GIS technologies, participatory mapping projects are increasingly beginning to contribute to planning and managing local resources by enabling community information to be incorporated directly into, and compared with, government planning information and processes.

- To enable communities to advocate for change within Mt. Elgon and Cherangany ecosystem

Within the broad participatory mapping toolbox, counter-mapping is the map-making process whereby local communities appropriate the state's techniques of formal mapping and make their own maps to bolster the legitimacy of customary claims to land and resources (Peluso, 1995). These maps are viewed as alternatives to those used by government, industry and other competing outside groups. They become a tool in a broader strategy for advocacy. They present communities' claims, which often do not coincide with the government's ideas of who has rights to particular areas of land.

- To increase the capacity within communities leaving in Mt. Elgon and Cherangany Ecosystem

Often the benefits of participatory mapping initiatives are far wider and more intangible than those that result simply from map production and use. One of the greatest strengths of these initiatives is the ability of the mapping process to bring community members together to share their ideas and visions on resources management, which can contribute to building community cohesion (see Alcorn, 2000). With indigenous people in particular, when elders share traditional place names and histories with other members of the community through the map-making process, it can generate a resurgence of interest in their local knowledge, especially among community youth. This can help a community sustain a sense of place and a connection to the land which in turn will help reinforce a sense of identity. The map-making process can also act as a focus for discussions that will assist with recognizing assets, concerns and issues within the community. Discussions might raise community awareness about local and regional environmental issues or amplify community capacity to manage and protect lands. During the course of these discussions, a community can formulate a common vision, which in turn may help develop an effective community-based plan for future land-related development. Participatory mapping is not simply about being an expert cartographer, but about community building.

Once a community has a clear understanding of its own identity and a vision for the future, it will be in a stronger position to effectively communicate and deal with external agencies and it will be more likely to be involved in planning for its own future.

- To address resource-related conflict within Mt. Elgon and Cherangany ecosystems

Participatory mapping can be used to manage (i.e. avoid and reduce) conflicts between a community and outsiders and to address internal conflicts within Mt. Elgon and Cherangany ecosystems. Maps can represent a conflict graphically, placing the parties in relation to the problem and in relation to each other. Through delineating boundaries of competing groups that represent overlapping land claims (especially where rights and responsibilities over land and resources are unclear), these select areas of tension are made visible. This process can help identify key areas of conflict and help narrow the tension to identifiable, and subsequently manageable, units. When people with different viewpoints map their situation together, they learn about each other's experiences and perceptions.

Despite the apparent positive benefits of participatory mapping initiatives, a number of negative consequences might also arise. While these maps contribute to community cohesion, they can also be an agent for conflict and disagreement between different groups within a community and between different communities within the ecosystems. Documenting sensitive information using the community mapping process might also serve to make that information more vulnerable to exploitation; this is particularly the case when maps draw attention to valuable natural resources or archaeological sites. Great care needs to be taken when implementing participatory mapping initiatives.

2.3.4 Participatory mapping as a Validation tools

A broad range of participatory mapping tools exists. The choice of which we used was determinedby the way in which the map will be employed, the perceived impact the mapping tools will have on the target audience and the available resources (e.g. financial, human and equipment).

Hands-on mapping

Description: Hands-on mapping includes basic mapping methods in which community members draw maps from memory on the ground (ground mapping) and paper (sketch mapping). These maps represent key community-identified features on the land from a bird's eye view. They do not rely on exact measurements, a consistent scale or geo-referencing, yet they do show the relative size and position of features. These maps have been commonly used in RRA, PRA and PLA initiatives.

Participatory mapping using scale maps and images

Description: Local knowledge is identified through conversation and then drawn directly onto a photocopied map or remote-sensed image (or else onto clear plastic sheets placed on top of the map). The position of features is determined by looking at their position relative to natural landmarks (e.g. rivers, mountains, lakes). This method is commonly used where accurate and affordable scale maps are available. This method also works well with aerial and satellite images, which can be particularly helpful when working with people who cannot read a topographic map and with non-literate communities, including those from marginal livelihood systems (e.g. indigenous peoples, forest dwellers and pastoralists). Additional information can be located on the map using GPS data gathered in the field.

Participatory 3-D models (P3DM)

Description: Participatory 3-D modelling is a community-based method that integrates local spatial knowledge with data on land elevation and sea depth to produce stand- alone, scaled and geo-referenced models. P3DM are scale relief models created from the contours of a topographic map. Sheets of cardboard are cut in the shape of the contour lines and pasted on top of each other to create a three-dimensional representation of topography. Geographic features can be identified on the model using pushpins (for points), coloured string (for lines) and paint (for areas). Data depicted on the model can be extracted, digitized and incorporated into a GIS. On completion of the exercise, the model remains with the community.

Geographic Information Systems (GIS)

Description: GIS are computer hardware and software technologies that are used for storing, retrieving, mapping and analysing geographic data. GIS technology has been long regarded as complicated, costly and used primarily by experts. Since the 1990s, the participatory GIS (PGIS) movement has sought to integrate local knowledge and qualitative data into GIS for community use. PGIS practitioners (who are often technology intermediaries from outside the community) work with local communities to democratize the use of the technologies. GIS technologies increasingly are being used to address land-related issues with examples springing up around the global South. Interestingly, these applications usually have been adopted without significant redesign of GIS. To an extent, this reflects the flexible nature of GIS software.

Multimedia and Internet-based mapping

Description: Maps are frequently supplemented with the written word, but this can be an imperfect medium to represent local knowledge, especially for indigenous peoples, forest dwellers and pastoralists who are more likely to be non-literate and accustomed to communicating orally. Much local knowledge about the land is transmitted in the form of stories and legends that use metaphor and sophisticated terminology that might be lost if the information is transcribed. Multimedia and Internet-based mapping can combine the usefulness of maps with other embedded digital media, such as video, images and audio, which can be better at documenting the complexities and the oral and visual aspects of local knowledge.

This form of participatory mapping is becoming increasingly popular in either stand-alone systems or through the Internet and can be used to communicate complex, qualitative local knowledge related to the landscape.

2.4 Application of Revised Universal Soil Loss Equation (RUSLE)

2.4.1 Introduction to RUSLE model

The Revised Universal Soil Loss Equation (RUSLE) is a modification of the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978). The modifications were made by Renard *et al.* (1997) to estimate soil lost due to erosion minus sediment yield. As in USLE, the RUSLE estimates soil loss by water using the functional relationship among the major factors causing water erosion: climate, topography, soil properties, surface soil conditions and human activities (Renard *et al.*, 1997). RUSLE considers factors causing erosion such as climate, soil properties, vegetation cover and management practices are considered for estimating soil loss. The model estimate erosion rate in tonnes per hectare per year using the linear equation below:

$$A = R \times K \times (LS) \times C \times P$$

Where:

A = mean annual soil loss expressed in tonnes per hectare per year

R = rainfall and runoff erosivity index (in MJ mm/ha/yr)

K = soil erodibility factor (in ton/ha/h/ha/MJmm)

LS = slope steepness and slope Length factor (dimensionless)

C = cover factor (dimensionless)

P = conservation practice factor (dimensionless).

2.4.2 Factors in RUSLE Model

Rainfall facotr R

The R factor is called erosivity index, which means the active force of the rain which cause detachment and successive transport of soil particles. Precipitation is a very important erosion factor particularly in arid areas, where the soil is usually directly exposed to rain drops and its composing particles do not have a great cohesion power. The effects of rain are manifold, where the first contribution of precipitations to the erosion starts when rain drops touch the soil causing the "splash erosion". Depending on the energy of the drops (size, height from which they start to fall) and on the characteristics of the terrain on which they fall down, it will be a great or little detachment and displacement of soil particles. In a following phase, when the rainfall event is so strong that not all the water is penetrating the soil, the water which accumulates on the ground (facilitated by low soil permeability) starts to flow following the maximum sloping direction and digging more and more big and deep channels (rill and gully erosion). From these bases the R factor expresses the power of the rain to start an erosion process. Traditionally, R is calculated for each rainfall event as the kinetic energy of a rainstorm, times its maximum intensity over 30 minutes divided by 100 (erosion index, Wischmeier, 1959 cited in Arnoldus, 1977): it is calculated using the following equations:

$$R = EI_{30}$$

Where:

E = Kinetic energy of the storm

I_{30} = the intensity of the storm measured as the rainfall in millimetres received per second. For Ethiopia, Rabia (2012) used the equation below for calculating R (which was modified from Hurni, 1985).

$$R = 0.55P - 24.7$$

Where:

P is the annual precipitation in millimeters based on the five-year mean annual rainfall measured at nearby rain gauges.

In this study for the two ecosystems, the P value was obtained from averaging 12 months rainfall raster data from Worldclim calculated for the period 1950-2010, where the R-values were calculated in ArcGIS 10.5.

Soil factor K

K factor is soil erodibility factor, which represents both susceptibility of soil to erosion and the rate of runoff. It depends on a lot of biological and chemical soil characteristics such as its mineralogical composition, particle size, the permeability and the presence of organic matter. The granulometry can be considered as the most important factor influencing K. It was found that the erodibility of a soil increases proportionally with the amount of fine sand and silt content (Giordani and Zanchi, 1995) and the middle range of granulometry classes (diagram of Hjulstrom cited in Roose, 1996). Even the organic matter content is important to stating Erodibility, as it contributes to increase particle aggregation (by the presence of chelating agents) and water infiltration. Wischemeier *et al.* (1971) as cited Renard *et al.* (1997) developed soil erodibility nomograph, an equation for computing K from five soil parameters explained below.

$$K = \left(\frac{2.1 * 10^{-4} (12 - OM) * M^{1.14} + 3.25(s - 2) + 2.5(p - 3)}{100} \right)$$

Where:

OM = the percentage organic matter

M = M is the particle size parameter computed using the relationship below

$$M = (\%Finesand + \%Silt) * (100 - \%Clay)$$

Where sand, silt and clay are soils with particle size in mm between the ranges of 0.1 to 0.05, 0.05 to 0.002 and less than 0.002 respectively (USDA classification cited in Renard *et al.,* 1997).

s = the soil structure code derived from Wischmeier and Smith (1978) nomograph:

-1: very fine granular (<1mm)

-2: fine granular (1-2mm)

-3: medium coarse granular (2-5mm)

-4: blocky, platy or massive (5-10mm)

p = the permeability soil class as described in the USDA classification for different textural classes (USDA, 1983 cited in Renard *et al.,* 1997) and range from value 1 (rapid to very rapid drainage), assigned to sand, less susceptible to erosion for its good infiltration, up to value 6 (very slow drainage), given to silty-clay and clay soils, characterized by a high water retention but allowing overflow once soil is saturated.

Slpoe-Lenght factor LS

The topographic factor is a very important parameter in water soil erosion, since the gravity force is playing a decisive role in surface runoff. LS factor takes in account together the steepness (S), which increase the velocity of runoff, and the length (L) of a slope, which contributes to enlarge the ground surface affected by runoff. Since characteristic stone bunds constructions have been found in the study area, the removal of rock fragments for this purpose accelerates soil loss by water (Poesen *et al*., 1994; Nyssen *et al*., 2001). What is more, the relatively clear water that passes through the bunds has greater erosion potential in the downslope (Hairsine and Rose, 1992). These two factors are on average thought to compensate for the effects of the decreased plot slope length due to the stone bund building. This dimensionless factor has been calculated using two equations to estimate the topographic parameter; one for slopes up to 20% gradient and one for steeper slopes (Arnoldus, 1977).

For slope up to 20%, the below formulae was used;

$$LS = (L)^{0.5} \times (0.0138 + 0.00965S + 0.00138S^2)$$

For slopes over 20%:

$$LS = \left(\frac{L}{22.2}\right)^{0.6} * \left(\frac{S}{9}\right)^{1.4}$$

Where:

L is the slope length expressed in meters;

S is the slope gradient in percentage.

The SL factor for this study in the two ecosystems was derived from 12 Meters spatial resolution Digital Elevation Model captured by Sentinel 1 sensor.

Cover management factor, C

The cover management factor C, reflects the effect of ground cover on the rate and magnitude of erosion. Examples of groundcover are rock fragments, portions of live vegetation including basal area and plant leaves that touch the soil, crypto-gams, crop residue, plant litter, and applied materials, including manure, mulch and manufactured erosion control products like blankets. The C-factor measures the effects of all interrelated cover and management variables (Renard *et al.,* 1997). The factor is measured as the ratio of soil loss from land cropped under specific conditions to the corresponding loss from tilled land under continuous fallow conditions. By definition, C equals 1 under standard fallow conditions. As surface cover is added to the soil, the C factor value approaches zero. A C factor of 0.15 means that 15% of the amount of erosion will occur compared to continuous fallow (Dumas and Printemps, 2010). In this study, the C factor values were obtained from previous studies for the land cover types. The land cover classes and their corresponding C factors are listed in Table below

Table 1: Land cover types and corresponding C factor values

LANDCOVER	C FACTOR VALUE
Rainfed annual crops	0.5
Irrigated annual crops	0.56
Rainfed perennial crops	0.5
Irrigated perennial crops	0.56
Fallow	0.71
Forest plantation	0.39
Close forest	0.25
Open forest with closed scrub	0.20
Open forest with open scrub	0.39
Open forest	0.40
Sparse forest with closed scrub	0.28
Sparse forest with open scrub	0.42
Sparse forest	0.39
Closed scrub	0.30
Open scrub	0.35
Sparse scrub	0.45
Grassland	0.03
Bare ground	1

Land cover types and corresponding C factor values (mod. from Renard et al. (1997), Nyssen et al. (2007) and Stone and Hiborn (2012)).

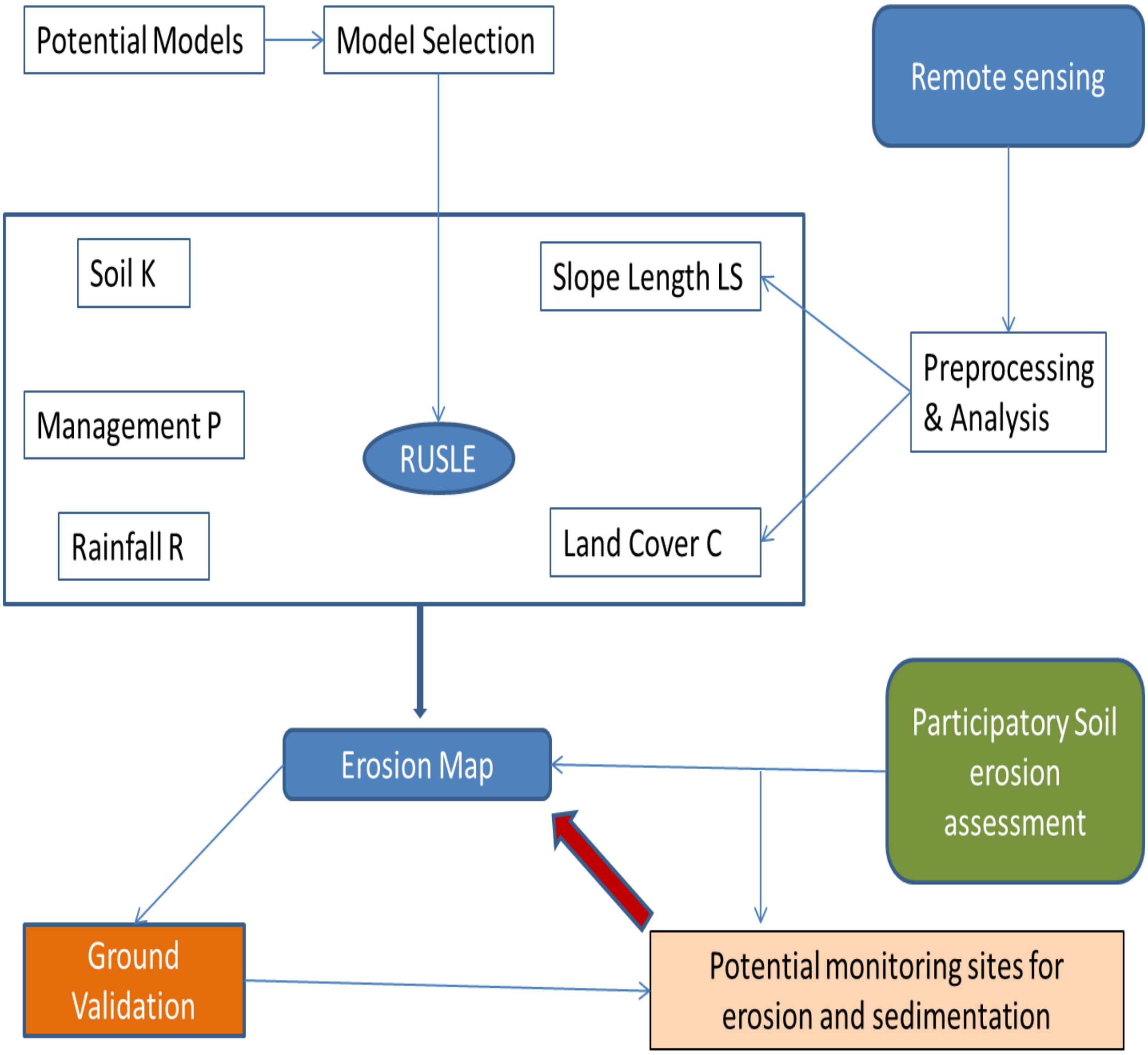


Figure 3: Methodology for Erosion assessment

3 CHAPTER THREE: RESULT AND DISCUSSION

3.1 Introduction

From the application of Revised Universal Soil Loss Equation Model which integrates five parameters in erosion assessment, final quantitative map amount of soil loss in t/ha in a year was generated for Mt. Elgon and Cherangany ecosystems . Through the integration of the RUSLE model and Participatory mapping, it was therefore possible to generate both erosion and sedimentation situation for the two ecosystems, in this way, it is possible to distinguish areas at high risk of erosion as well as high risk of sedimentation. The output maps with the contribution of the community members gives an idea of where sediments are being deposited, hence giving a complete scenario of soil loss processes within Mt. Elgon and Cherangany ecosystems. From the map it is possible to observe that high erosion areas are widespread in to the slope and deposition zones are mostly concentrated in stream sides and in to the stream channel.

For a better visual appreciation of these quantities, RUSLE values for Mt. Elgon and Cherangany ecosystems were grouped in five classes: Very Low (0 to 2 t/ha*y), Low (2 to 7 t/ha*y), Medium (7 to 15 t/ha*y), High (15 to 25 t/ha*y) and Very High (more than 25 t/ha*y). The first two classes are considered in the range of soil loss tolerance values. High class has to be controlled to gain a sustainable productivity, while the last class is very dangerous because it can be destructive in few years if no interventions are done and soil loss trend is maintained constant in the future.

Table 2: Erosion Class Values

RUSLE Class	RUSLE Value
Very Low	(0 to 2 t/ha*y
Low	2 to 7 t/ha*y
Medium	7 to 15 t/ha*y
High	15 to 25 t/ha*y
Very High	more than 25 t/ha*y

3.1.1 SL FACTOR (Cherangany)

The terrain of Cherangany ecosystem is relatively variable from flat foot slopes to steep scarps. The slope gradient and length therefore vary with position of the given point in the landscape. The longest slope length values were observed in flat or gently sloping areas with low slope gradients while high and steep areas had low slope length.

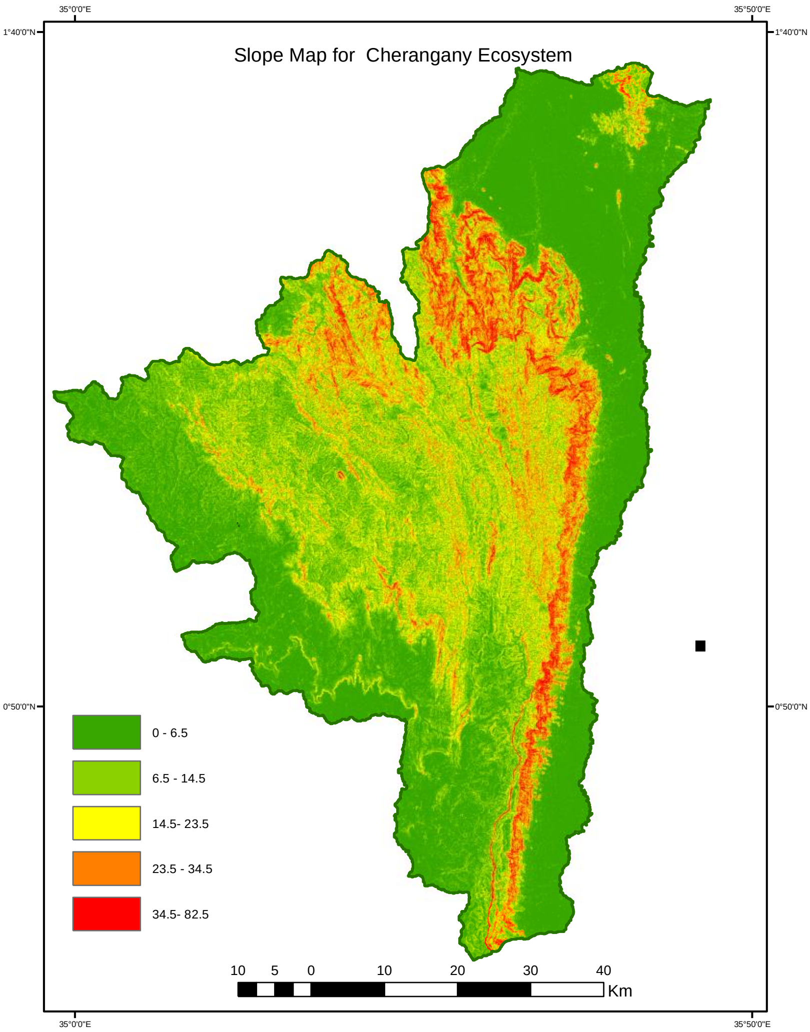


Figure 4: Slope Length Map for Cherangany ecosystem

3.1.2 SL FACTOR (Mt. Elgon)

The terrain of Mt. Elgon ecosystem is relatively variable, relatively flat on the North-Eastern and Southern parts of the ecosystem. The topography is highly ragged on the Western, where National park is located. The ragged part is dominated by closed montane forest ecosystem.

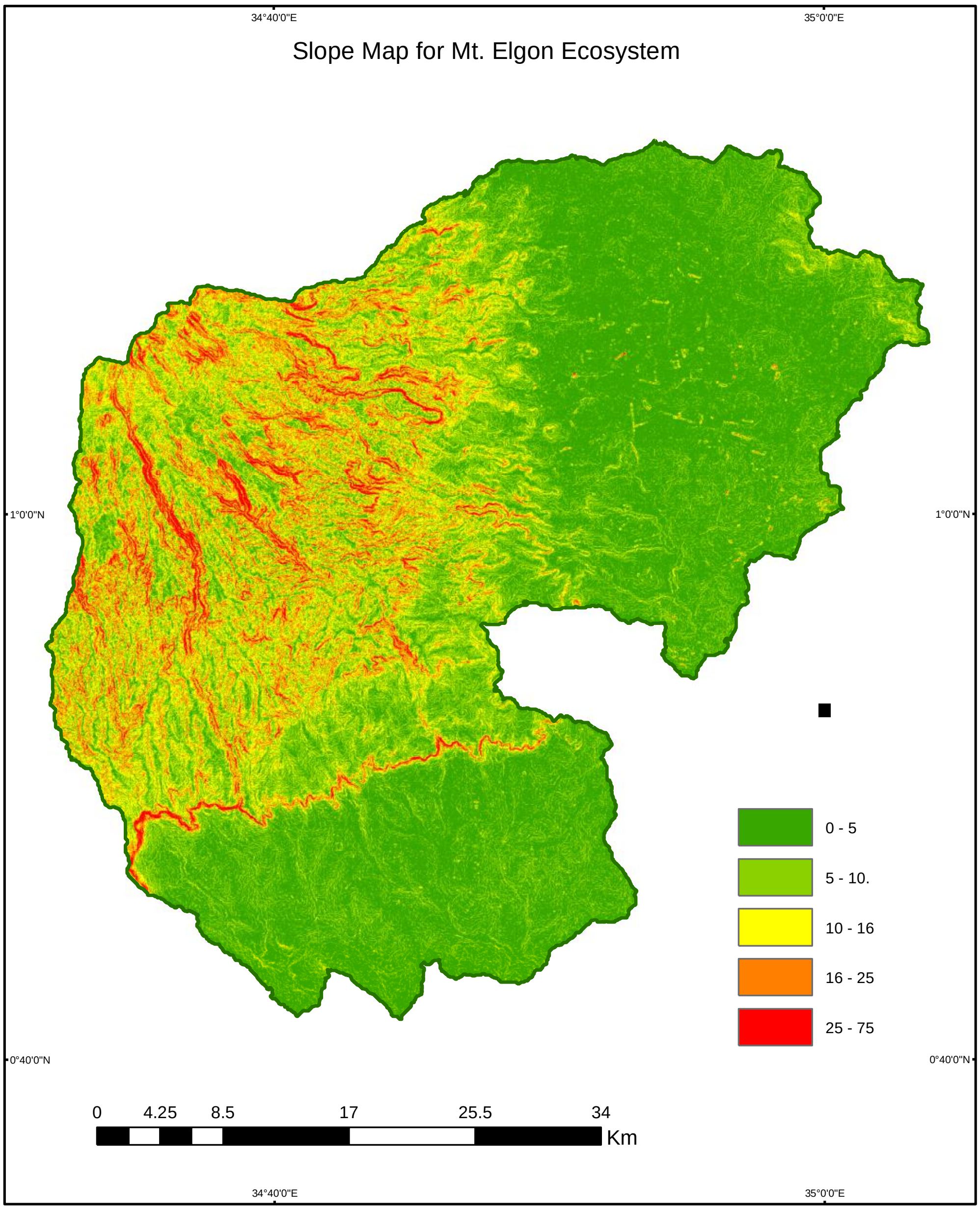


Figure 5: Slope Length Map for Mt. Elgon ecosystem

3.1.3 Rainfall (Cherangany)

In Cherangany Ecosystem, the spatial distribution of rainfall erosivity vary greatly with values ranging from 43 to 113 MJ* mm/ha/yr. The northen-eastern part of the ecosystem receives low rainfall compared to the central part of the ecosystem. The rainfall distribution explain the variation in land cover types, as the central parts of the ecosystem is mainly forest and farms while the north-east of the ecosystem is mainly shrub and grasslands with little crop farming and more of pastoralism activity.

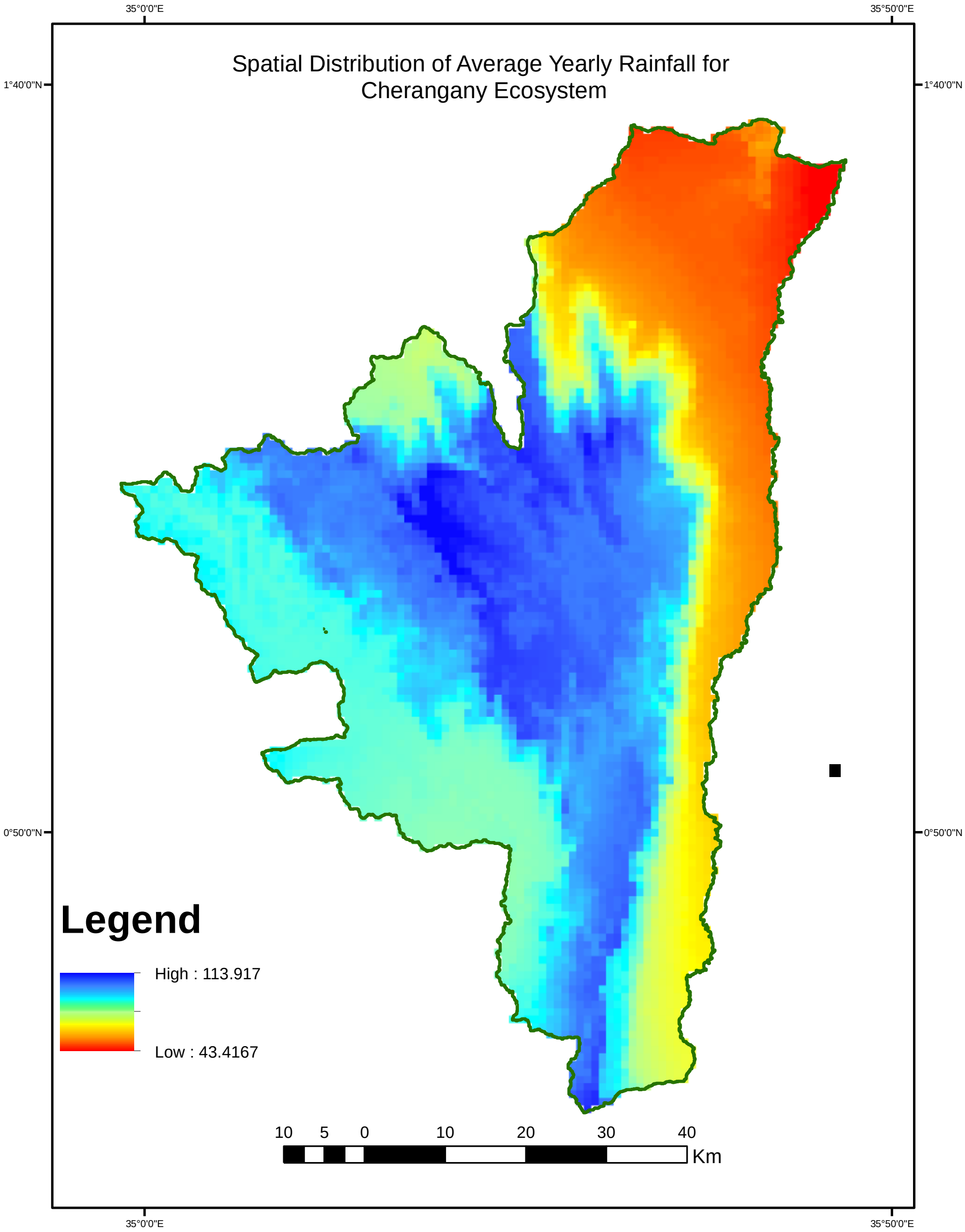


Figure 6: Rainfall Map for Cherangany ecosystem

3.1.4 Rainfall factor (Mt. Elgon)

In Mt. Elgon Ecosystem, the spatial distribution of rainfall erosivity vary greatly with its values ranging from 87 to 156 MJ* mm/ha/yr. The north-eastern part of the ecosystem receives low rainfall compared to the Western and Southern parts of the ecosystem.

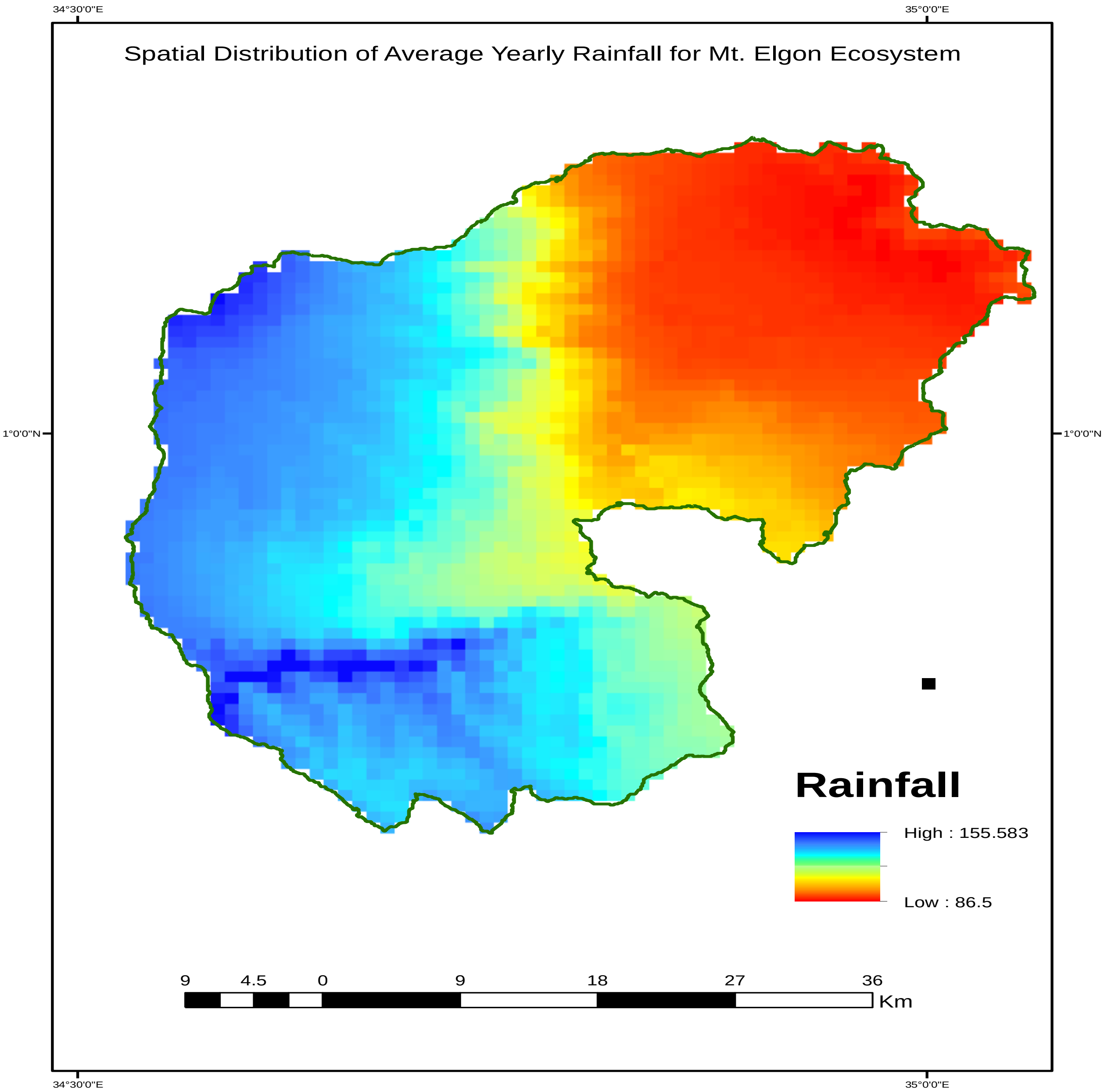


Figure 7: Rainfall Map for Mt. Elgon ecosystem

3.1.5 C FACTOR (Mt. Elgon)

The land use of Mt. Elgon ecosystem is mainly farmland on the lower parts of the mountain, while the slopes of the mountain has Mt. Elgon Forest reserve, Mt. Elgon National Park and Chepkitale National reserve which consists mainly of natural forest, leading to patches of grassland towards the peak with predominantly bare and rocky peak.

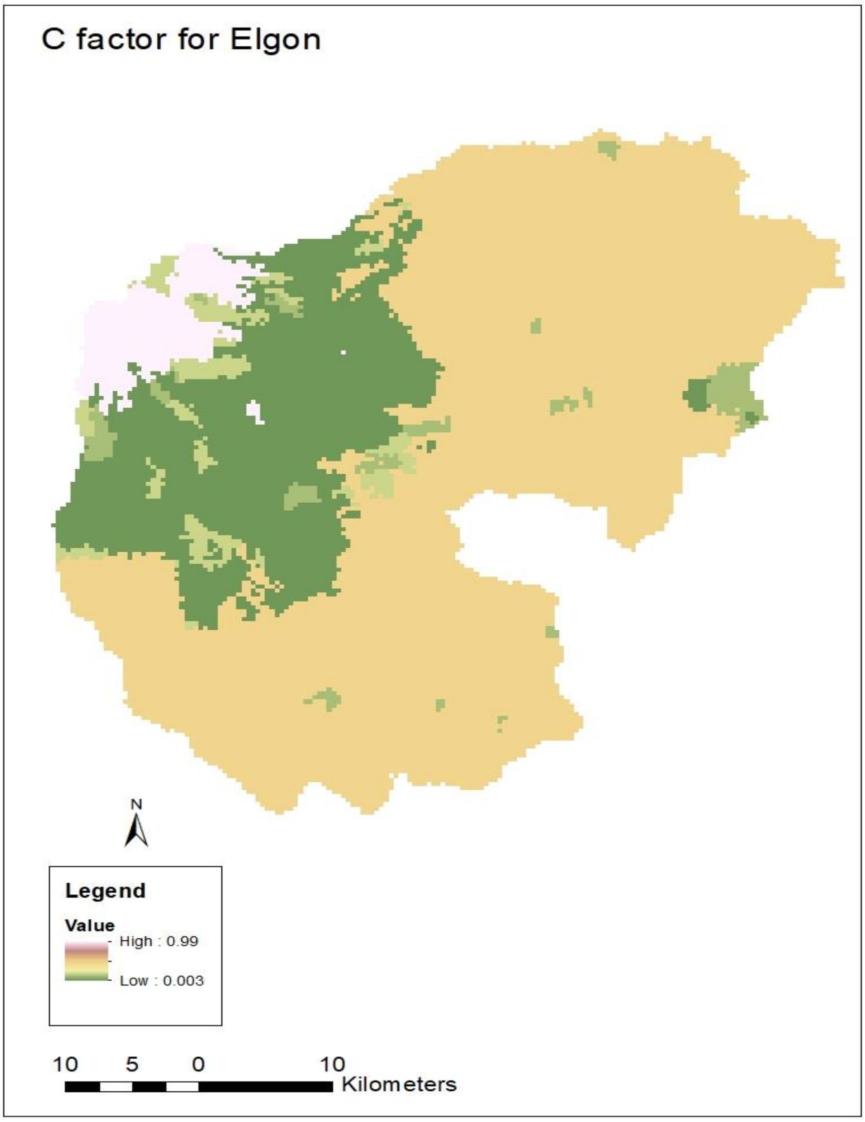


Figure 8: Land Cover factor for Mt. Elgon ecosystem

3.1.6 C FACTOR (Cherangany)

The Cherangany ecosystem falls within four Counties, (Trans Nzoia, Uasin Gishu, Elgeiyo Marakwet and West Pokot). Land use in the ecosystem consists of farming activities are mainly on the western side. With several forest reserves on the higher parts of Cherangany hills consisting of both natural and planted forests, while the eastern side of the ecosystem is predominately bushland.

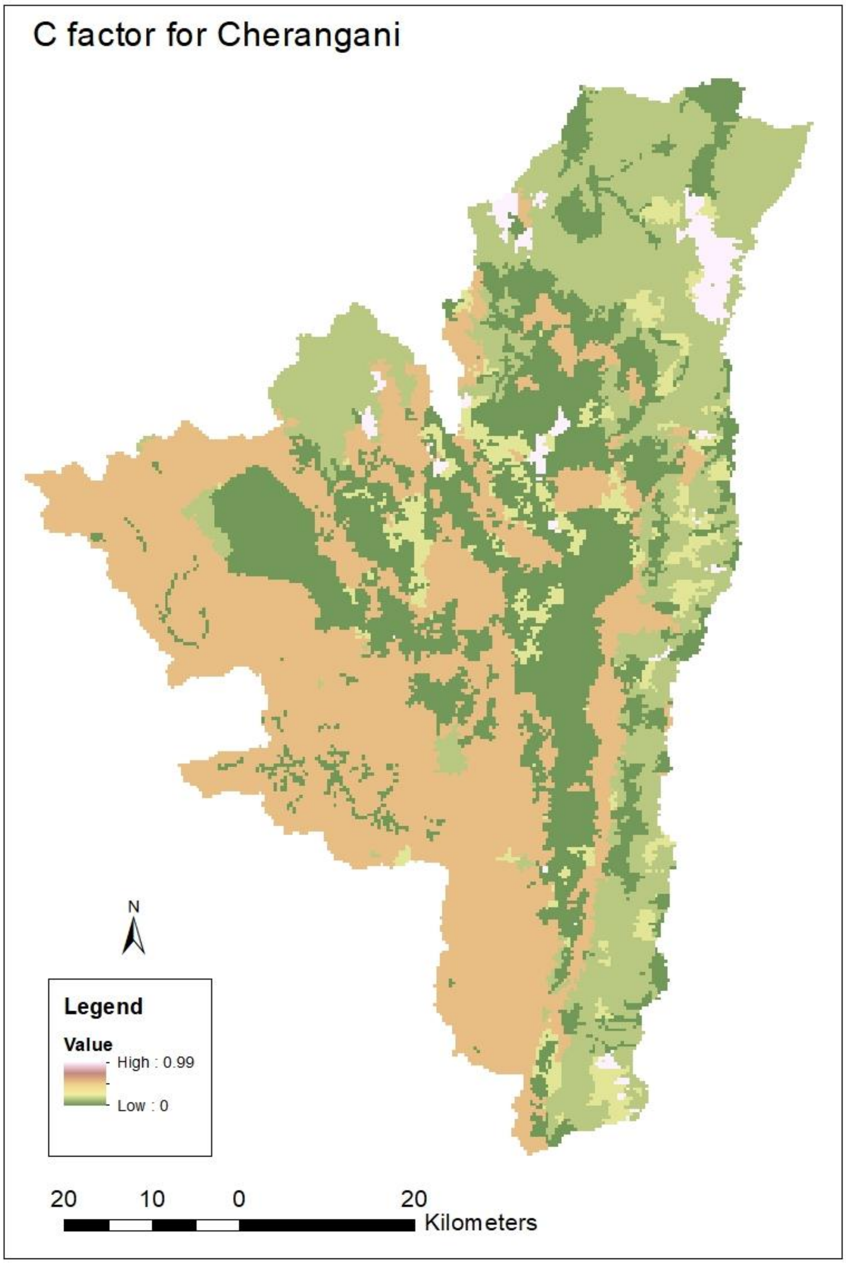


Figure 9: Land Cover factor for Cherangany ecosystem

3.1.7 K FACTOR (Mt. Elgon and Cherangany)

The K factor values for Mt. Elgon ecosystem was derived from Kenya Soil and Terrain database (KENSOTERv2) using Soil erosion risk mapping using RUSLE in Rwanda.

Table 3: Soil factor Values used

SOIL CODE	SOIL NAME	TEXTURE	K
KE75	Haplic LIXISOLS	SC	0.0145
KE73	Eutric CAMBISOLS	CL	0.0237
KE72	Humic FERRASOLS	C	0.0145
KE89	Rhodic NITISOLS	C	0.0369
KE162	Humic NITISOLS	C	0.0237
KE113	Humic NITISOLS	C	0.0237
KE90	Eutric VERTISOLS	C	0.0553
KE91	Rhodic NITISOLS	C	0.0369
KE84	Eutric GLEYSOLS	C	0.0145
KE87	Mollic GLEYSOLS	C	0.0237
KE85	Haplic FERRASOLS	SL	0.0369
KE88	Rhodic FERRASOLS	SL	0.0369
KE86	Humic NITISOLS	C	0.0237
KE21	Haplic ACRISOLS	SCL	0.0145
KE394	Rhodic FERRASOLS	C	0.0145
KE18	Haplic ACRISOLS	CL	0.0237
KE17	Eutric GLEYSOLS	C	0.0145
KE25	Ferralic ARENOSOLS	SL	0.0369
KE79	Ferric ACRISOLS	CL	0.0237
KE139	Calcaric REGOSOLS	CL	0.1054
KE80	Dystric CAMBISOLS	L	0.0553
KE111	Eutric PLANOSOLS	CL	0.0237
KE77	Haplic LIXISOLS	C	0.0145
KE131	Eutric REGOSOLS	SCL	0.0237
KE56	Eutric REGOSOLS	SCL	0.0237
KE292	Calcic SOLONETZ	SiL	0.079
KE136	Calcaric REGOSOLS	CL	0.1054
KE78	Haplic LIXISOLS	C	0.0145
KE81	Chromic CAMBISOLS	SCL	0.0237
KE177	Calcaric CAMBISOLS	C	0.0369
KE83	Humic CAMBISOLS	SCL	0.0237
KE82	Humic CAMBISOLS	SCL	0.0237
KE74	Humic ACRISOLS	SC	0.0145
KE71	Humic CAMBISOLS	SCL	0.0237
KE262	Dystric REGOSOLS	SCL	0.0553

SOIL CODE	SOIL NAME	TEXTURE	K
KE99	Humic NITISOLS	C	0.0237
KE69	Haplic FERRALSOLS	C	0.0145
KE260	Chromic CAMBISOLS	SCL	0.0237
KE100	Humic NITISOLS	C	0.0237
KE179	Euric GLEYSOLS	C	0.0237
KE178	Eutric CAMBISOLS	C	0.0053

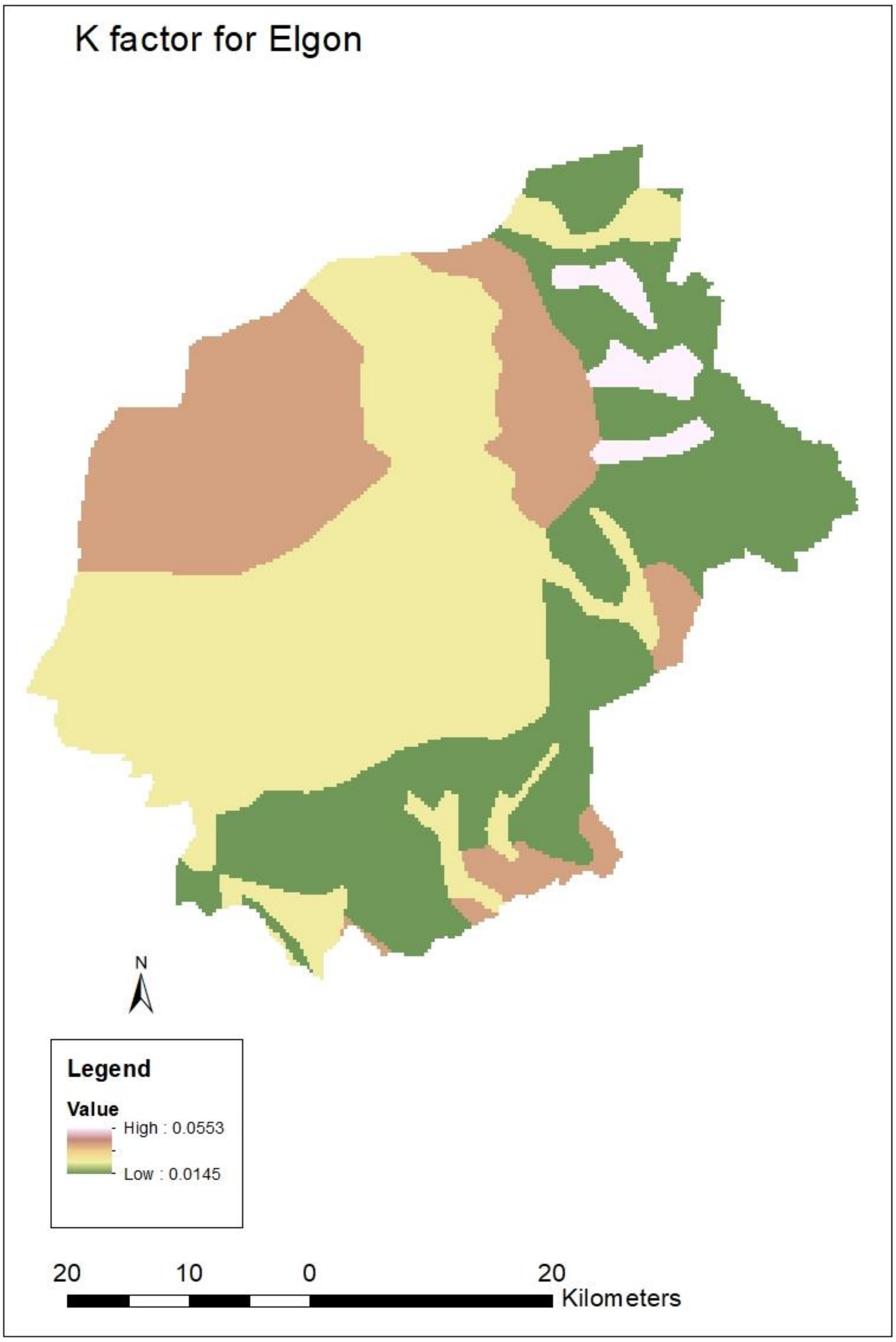


Figure 10: Soil Factor for Mt. Elgon ecosystem

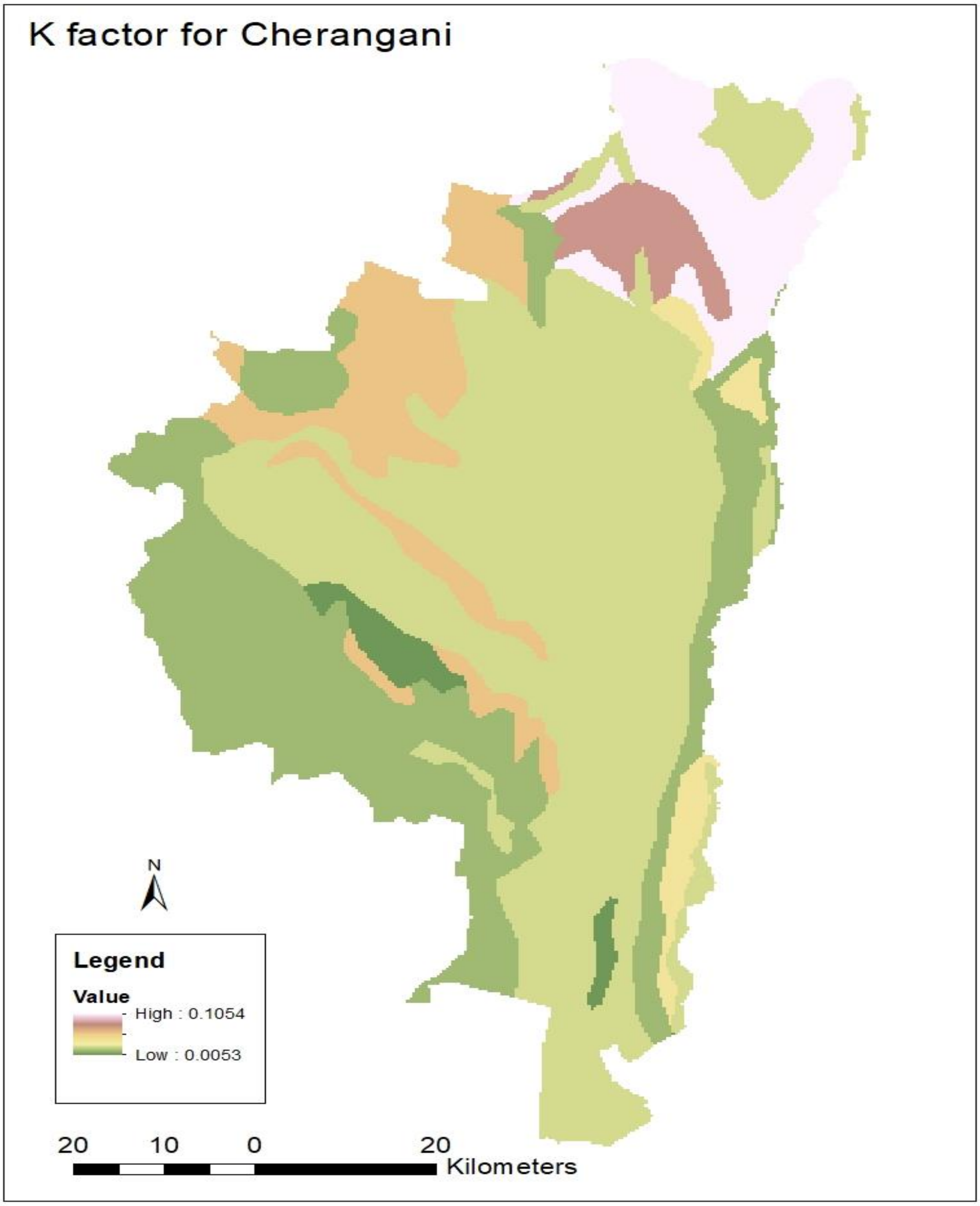


Figure 11: Soil Factor for Cherangany ecosystem

3.2 Mt. Elgon Ecosystem

Mt. Elgon ecosystem was divided based on the administrative boundaries into eight Zones namely; Cheptaisi, Kapsokwony, Sirisia, Kimilili, Webuye, Mt. Elgon Forest, Saboti and Kwanza.

Kwanza region covers the largest part of the ecosystem with an Area of 763.58 Km^2, followed by Mt. Elgon forest zone which covers an Area of 487 Km^2. In Mt. Elgon Ecosystem, Tongareni covers the smallest extent of 37.57 Km^2.

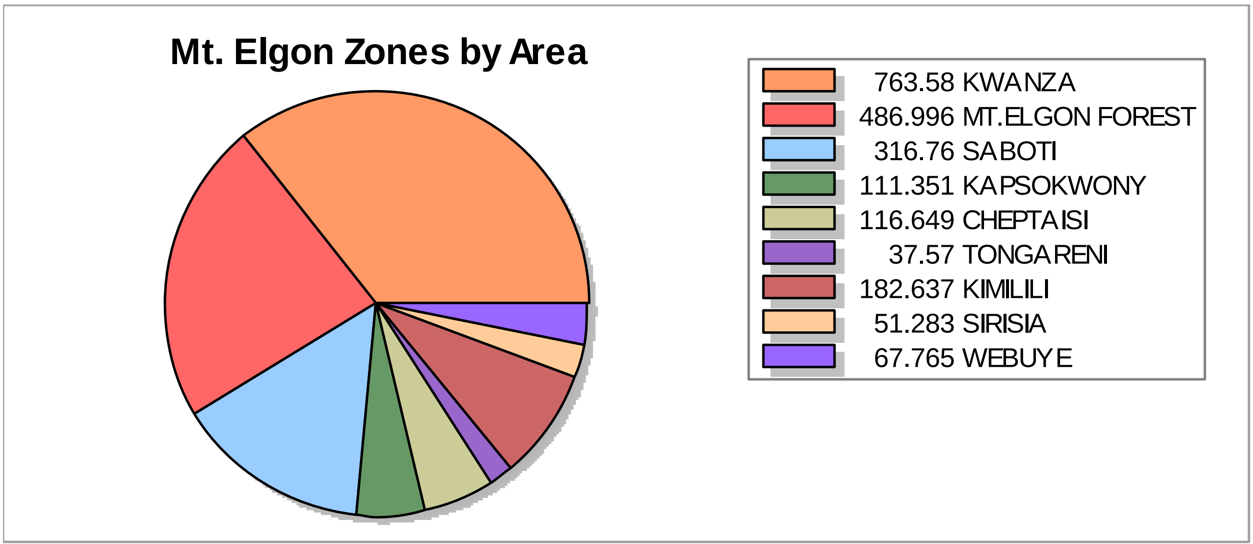


Figure 12: Mt. Elgon ecosystems Zones by Coverage

In terms of erosion and sedimentation within the ecosystem, the highest erosion rate value is 35 tons per year with the lowest erosion value of 0.2 tons of soil per year. The high erosion class is common in Kapsokwony, Cheptaisi and Kimilili regions of the ecosystem. Over 50% of Kapsokwony region is losing over 30 tons of soil per year. This can be attributed to soil type within the zone, steeply slope of the ecosystem together with the land use which is majorly agriculture without erosion control measures.

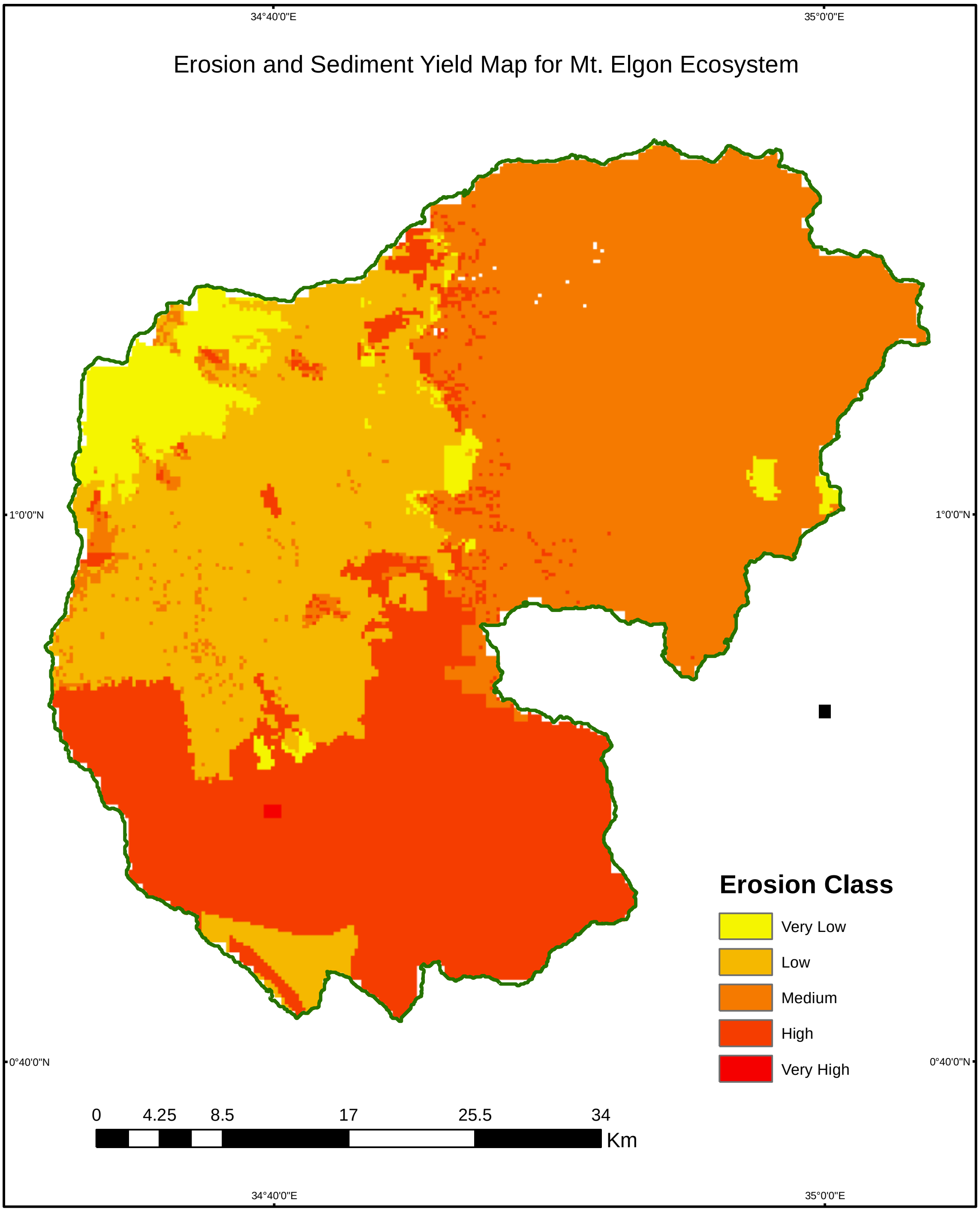


Figure 13: Erosion and sediment yield map for Mt. Elgon ecosystem

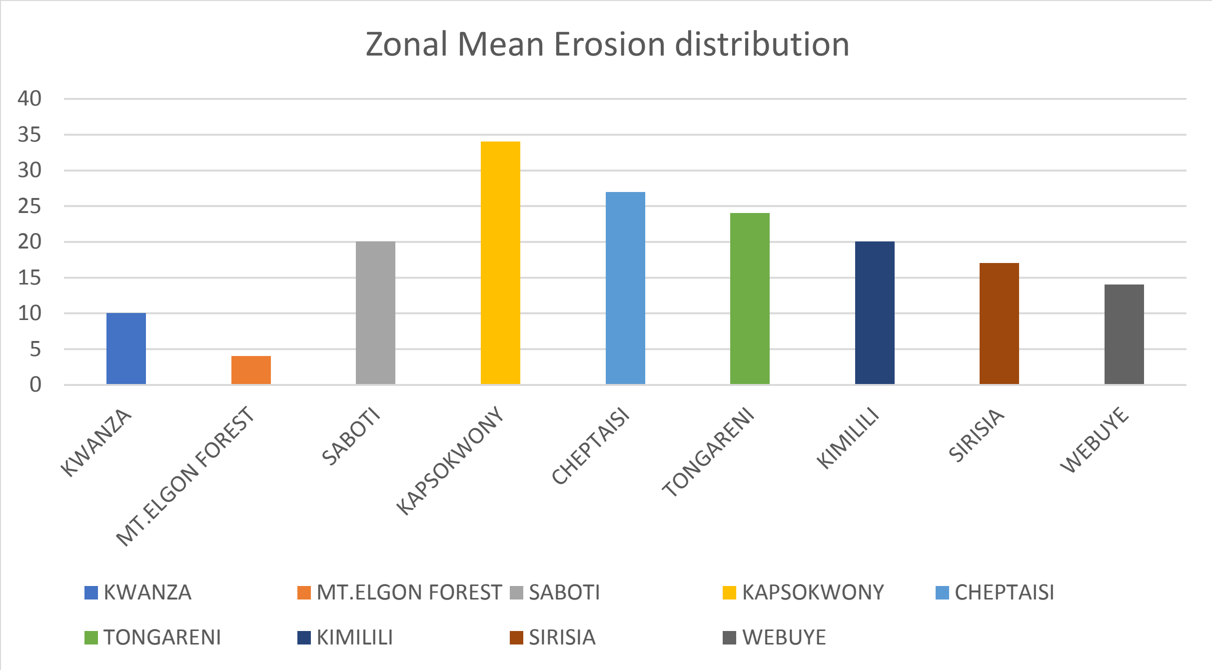


Figure 14: Mean Zonal erosion distribution in Mt. Elgon ecosystem

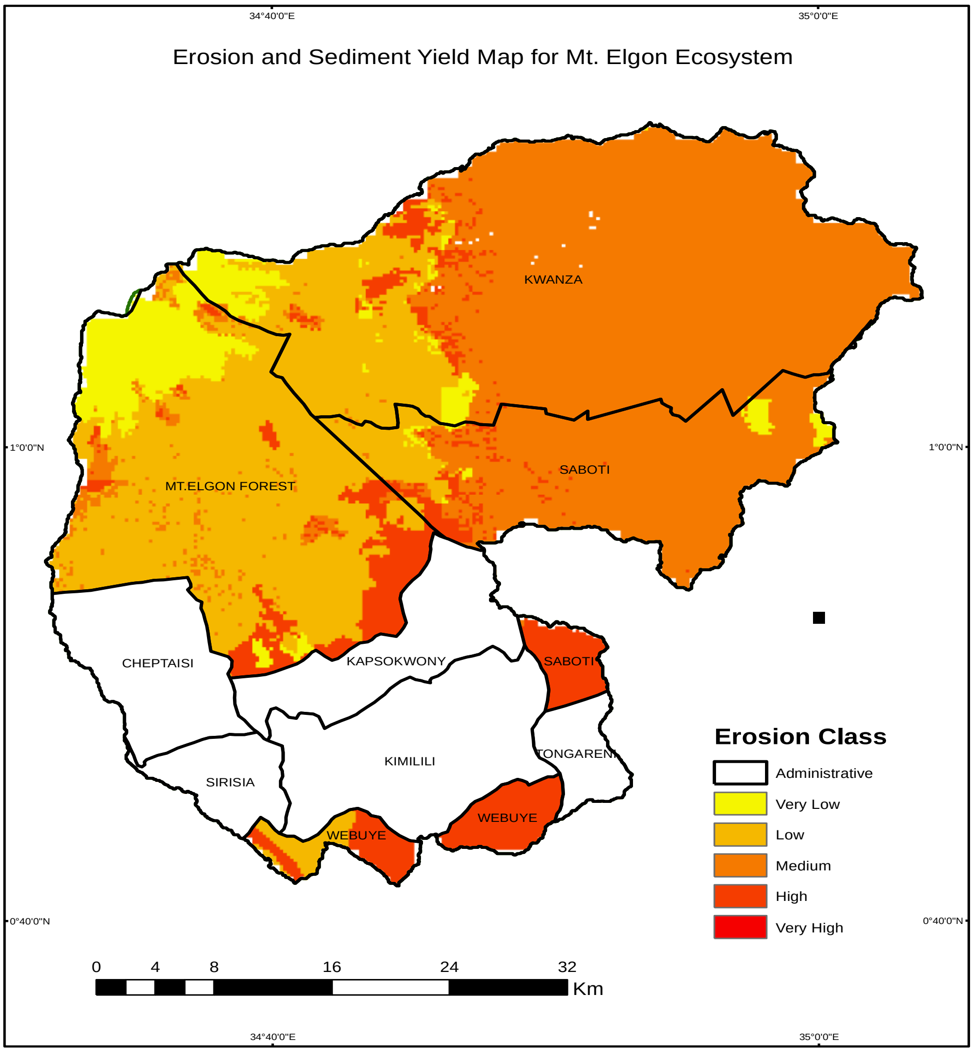


Figure 15: Zonal erosion distribution Map in Mt. Elgon

Low erosion is taking place in Mt. Elgon Forest zone which is majorly closed forest, open forest and national park as the major land use land cover. However, at the ecotone zone which is the lower part of the zone is also experiencing high erosion due to land cover degradation.

High erosion in the lower part of the ecosystem can also be attributed to high amount of rainfall as compared to North-West part of the ecosystem which receives low rainfall.

Picture 1: Measuring the Depth of Gully in Cherubei Village, Mt. Elgon Ecosystem

Picture 2: Sheet erosion in Cherubei, Mt. Elgon Ecosystem

Not all the detached soil particles are transported to the water bodies; some are deposited on the lower gentle slopes with some vegetation or grass cover that reduces the speed of upland runoffs. The reduction in runoff results into increased infiltration and percolation. The deposited soils on the lower regions of the ecosystem form rich alluvial plains that are used by farmers to grow vegetables.

In Mt. Elgon ecosystem, River Kaptkateny, Kibisi, Kaptesang, Sosio and Musindet receive a lot of sediments due to high erosion rate in the lower region of the ecosystem which can be attributed to Soil type, Slope Length factor and land use which is majorly crop farming without management practices to reduce the erosion. However, river Koitobos, Nai Swamp, Kapkukul, Kabewyan, Chepereiwe receice slightly lower sediments due to low rate of erosion on the Northern part of the ecosystem. This is due to low annual rainfall and reduced slope-length factor together with compact soil within the upper part of the ecosystem.

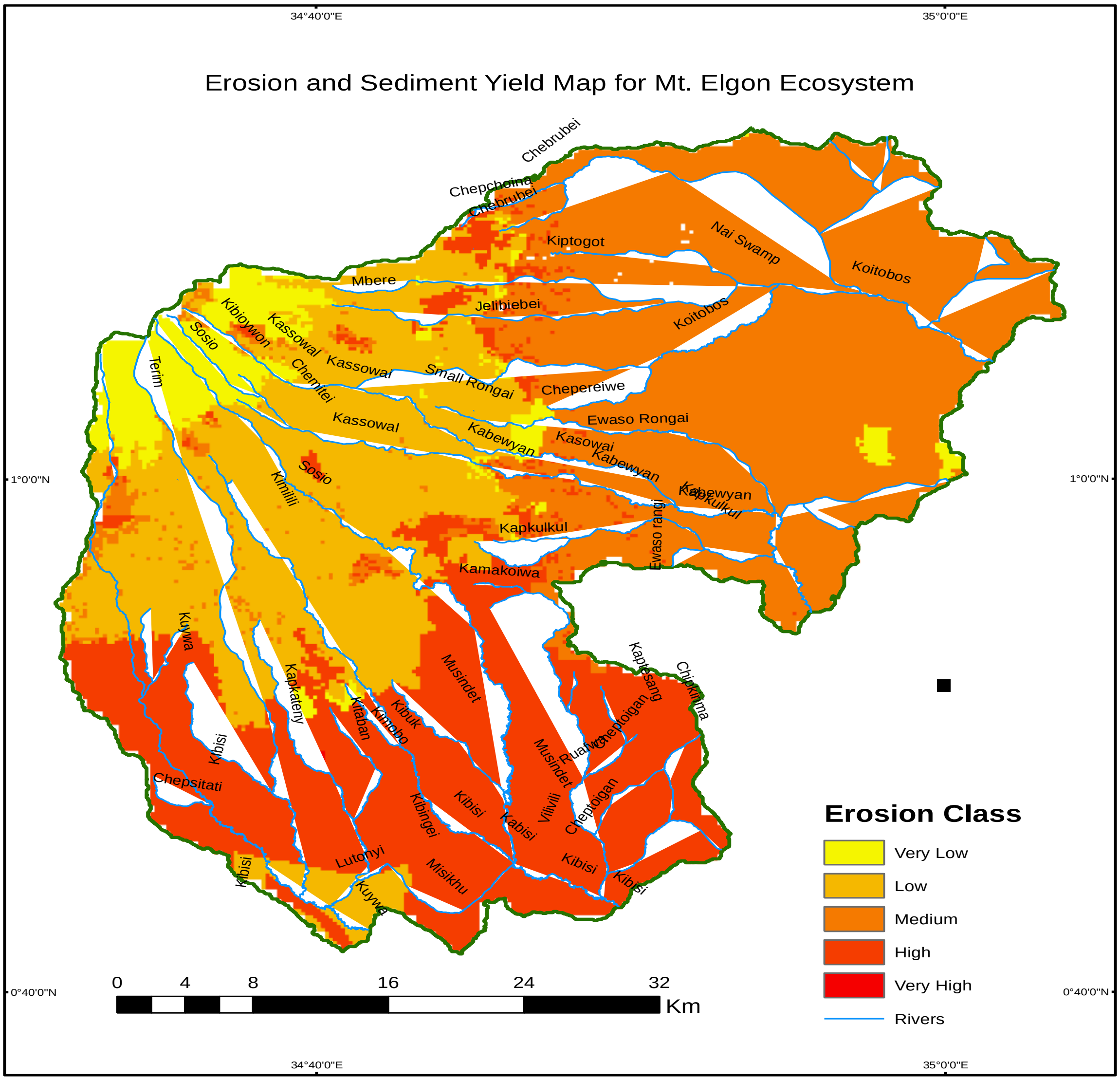


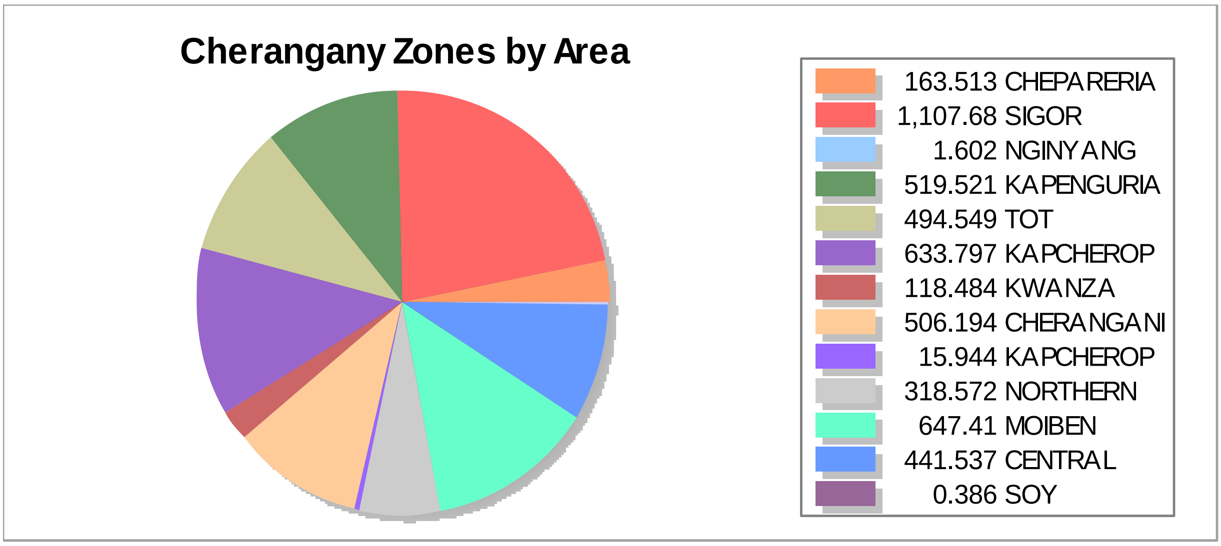
Figure 16: Rivers and sediment yield Map for Mt. Elgon Ecosystem


Picture 3: Sediment in River Kibisi,Mt. Elgon ecosystem


Picture 4: Sediments transported to water bodies, River Kibisi, Mt. Elgon

3.3 Cherangany ecosystem

Climatic, edaphic and human activity varies greatly within Cherangany ecosystem. On the Northern part of the ecosystem, main human activity is pastoralism.



Picture 5: Measuring Rills/Gully erosion in Chepareria, Cherangany ecosystem

Picture 6: Gully erosion in Chepareria, West Pokot

Picture 7: Approximation of amount of soil lost through erosion in Chepareria, West Pokot

Picture 8: Approximation of amount of Soil loss through erosion in Chepareria, West Pokot Cherangany

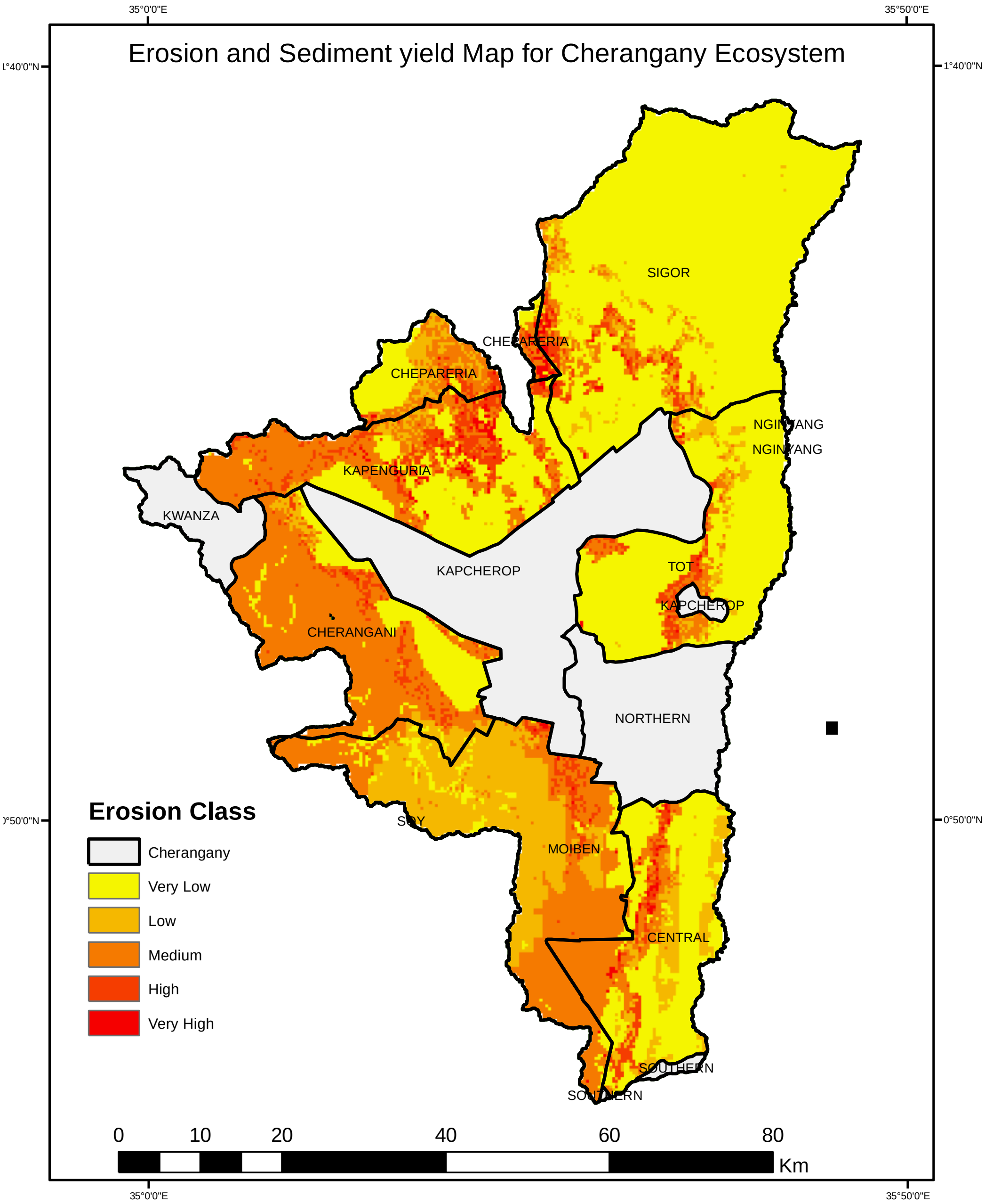


Figure 17: Zonal erosion Map for Cherangany ecosystem

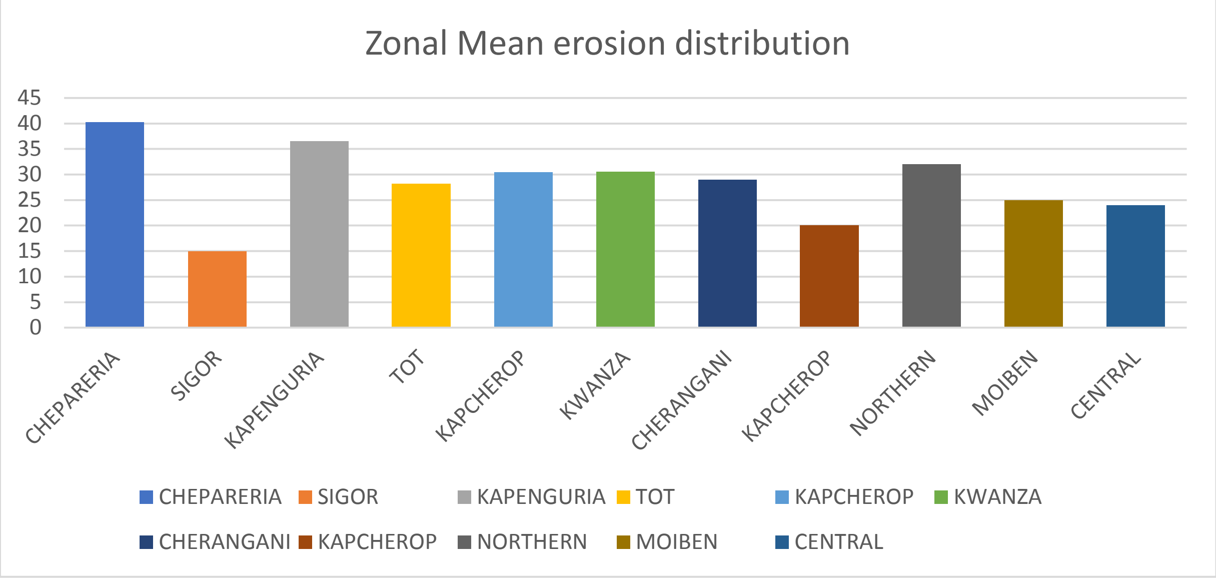


Figure 18: Mean erosion distribution in Cherangany ecosystem

Picture 9: Sediment flow in Kapcherop, Cherangany

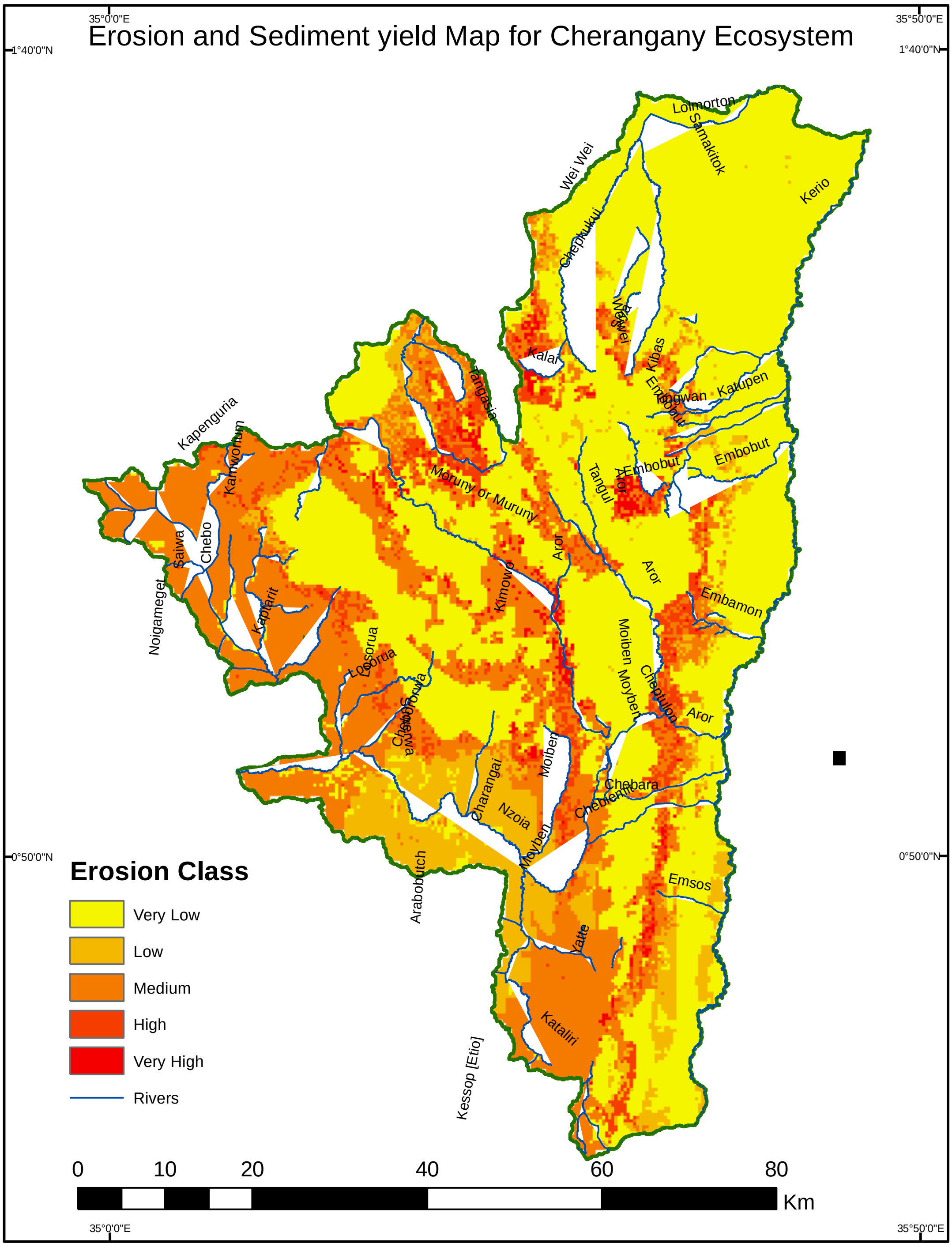


Figure 19: Drainage system in Cherangany ecosystem

Picture 10: Sedimentation in Kapcherop, Cherangany ecosystem

3.4 Participatory Soil erosion assessment in Mt. Elgon and Cheranagany

3.4.1 Overview

During the field verification with the involvement of the community members through participatory mapping, the erosion map was overlaid with maps generated by local farmers. These community erosion maps were mapped in the field using satellite image as background and with the participation of the community, the erosion areas were identified.

A group of farmers visited some fields and we compared the erosion risk (priority) indicated by the map with field conditions. The relative degree of erosion was estimated by observing certain visual signs, such as pedestals, rills, litter movement, flow patterns, deposition, and gully features. Visual indicators provide a qualitative assessment of erosion. Major advantages of using visual indicators include: It allows for a relatively quick process; many observations can be made during a field trip; the potential erosion problems that require site-specific monitoring can be identified (Ypsilantis WG 2011). Therefore, by involving local community in the field erosion assessment, a ground truth verification process (gathering data from the field about soil erosion type and severity and compare it with the maps) using randomly selected fields indicated that 90% of the targeted areas were correctly identified using the erosion risk map. Most of the fields classified as high erosion risk were located at higher positions with steep slope and convex shape.

Scientists and farmers judged these to be an obvious source of erosive runoff for those fields ?located below these fields, and arrived at a comparable judgment for the fields classified with?moderate or low erosion risk. Li et al. (2013) reported that the cultivated land on steep slopes that are located in the upper part of landscape are a major sources of sediment delivered to the flat areas located in the lowland within the same landscape.

Location of PGIS Activities

The PGIS activities were carried out in three Counties i.e. Elgeyo Marakwet, Trans Nzoia and Bungoma. Three of these covered Cherangani Hills and two covered Mt. Elgon. For each site, 5-7 community members were raandomly recuiited to discuss with the teams and share their experiences in their local area. They also drew a map showing the key features such as roads, mountain/hills, rivers, shopping centres and how these associated with soil erosion hotspots which they gave by name. These findings are given in the specific notes made below.

KAPCHEROP (ELGEYO MARAKWET)

Key land uses

- Crop farming (maize, beans and potatoes)
- Dairy farming
- Plantation forest (GOK)

Common tree species

- Cypress
- Eucalyptus
- Pine
- Rosewood
- Podo
- Many indigenous trees are now very rare due to over-exploitation

Clearing of forests

- Encroachment started during colonial times
- There is currently no cutting of trees in protected forests by locals
- Plantation forest cleared by KFS when trees are ready and replanted
- Tea zone in Kapcherop and Kaimoi protect forest from encroachment

Constraints for tree planting

- Availability of tree seedlings
- Unavailability of required tree seed

Soil erosion

- There is increased soil erosion in the recent past
- Some farmers made terraces and used gabions to mitigate erosion
- Crop residue is mostly used as fodder
- Soil sediments go to rivers
- River Nzoia has a dam being constructed and may suffer from sedimentation
- Most on-farm soil erosion is currently presumed under control
- After rains water for drinking is brown with sediments but it is not treated

Erosion hotspots

Presence of landslides and gullies at Kipseron (located about 2km north of Kapcherop)

KOITUGUN (ELGEYO MARAKWET)

Main Land use

- Crop farming
- Livestock farming
- Tree planting

Tree species

- Podo carpus
- Cedar
- Rosewood
- Eucalyptus
- Cypress
- Grevellia

Management and issues

- Replacing tea with maize
- Terracing of cultivated steep areas is needed
- Placement of gabions in gullies is needed
- Planting nappier grass and sugarcane on embankments
- There are landslides in some steep areas
- Erosion present mostly at the highest points
- Crop residue is used as fodder, hence no soil cover when rains come

Types of erosion

- Sheet erosion
- Rill erosion
- Gulley erosion
- landslides

Constraints in tree planting

- There is need for training on tree planting technology
- There is need for supply of tree seeds and/or seedlings on demand

Erosion hotspots

- Logoon (presence of landslides)
- Sugutia
- Kiptangoi
- Kiptugu

CHEPKORNISWA (WEST POKOT)

Land use

- Livestock grazing is the main activity
- Crop farming (mainly maize) is the next activity
- Trees on hills, ridges and valleys

Tree species

- Acacia tortillis
- Chuwuw
- Chesamus
- Koloswo
- Panan
- Tuyunwo

Deforestation and tree planting

- High level of deforestation is still taking place especially on the hills
- Lack of knowledge on importance of tree planting
- Unavailability of tree seed and seedlings
- Avail soft loans for farmers to enhance agriculture

Type of erosion

- Gulley erosion
- Rill erosion
- Splash erosion

Erosion is most intense on lower areas due to a) lack of proper management practices, and b) the soil type which is prone to erosion

Erosion hotspot

- Lotuv
- Murombus
- Pere Phepolokore
- Chemorir valley
- Laber

Ways to mitigate erosion

- Terraces cultivated steep areas
- Placement of gabions in gullies
- Plant grass on terraces to stabilize

Destination and effects of eroded soil

- Into rivers and lakes
- High levels of water pollution in rivers
- Low crop yield due to poor soils

KIBUK (BUNGOMA)

Land use

- Crop farming
- Livestock keeping
- Tree cover
- Quarry (limited area but intense)

Tree species

- Elgon teak
- Cypress
- Pines
- Eucalyptus

Issues and management

- The area was severely deforested for timber harvesting and farmlands
- As late as 2015/2016 logs carried to Southern Sudan
- Logging going on now but not all authorized by government
- Charcoal, fuel wood harvested illegally
- Some unscrupulous farmers are uprooting tree seedlings planted under PELIS
- Sale of trees for school fees and food contributing to on-farm deforestation
- Land use changed mostly from forest to farm lands

Types of erosion

- Gulley erosion
- Rill erosion
- Sheet erosion
- Splash erosion
- Landslides

Erosion is highest on the slopes. Crop residue is mostly used as fodder and not for erosion control. Excess crop residue is sometimes burned.

Erosion hotspots

- Chebukwabi
- Sambocho
- Chesikaki
- Kimama
- Chebaibai
- Kipyeto sub location
- Kobuk sublocation
- Koshok sub location
- Kapsokwony sub location

Ways of managing soil erosion

- Construction of terraces on cultivated steep areas
- Plant napier grass
- Plant trees along river banks and very steep areas

Effects of soil erosion

- Sediments covering of fishponds, dam and water pans
- Reduced crop yield due to loss of fertile soil

KIMWONDO (TRANS NZOIA)

Land use

- Mainly for crop farming
- Livestock keeping

Land use change

- Mt Elgon forest used to be up to where Suam road is before excision
- Most of it was indigenous forest especially high value Elgon Teak
- The land is now used for maize farming

Key tree species

- Cypress
- Eucalyptus
- Podo
- Cedar
- Elgon teak

NB: Close availability of forest products from the gazzetted forest is causing low level of on-farm tree planting

Soil Erosion

- Erosion is highest on steep farm lands
- Steepness of slopes seems to be increasing in sloping areas
- Crop residue is used as fodder and soil is bare when it rains
- High levels of water pollution by soil
- In some places stones are now exposed as the soil has been carried away

Types of erosion

- Gulley erosion
- Splash erosion
- Sheet erosion
- Rill erosion

Erosion hotspots

- Khalabana
- Basale
- Salama
- Chomkegen

Ways to mitigate erosion

- Terracing steep farming areas
- Plant nappier grass
- Plant trees on steep slopes
- Use gabions in gully areas

Picture 11: Participatory erosion assessment in Cherangany ecosystem

Picture 12: Participatory erosion assessment in Cherangany ecosystem

Picture 13: Participatory erosion assessment in Cherangany ecosystem

Picture 14:Participatory erosion assessment in Chepareria, Cherangany ecosystem

Picture 15: Participatory erosion assessment in Cherangany ecosystem

Picture 16: Participatory Erosion assessment in Kapsokwony, Mt. Elgon

3.5 Synthesis of implication of land use change and erosion on livelihood sustainability

Genesis of the problem: Land cover change

One of the most important changes in the two ecosystems for the last fifty years is land cover. For hundreds of years the ecosystems have sustainably provided goods and services to the residents as the population was lower. Like virtually all other forests in tropical Africa, increasing population, higher technologies and greater demand for development has put immense pressure on the two ecosystems. The older generation is aware of the close to pristine conditions they knew in their youth. This unfortunately is gone forever. Changes in land cover include size of forests to their composition as some of the trees are reduced or disappear altogether. Among the major threats to forest ecosystems in Kenya and Uganda are encroachment by settlements or agriculture, illegal logging, excision, charcoal production, livestock grazing and subdivision of land Roussel (2012).

From analysis of Landsat imagery for 1973 to 1988 and 2003, Taylor (2015) showed that there were significant changes in land use land cover in the western Kenya districts with the area under agricultural increasing from 28% in 1973 to 70% in 2003 while those under wooded grassland decreasing from 51% to 11% over the same period. However, degazettement of forests for resettlement of people living within forest reserves has had limited success as people have continued encroaching into the forests (Roussel, 2012). Conflict between the public and private goods is the cause of deforestation, soil erosion, pollution of the rivers, improper solid waste disposal, increased flash floods and landslides and loss of wetlands (Roussel, 2012).

Accelerated soil erosion

Volcanic mountains in the East African Rift (e.g. Mt. Kenya, Mt. Kilimanjaro, Mt. Elgon) are some of the most productive agricultural regions, often dominated by coffee and banana cultivation (De Bauw et al, 2016). Consequently, these regions suffer from a high and increasing population density with a declining soil fertility status imposing pressure on the available land, which in turn results in encroaching into the national forests. Lack of soil protective cover leads to high erosion and run-off in steep areas, hence siltation of rivers and dams (Macharia, 2013). According to Roussel (2012), soil degradation in the Mt. Elgon area is linked to soil fertility depletion and soil erosion, long-term cultivation with diminishing fallow periods, limited crop rotation practices and low fertilizer inputs. Quoting Waswa (2012), Taylor (2015) reported that field observations and measurements showed that over 55% of the farms sampled lacked any form of soil and water conservation technologies. Sheet erosion was the most dominant form of soil loss observed in over 70% of the farms.

Unfortunately, these areas are also experiencing the highest degradation risk despite being some of the most productive in the country. This is compounded by increased fragmentation and deforestation due to increasing pressure for new cultivation and grazing lands as well as for settlement. According to Olago et al (2015), the ongoing climate change is likely to experience increased intensity of runoff, changes in soil properties, increased frequency and magnitude of landslides, and increased soil erosion.

Thus the long-term effect of soil erosion is washing away of the fertile top soil and hence reduction in agricultural productivity.

Fertilizer application in agriculture

Both Mt. Elgon and Cherangany Hills are highly agricultural. They constitute Kenya's bread-basket, being the single most important source of maize for the country with an estimated 210000 hectares put under maize annually. Rural households in southern Mt. Elgon derive nearly three-quarters of their income from crop farming, with smallholders dominating the agricultural sector with over 90% of crop production being produced on farms averaging less than 2 hectares (Roussel, 2012). Maize production requires high fertilizer inputs, and the ongoing soil erosion exacerbates this condition.

Virtually all soil samples were found to have low organic carbon in Kimilili and Bungoma East, and at least 52% were also low in N, P and K. In Keiyo Marakwet the percent of samples failing this threshold are at least 53. Furthermore, in Mt Elgon 55% of the samples had available P below adequate levels (Macharia, 2013).

Osundwa et al (2016) showed that applications of DAP to maize in Siaya, Uasin Gishu and Trans Nzoia resulted in significant increases in crop yield, demonstrating a general low soil fertility status. Soil fertility problem has been identified as a major factor hindering maize productivity in Trans Nzoia (Owino, 2010) where majority of the soils are acidic, deficient in nitrogen, phosphorus and at times other nutrient elements. Application of 188 kg/ha of DAP gave the best crop yield (Owino, 2010). Oluoch-Kosura et al (1999) found that 82.7% of large-scale farmers had by 1991 adopted fertilizer application in high-potential zones, while 63.2% of scale-scale farmers had done so in the these zones. Although farmers are aware of reduced soil fertility and its effects, their capacity to address the issues is limited leading to poor yields Roussel (2012).

De Bauw et al (2016) studied soil fertility constraints along the slopes of Mt. Elgon and explores its corresponding gradients in plant nutritional status. The authors found that Soil pH, soil available P and exchangeable K, Ca and Mg are significantly decreasing with elevation. Consequently, different altitude-specific nutrient limitations may be present due to antagonistic interactions between elements. It follows that a general fertilizer recommendation cannot be made in these regions and that the soil fertility problems along these slopes should be specifically addressed and appropriately managed according to the local requirements.

Due to the net impact of soil fertility depletion, sustainable production of maize will require regular soil fertility amelioration which more commonly done with commercial fertilizers. Other options of improving soil fertility include application of farm yard manure, composting, and integrated N-fixing plants. Even then, better targeted information will be needed for specific crops in response to the different crop requirement and soil fertility status.

Structures in soil conservation measures

Soil conservation in the eastern Africa region has a long history going back almost 70 years. In the two East African countries of Uganda and Kenya, the colonial authorities used coercive approaches to introduce new land-use and conservation methods, such as terracing and forced destocking, resulting in negative attitudes to conservation. This 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. For Kenya, the Soil and Water Conservation Programme under the Ministry of Agriculture that was implemented for about twenty five years from 1974 assisted a great deal. But it is now almost twenty years with no coherent resource management strategy in place, and there is genuine alarm over the reversal of the massive gains made.

The effectiveness of erosion management requires quick reduction of slope and slope length. Structural measures are quick to achieve this but expensive. In their work west of Mt. Elgon, Mugagga and Buyinza (2013) reported that check dams and gulley controls were the most common structural measures adopted by farmers in all the three sites studied. They also observed that the level of adoption by park-adjacent communities was lower compared to distant ones. People near the forest were reluctant to invest in long term conservation techniques due to the tenure insecurity. On the other hand, the authors attributed the high adoption rate by distant communities to the transferability, alienability, exclusivity and enforceability rights that secure private land.

The observations by Mugagga and Buyinza (2013) are important to consider because they are socially and economically important for sustainable management of land resources and ultimately influence how people manage their land.

Strategies for coping with multiple challenges

In response to existing challenges and assured climate change, scientists the world over are working hard to develop effective coping strategies that land users can apply to enhance sustainability. The challenges cited above require expanded and specific strategic action. (Roussel, 2012) proposed an integrated approach comprising complementary projects targeting a specific sector of intervention in the watershed afforestation and reforestation, agriculture and Agroforestry practices, soil and water conservation practices, river bank protection, wetland management and solid waste and storm water drainage management. The key focus is environmental conservation, income generation and strengthening of local institutions. Olago et al (2015) agree with this approach but gave a more comprehensive the list of specific technology options including river bank protection, construction of dams, managed aquifer recharge, development of water allocation plans, rainwater harvesting, water retention through terracing and infiltration ditches, irrigation development, planting of high yielding and drought resistant crop varieties, development of agroforestry, development of better water use efficient technologies, application of soil moisture retention methods, crop rotation, development of information and early warning systems, treatment and recycling of wastewater and breeding and cultivation of diversified native species.

3.6 Pollution in the Ecosystems

3.6.1 Introduction

In the context of Mt Elgon and Cherangany Ecosystems, it is easier to connect with the larger, more easily felt need of the region. There is no doubt that the best body that easily demonstrates pollution effects on the region is Lake Victoria. The two ecosystems are connected to the Lake through the commonly shared Nzoia River Basin.

Given the nature of this assignment and the methods that are applied to make pollution assessments, it was not possible to carry out a detailed field investigation. However, there has been very keen interest on Lake Victoria that has generated a lot of reason for scientific investigations around the Lake.

This report is therefore a synthesis of some available reports on various aspects of pollution around the lake, with special reference to Nzoia River Basin. Specifically, the report covers the following:

1) General changes - water temperature, pH and conductivity levels
2) Changes in dissolved oxygen (DO), biological and chemical oxygen demand (BOD and COD)
3) Total Dissolved Solids (TDS) especially heavy metals
4) Nutrients in river water
5) Total Suspended Solids

3.6.2 General changes

Based on their work on monitoring water quality at Mumias Sugar Company, Akali et al (2011) reported no significant change in water temperature. However, they observed that the treatment process tended to lower the pH to slightly acidic levels with a mean value of 5.5 which is below the recommended NEMA level of 6.5-8.5. The more acidic the discharge was likely to increase acidity of the receiving river water and affect the aquatic environment. TDS load at 55.8 mg L^{-1} upstream of the factory increased from 542.47 then 1538.5 mg L^{-1} which is beyond NEMA standard of 1200 mg L^{-1}. TDS value at the effluent discharge point was high but within allowable limits at other sampling points downstream of the discharge point. The authors concluded that TDS loading from Mumias Sugar Company was not a significant pollution hazard in the River Nzoia catchment.

TDS values vary considerably from one water body to the other. Davis (1996), quoting Yurith (1982) gave average TDS value of 2500 mg L^{-1} and a pH of 9.2 Lake Turkana. Lake Turkana is a permanent water body and is fed chiefly by the Turkwel river (deriving significant amounts of water from Mt Elgon and Cherangani Hills) and Omo River (Ethiopia). The reason for its high value is the high evaporation rate in the region.

In comparison, Lake Victoria is much more sensitive to pollution than the other Great Lakes due to its relatively short water residence time of 23 years (Davis, 1996). It is also the recipient of all rivers around the Basin. It has much lower TDS but which vary around the lake. Tenge et al (2015) found conductivity levels of 164-291 µs cm^{-1} for Malakisi River even though it came from a watershed that is very similar to upper Nzoia. This level of turbidity was higher than WHO recommendation.

BOD and COD

Davis (1996) found that some indication of the level of organic acid anions, humic acids and fulvic acids can be given by typical biochemical oxygen demand (BOD), chemical oxygen demands (COD) and NO, levels obtained in recent surveys. Moreover, BOD values are nearly always several times higher than the averages for freshwater and maximum permissible drinking water levels. In many studies however, COD and NO, levels are often low and well within drinking water levels.

Tenge et al (2015) studied water quality status of Malakisi River, one of the rivers to the south of Mount Elgon. They found COD and BOD and conductivity levels of the river to be, respectively, 15- 40 mg L^{-1} and 7 -21 mgL^{-1} compared to the WHO standards of 50 and 20. These levels were low compared to the WHO limits, indicating low organic pollution of the river water. The authors also found the River to record low levels of Zn, pH, NO_3^-, PO_4^{3-}, SO_4^{2-}, F-, BOD, COD, total hardness and conductivity levels, so that the River met the WHO water quality criteria for these parameters. However, Cu, Mn and Fe were found to be higher than WHO maximum required levels. On this basis, the authors were of the view that Malakisi river is polluted and preliminary treatment of water is required.

In their study, Akali et al (2011) found that effluent from Mumias Sugar Factory caused significant changes on upstream water by increasing BOD, COD, TDS and TSS by 24% (2663 to 3340.6 mgL^{-1}), 100.6% (5562 to 11158 mgL^{-1}), 183.6% (542.5 to 1538.5 mgL^{-1}) and 266% (220 to 805.1 mgL^{-1}). The treatment systems at the sugar miller were obviously not very effective in handling the waste being directed at the river. Western Kenya is a key producer of sugar, and it is not clear how compliant the other sugar millers are with respect to environmental standards. Going by the discharge at Mumias, stricter measures clearly need to be enforced. In their study, Twesigye et al (2011) demonstrated that there were also increases of TDS, EC and TSS, mixed results of NO3- and PO4-, and consistent decreases in DO for water samples taken from Nzoia at Pan Paper, Nzoia Sugar, Mumias Sugar and lower Nzoia River.

Nutrients Flows

Mt Elgon and Cherangany ecosystems are a heavily agricultural as they constitute the most important maize production region in Kenya. Maize production requires application of substantial fertilizers every year to sustain yields. Most of this is placed in the top 5-10cm of the soil. When erosion is accelerated, the applied fertilizer is one of the substances that farmers also lose besides soil. The loss of fertilizer through erosion is enormous.

In their study, Tenge et al (2015) found that the levels of nitrates, phosphates and sulphates for Malakisi river during dry and wet seasons was 0.07-1.0 mgL^{-1} (NO_3^-), 0.06–1.442 mg L^{-1} (PO_4^{3-}) and 0.09–1.1mg L^{-1} (SO_4^{2-}). These figures were very low compared to WHO limits. The NO_3^- and PO_4^{3-} were however slightly higher than those established in Nzoia river (NO_3^- 0.01-0.13 mg L^{-1}, PO_4^{3-} 0.01-0.43 mg L^{-1}). Nzoia river, however, had higher SO_4^{2-} level (29.9 -66.7 mg L^{-1}) compared to Malakisi river. High concentration of the nutrients P and N are important contributors to the increasing eutrophication of Lake Victoria, and is generally held responsible for the continuing proliferation of the water hyacinth in the Lake Oguttu et al (2008). Both physical and chemical analysis of water quality revealed high levels of phosphates and nitrates along the agricultural zones of River Nzoia Basin (Twesigye et al, 2011). In another study, Nyilitya et al (2016) showed that Nzoia River downstream of Eldoret town had $\delta^{15}N$ and $\delta^{18}O$ values of 13‰, 6‰ respectively while the river after Mumias sugar factory had 9‰, 10‰ isotope values respectively. A plot of $\delta^{15}N$ versus $\delta^{18}O$ indicates that most of nitrate from the three catchments originates from Soil Nitrogen and manure or sewage. However, sewage and industrial effluents has high contribution to river and ground water nitrate near towns and densely populated areas as observed by the enriched $\delta^{15}N$ values for Kisumu City Rivers ranging 10‰ to 18‰.

The Nile Basin Initiative (2005) presented detailed data on all major rivers flowing into Lake Victoria. Among these is Nzoia which is indicated to discharge an average 170.3 $m^3 s^{-1}$. This water has TN, PN and TSS of 0.897, 0.25 and 466 mgL^{-1}. The average TSS translates into 2504 metric tons annually.

Metals

Further to the results quoted above, Tenge et al (2015) also found that concentration values for Zn during dry and the wet was 0.16-0.50 mgL^{-1} and 0.20-0.60 mgL^{-1} respectively. Concentrations varied from one sampling station to another but all values remained within the WHO recommended limits. The concentration levels of Mn were 0.1-0.35 mgL^{-1} during both dry and wet seasons and were greater than the WHO maximum limit of 0.1 mg L^{-1}. This could have been due to the use of insecticides in tobacco farming including dithane M-45 or Mancozeb fungicide which is the main pesticide and fungicide frequently used. Mancozeb (dithane) is a product of Zn ion and Mn ethylene bisdithiocabamate with compositions of 7.4 % Mn2+ and 0.9 % Zn2+, respectively. The concentration values for Fe and Cu were 0.330-1.121 mg L^{-1} and 0.015-0.133 mgL^{-1}. These levels were also higher than the WHO limits of 0.3 mg L^{-1} and 0.05 mg L^{-1} respectively. In his study on the Mara River system, Kiragu (2009) found that concentrations of Zinc, Manganese and Lead were 0.014-0.114, 0.0001-0.029 and 0.0003-0.0020 mgL^{-1} and within the WHO safe limit. Iron concentration was 0.01-0.638 mg L^{-1} and above the WHO maximum allowable level of 0.30, while that of Copper was 0.0003-0.0020 mg L^{-1}. Davis (1996) quoted chromium concentration values above 20 mg L^{-1} for effluent discharge points of Thika River, far above WHO guideline figure is 0.05 mg L^{-1}. The main sources of heavy metal and trace element contaminants are industrial effluents such as from the leather, sugar and coffee factories and fertilizers. Oguttu et al (2008) found that leather industries discharged peaks of up to 1 250 mg·L^{-1} of the toxic Cr+6. An industry discharging effluents with such concentrations are of little benefit to a community.

Sediments

Tenge et al (2015) found that turbidity levels of the water at all the sampling stations during dry season and wet season were 54 - 238 and 60 – 248 NTU, respectively. The turbidity of Malakisi river alone before joining the Ndakaru river was 54 – 62 NTU. The level increased drastically after joining with the Ndakaru river where the turbidity level was 238 – 248 NTU. These turbidity levels were similar to those found from Nzoia River but were all above the WHO maximum limits of 5.0 NTU. Turbidity levels of Malakisi River water found to be similar to that of Nzoia river (7 – 66 NTU). However, they are much lower than the maximum obtained for Kerio Valley (620 NTU) and Mara river (1999 NTU). Turbidity seems to increase significantly in wet seasons as it is associated with soil erosion and transport to the rivers.

In a similar study of the Mara River using a different parameter, Kiragu (2009) found that sediment concentration for two of the major tributaries of Mara River showed Nyang'ores River with 35.5-268.5 mgL^{-1} and Amala River with 26.4-258 mgL^{-1}). The mean daily sediment loading of 128.47 tons day^{-1} (Nyangores) and 131.70 tons day^{-1} (Amala) imply that the Mara system still near pristine conditions. The author found that like other basins around Lake Victoria, sediment loading decreased to a minimum in the dry period from February to March before the long rains and then the loading remained at mean discharge in April-May before reaching a maximum in June. High concentration of suspended material at Amala River in June was caused by an increase in erosion attributed to increased agricultural activities and growing commercial centres. The author also used turbidity as a measure of suspended sediment. He found turbidity to be 45-250 NTU (mean 110 NTU) for Nyang'ores River and 28 NTU-290 NTU for Amala River (mean 130 NTU). These average turbidity figures for Mara River lie between the levels of Nyando and Nzoia Rivers. Evidence of soil erosion was seen in the development of gullies in the farms and along cattle tracks near the town. KIRAGU – furthermore, the average daily sediment loading indicates that the variability of sediment generation flow was more in Amala River (c.v of 92.7%) than in Nyang'ores River (c.v of 49.0%).

Fecal coliforms

In their work on Malakisi River, Tenge et al (2015) found that water samples in both wet and dry seasons had high levels of fecal coliforms during dry and wet seasons which ranged from 28 – 46 cfu/100ml, well above the WHO standard of 0. Davis (1996) was of the view that faecal contamination of surface waters, shallow wells and boreholes is an ever present problem over much of the sub-region, which is largely due to a lack of proper sewage disposal facilities.

Effects of pollution

In their study of macro invertebrate communities in Kipkaren and Sosiani Rivers in upper Nzoia, Aura et al (2011) found that there was higher species diversity upstream of Kipkaren River compared to downstream points. Higher abundance in these areas was probably due to less anthropogenic impact as indicated by higher levels of dissolved oxygen. Lower areas had been impacted by activities such as urbanization, agricultural inputs and sewage discharge which change conductivity, nutrient and dissolved oxygen levels. Other suggested causes are invasion by livestock and inability of some of the organisms to adopt and therefore they could not cope with the changes. The authors quoted previous works which show that changes in benthic macro invertebrates are not so much influenced by food availability but by differences in the ability of genera to tolerate the environment around it. In the case of Sosiani River, the authors concluded that the reason of the high abundance of macro invertebrates in uppermost area where there was nutrient inflow in sewage was probably due to high abundance of tolerant taxa to the sewage discharge from Eldoret Municipality.

For many of the basins around the Lake Victoria basin, agriculture is the most important source of income. In Nyando catchments, the major pests and diseases farmers have to contend with include various thrips, caterpillars and leaf miners, maize stalk borer aphids, cutworm, diamond back moth, termites and tobacco mosaic virus. Abongo et al (2014) found that organophosphates and other banned organochlorine pesticides such as lindane, aldrin and dieldrin were still being used by farmers. Pesticides transport was by storm water run-off and air drift into the lake. Fourteen pesticides were identified as commonly used of which four are toxic to bees and five to birds. There were symptoms of human ill-health that were associated with the use of some of these chemicals. With respect to wildlife, farmers identified declines in the number of pollinating insects, the disappearance of Red-billed Oxpecker and wild bird's fatalities. Use of agro-chemicals is not an isolated case for Nyando basin. Twesigye et al (2011) Soils from some selected fields in Nzoia River basin showed high levels of compounds such as aldrin, dieldrin, endosulfan, DDT, and endrin which are banned organochlorine pesticides.

Summary

The literature review presented above has looked at the major problems of pollution common to most agriculture watersheds in Kenya. The review has greater significance when associated with the two ecosystems which feed into Nzoi River widely reported in this study since the river largely exists because of water flows from the two ecosystems. Consequently, any flow in the river is a significant reflection of the status of the two ecosystems. High turbidity and high suspended solids is a direct indication of accelerated erosion from agricultural areas. High levels of nutrients especially N and P is an indicator of agricultural intensification without the appropriate management in place. On the other hand, high concentrations of industrial chemicals, BOD, COD and heavy metals will normally be an indicator of point source pollution from industries. Pollutant loading aside, it has been shown that pollution has negative impacts on acquatic organisms. Indeed, these can be a good proxy for measuring the health of an ecosystem. Their reduction or disappearance is an indicator that the system has problems and require urgent interventions. But human beings are also affected negatively: they may die from poisoning, pay more for cleaning polluted water, suffer from diseases, pay dearly for medical care, and lose economically when important organisms are no longer supported by the ecosystem. These negative effects are felt both on site and far away. Targeting of interventions addressing pollution problems should consider the this fact when dealing with far-flung areas.

4 CHAPTER FOUR: CONCLUSIONS

The applied methodology, based on GIS analysis of topographic data, made it possible to locate the areas where soil loss is high within Mt. Elgon and Cherangany ecosystem and to prioritize areas to implement soil and water conservation interventions. The community participation was important to verify the relevance and accuracy of the soil erosion risk (priority) maps and to motivate the community to use the map as a base for erosion understanding and to implement the conservation interventions. The approach is easy and uses available information and could be applied in both two ecosystems which are experiencing similar challenges. The result from the approach was tested and validated in selected areas with homogeneous soils, land use and climate pattern, hence, topography is the main driver for the variations in soil erosion. The study shows that the integration of GIS and participatory community mapping aspects has a potential to provide a basis to target susceptible areas for soil erosion with appropriate soil and water conservation. This helps in implementing efficient and sustainable conservation plans with high acceptance by the community.

Form the current study; it is agreeable that indeed soil erosion and sedimentation varies greatly between and within the two ecosystems. The highest erosion value is recorded in Cherangany ecosystem within Chepareria region with erosion value higher than 40 tons of soil per hectares per year. This is attributed to soil type, topography which is very steep and land use which is majorly grazing without management interventions. The low erosion and sedimentation rate are observed in areas with forest cover which are majorly restricted areas.

In Mt. Elgon ecosystem, the high erosion and sedimentation rate is majorly experienced in the lower part of the ecosystem, around Kimilili and Kapsokwony with low rates on the upper side of the ecosystem which is Kwanza region. The high erosion rate is attributed to soil and land use type without management strategy. It is interesting to note that during field visits and validation process, it was also observed that most of the erosion occurs on private farmlands with no formal management practice in place.

Land and soil management for sustainable production and development both Mt Elgon and Cherangany is of great concern, as land cover transformation and forest degradation are also taking place rapidly. The use of pesticides and fertilizers in agriculture is a potential problem, and could threaten biodiversity both directly (through poisoning) and indirectly (through eutrophication of aquatic habitats).

5 CHAPTER FIVE: RECOMMENDATIONS

The findings of the study showed that Mt. Elgon and Cherangany Hills are under continuous LULC dynamics and the two ecosystems are prone to soil erosion. The model showed the erosion risk areas of the two ecosystems and the factors which affect soil erosion. PGIS together with the RUSLE model helped to understand and in the validation of the findings and minimize the gap between the stakeholders' and scientists' understanding. Therefore, stakeholders, responsible bodies, including land managers and others, who have interest in related issues, should incorporate it during land use planning, soil and water resource conservation and management practices. As a result, the following recommendations are made for sustainable land use management, agricultural production and soil erosion management within Mt. Elgon and Cherangany ecosystems:

- The findings of this particular research suggest that land degradation in the steeper slopes is severe which needs urgent land rehabilitation intervention such as forestation programs, terracing and other remedial solutions within Mt. Elgon and Cherangany ecosystems.
- Soil erosion is a potential problem, mainly because of the mountainous nature and high mean annual rainfall, which exposes the soil as a whole and renders it susceptible to erosion. Basically, man cannot modify rainfall erosivity and soil erodibility factors. However, as the slope gradient and slope length factor is dominant in the magnitude of potential soil erosion in the area, it is possible to modify them through soil conservation practices at a small scale on agricultural land using detailed field assessment.
- Creating awareness among the society concerning optimum use of natural resources, conservation systems, driving forces including population pressure and their respective benefits is vital for sustainable land resource management. Therefore, the local managers and responsible sectors in Mt. Elgon and Cherangany to emphasize the importance of participation of the local communities in conservation activities and decision making regarding land use within the ecosystems.

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