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Assessment of Soil Erosion Hazards in Kambiti Subcatchment, Murang'a County, Kenya

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ABSTRACT

Erosion is a global problem that destroys soil and adversely affects ecosystem productivity. Soil erosion generally involves many processes but the major activities involve particles being transported and deposited to another location. With an increasing population, soil erosion, water availability, energy production, and biodiversity loss are some of the most pressing environmental problems around the world. Erosion is a hazard associated with agriculture in tropical and semi-arid areas. Kambiti sub catchment is part of the upper Tana catchment. The upper Tana catchment includes 25% of Kenya gazette forest. A large area of land has been degraded, resulting in a drastic reduction in surface water availability during the dry season and poor-quality water during the wet season caused by high silt levels. The main objective of the study is to assess erosion hazards using RUSLE model in Kambiti sub catchment area, Murang'a County. The specific objectives of the study were to determine the effect of rainfall erosivity and soil erodibility factor in Kambiti Sub catchment area in Murang'a County, to determine effect of slope factor to soil loss in Kambiti Sub-catchment area in Murang'a County, to determine the effect of crop protection and management factor in Kambiti Sub catchment area in Murang'a County to soil loss and to determine the strategies for management of soil and water in Kambiti Sub catchment area in Murang'a County. Data was collected from the catchment and analyzed using arc Geographical Information System to obtain the specific parameters in the revised universal soil loss equation model. Interpolation method was used to determine the mean annual precipitation. The k factor is a function of soil texture. Shape file for geological structure for Kenya was obtained from Kenya Agriculture and livestock Research Organisation and analyzed by use of arc GIS to obtain soil erodibility factor. The slope factor was analyzed using digital elevation model from arc view. Digital elevation model was gotten from STRM download. The C factor was derived from Landsat imagery from sentinel of 30metres by 30 metres. It was further analysed by unsupervised classification from Arc GIS. The sentinel clip of Kambiti sub-catchment was joined with ground trothing observations. The results were useful in estimation of soil loss therefore profiling the areas prone to soil loss. Study findings indicated rain drop impact and runoff were primarily responsible for causing erosion in Kambiti sub catchment. Anthropogenic factors played an important role in amplifying the severity of the damage, such as persistent vegetative degradation and destruction of soil structure due to organic matter depletion and routine shallow tillage. In recent years, erosion control has been hampered by the occurrence of gaps in knowledge regarding the integrated nature of erosion processes, leading to land damage caused by rill and inter-rill erosion going unaddressed. Poor people and those lacking capital to invest in reclaiming land are the main causes of abandoning degraded land. Through strategic awareness campaigns and education, soil erosion will be assessed and the knowledge gap will be closed. Participation of farmers in land use decisions is inevitable as it ensures that people who utilize land resources are recognized as equal partners in identifying problems and designing solutions. It was also recommended that Identification and operationalization of alternative off-farm income.

Key Words: *Rainfall Erosivity, Soil Erodibility, Crop Protection, Soil Loss, Strategies for Management of Soil and Water*

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1.0 Introduction

1.1 Background to the Study

The loss of soil from the earth surfaces by disintegration is across the board and adversely influences the profitability of the biological systems (Nicholas, 2004). Soil disintegration is the after effect of separation of soil particles. Soil erosion is generally affected by wind, rainfall and surface run off. The rapid rise of human population has led to soil decomposition, water shortage, energy depletion, and loss of biodiversity as the foremost environmental issues around the globe (Hedahin, 2005). It is a risk related with agri-business in tropical, arid and semi-arid zones. It influences the efficiency and manageability of farming in the long haul (Ritter, 2012). The changes perpetrated effects on soil by human-actuated disintegration over extensive stretch are huge and have brought about profitable land ending up less beneficial and frequently in the long run surrendered (Moore, 1983). Rain or wind vitality causes erosion when the soil is exposed to them. During a rain shower, raindrops hit soil with extraordinary power, removing dirt particles effortlessly. Along these lines, raindrops evacuate a thin film of soil from the land surface and makes what is named as sheet disintegration. This disintegration is the overwhelming type of soil corruption (Nicholas, 2004). The effect of soil disintegration is increased on sloppy land where frequently the greater part of the surface soil is diverted as the water sprinkles downhill into valleys and conduits (Ghose, 1989). Land utilization change has been underscored as one of the conspicuous triggers of world condition move. It is developing as a standout amongst the most pressing issues (Kurt, 2002)). Land utilization change has unsafe result on indigenous habitat.

According to Anderson (2010), soil degradation is one of the biggest challenges facing society, with a decrease in productivity of 2-40% with an average of 8.2% for the whole continent, and silting of reservoirs equaling 19% of total storage volume (Anderson, 2010). The problem of land degradation is widespread within Kenya, which also faces poverty and repeated natural disasters, such as droughts and floods. No matter where they result from-natural or human-induced-climate changes, climate variations affect the resilience of diverse ecosystems and sustain the livelihoods of people living in these zones. Among the problems contributing to land degradation are a lack of knowledge about the nature, extent and severity of the condition, and an inadequacy of tools and methods for assessing, monitoring and managing the situation (UNEP, 2002). The severity and extent of land degradation is expected in many areas to increase over time, according to recent studies extrapolating on local patterns of land degradation. The study by Muchena (2008a) reveals that over 20 percent of land is cultivated, 30 percent is forest, and 10 percent is grassland. In many cases, this degradation is caused by cropping in marginal lands.

According to (Bai and Dent, 2006) the dry lands around Lake Turkana and marginal croplands in the Lake Victoria basin region have seen the biggest declines in productivity. Although loss of net primary productivity (NPP) is sometimes understood to indicate degradation, losses such as these also result in a corresponding loss of human capital and community breakdown in rural communities, as well as poverty-related social costs and a reduction in ability to invest in preventing degradation. Although loss of net primary productivity (NPP) is sometimes understood to indicate degradation, losses such as these also result in a corresponding loss of human capital and community breakdown in rural communities, as well as poverty-related social costs and a reduction in ability to invest in preventing degradation.

Land use changes are therefore being driven by unprecedented economic development, expanding cities and growing rural populations, which, in turn, are leading to economic destruction and environmental degradation. While land degradation and land improvement are global development and environmental concerns, there has been little authoritative action taken in the Lake Victoria basin. In this regard, assessment of land degradation at basin level is of pressing importance for policy informed decisions concerning food and water security, environmental integrity, and subnational as well as national strategies for economic development and resource conservation. Land degradation is primarily caused by inappropriate land use, erosion of soil, water, and vegetation cover, as well as loss of soil and vegetative biological diversity, which negatively impacts ecosystem structure and function, according to Bai, *et al.*, (2008). This phenomenon has also been attributed to intensive land use including overgrazing, excessive irrigation, intensive tillage, and excessive cropping (IPCC, 2001). Land degradation is largely driven by policies and institutional failures in the public sector, private sector, civil society, and economic sectors, as well as civil strife. Blaike and Brookfield (1987) contend that we are still confused about the nature of the interrelationships and thresholds between these technical, institutional, and policy factors at different levels and scales as well as their temporal dimensions. Understanding and prevention of soil erosion is very critical because its effects leads to decrease in soil productivity. It also a causes siltation and water quality degradation. Soil erosion modeling assist in elucidating areas vulnerable to soil erosion in base line scenario. It underscores the possible causes of soil erosion. One branch of empirical soil modeling is the universal soil loss equation including the Revised Universal Soil Loss Equation. This empirical model estimates the rate of soil loss per hectare. The simplicity of the RUSLE is that it can be integrated with geographical information system for analysis. Data analyzed includes digital elevation, mean annual precipitation, granularity of soil, land cover characteristics.

1.2 Statement of the Problem

Kambiti sub catchment is a part of the upper Tana catchment. The upper Tana catchment incorporates 25% of Kenya newspaper timberland (Onyando, 2015). It has significantly experienced land degradation and an extraordinary diminishment of surface water accessibility amid the dry season and low quality water amid the wet season because of high residue level. The prevalent soils in Kambiti sub catchment are the profound and very much depleted sandy soils. These soils are free and joined with the uneven territories which are effectively dissolved. Soil disintegration is one noteworthy natural issue in the catchment. The greater part of the land is sloping with meager vegetation. Rill disintegration is extremely normal in developed land while chasm disintegration is found in unprotected waste channels, pathways and course outlets. This is exacerbated by sand mining and poor soil preservation measures. Soil disintegration may posture genuine sustenance security danger in the territory. The hazard can be assessed utilizing a suitable model of soil disintegration. For conservation efforts and at the basin scale, it has become imperative to identify the amount of erosion in a spatially distributed manner. There are several situations where policy makers and land managers are more concerned with the spatial distribution of soil erosion risk than the absolute value of soil erosion loss.

1.3 General Objective

The main objective of the study is assessment of soil erosion hazards in kambiti subcatchment, murang'a county, kenya

The specific objectives were:

i. To determine the effect of rainfall erosivity and soil erodibility factor in Kambiti Sub catchment, Murang'a County.
ii. To determine the effect of slope factor in Kambiti Sub-catchment, Murang'a County.
iii. To determine the effect of crop protection and management factor in Kambiti Sub catchment, Murang'a County.
iv. To map soil loss and vulnerability in Kambiti Sub catchment, Murang'a County.
v. To recommend the strategies for management of soil and water in Kambiti Sub catchment, Murang'a County.

2.0 Literature Review

2.1 Introduction

By definition, soil erosion is the transport of topsoil by water or wind away from the land and into another area. From an aerial perspective, soil erosion can be considered a geomorphic process that occurs continuously on the earth's surface. Soil disintegration is characterized as the physical debasement of the scene after some time (Jabbar 2003). Disintegration is a characteristic topographical display coming about because of the evacuation of topsoil by common agents like breeze, water transporting them somewhere else. Human intercession can essentially build soil disintegration rates. It is a huge horticultural disadvantage and conjointly one among the primary world natural issues (Borseli 2012). Disintegration is activated by a blend of factors such as slant, atmosphere (e.g. long dry periods took after by genuine precipitation), unseemly land utilization, cowl designs (e.g. thin vegetation) and environmental debacles (e.g. timberland fires).In addition, some characteristic alternatives of a soil will manufacture it a considerable measure of danger of disintegration (e.g. a thin layer of earth, free surface or low natural issue content). The strategy for disintegration includes separation, transport, and resulting affidavit. Urbanization, deforestation, and alteration of land utilization designs are the significant explanation for disintegration as of late. Disintegration process brings about loss of soil from a watershed and it is difficult to assess soil misfortune as it is achieved by a perplexing collaboration of different hydro-geographical procedures. Evaluating the soil misfortunes hazard and its spatial circulation are one of the key variables for effective disintegration appraisal and expectation (Hagos.2016). Spatial and quantitative data on soil misfortune on a territorial scale adds to protection and disintegration control and administration of nature. Due to dry periods and erosive rainfall falling on steep slopes, soil erosion is a worldwide phenomenon that affects areas such as the great horn of Africa and large parts of sub-Saharan Africa (Onori *et al.*, 2006).

Deforestation, soil erosion, wind erosion, soil nutrient mining are some of Kenya's major problems in terms of land degradation. De Graff (1993) estimated that Kenya loses 72 tons of soil per hectare per year due to water erosion A study by Dregne (1990) reported that water erosion had permanently reduced soil productivity in some 20 percent of Kenyan territory. Often, soil erosion is observed on slopes near water streams, along riparian areas, and near marginal lands.

2.2 Soil Erosion Models

Since the 1930s, predicting and assessing soil erosion has been a challenge to researchers (Lal, 2001). These models can be classified as empirical, semi-empirical, or physical process-based, depending on their nature. Renard *et al.* (1991) note that one of the most commonly used empirical models is the Universal Soil Loss Equation (USLE), which was developed by Wischmeier and Smith in 1965, and the Revised Universal Soil Loss Equation (RUSLE). A number of other soil erosion prediction models, including Erosion Productivity Impact Calculator (EPIC) (Williams *et al.*, 1990), European Soil Erosion Model (EUROSEM) (Morgan *et al.*, 1992) and Water Erosion Prediction Project (WEPP) (Flanagan and Nearing, 1995), are also utilized. By estimating soil loss by volume or mass, these methods analyze soil erosion.

For quantitative and qualitative soil erosion evaluation, these models have been used, modified, and improved within research over many years. For a general estimation of erosion phenomena, the USLE/RUSLE model has proved useful. Although the model can simulate erosive rainfall events, its outputs are dependent on the single parameter estimation (Flanagan and Nearing, 1995 Recently, theoretical and empirical methods such as USLE and RUSLE have been combined to determine soil erosion sensitivity effectively (Li *et al.*, 2006). In order to describe causal factors, a number of multi-criteria methods were used to produce and combine spatial data. Other studies have advocated the use of a hierarchical weighted comparison method (AHP) in a GIS environment (Rahman *et al.*, 2009). Researchers have been able to perceive erosion in a simplified, less expensive, and more efficient way thanks to the integration of remote sensing and GIS technologies, according to Wenfu *et al.* (2008). This integrated approach was implemented by many researchers. GIS-processed DEM can be used to generate terrain, slope gradient, and slope length, which are all required inputs to soil erosion models. The data from multitemporal remote sensing (satellite images) provide valuable information about the state of seasonal land use and derivations of erosional and deposited features, such as gullies, barricades, braided channels, abandoned channels, and vegetation.

GIS technique has also been used to evaluate soil erosion hazards quantitatively by using different empirical models. (Rahman et al.,2009) observes that soil erosion is a complex issue that is influenced by a range of factors, making it challenging for investigators to understand how soil erosion is linked to these factors. Using the essential Geospatial methods, he recommends that soil-based erosion studies be conducted in a systematic and integrated manner. The use of remote sensing (RS) and geographic information system (GIS) technologies for soil erosion hazard assessment and the application of an empirical model specific to the spatial dynamics of soil erosion are required to produce reliable results. (Surjit *et al.*, 2015).

Reconsidered Universal Soil Loss Equation (RUSLE) was declared to be the redesigned rendition of USLE (Renard *et al.* 1997) which joins enhancements in factors in view of new information however keeps the premise of USLE condition. The changes depended on the amendments of USLE factors including improvement of another methodology to compute vegetation factor, acquainting new calculations with reflect rill to interrill disintegration in slant length and steepness elements, and update of climatic elements in light of extended database of precipitation overflow in Western U.S. RUSLE show is improved with a computer program to encourage the counts. The model has stood the test of times and gives feedback that is essential for general estimation of erosion phenomena. However, RUSLE is not able to predict deposition or the pathway taken by eroded materials and sediment as it moves down stream since it only estimate mean annual soil loss.

2.3 RUSLE Modeling factors

Based on conditions like precipitation pattern, soil composition, geology, editing framework, and administration procedures (Wischmeier, 1978), the Revised Universal Soil Loss Equation (RUSLE) predicts the long-term normal rate of soil disintegration in a field. This model predicts the amount of soil misfortune that will result from a single slope disintegration, but it does not account for erosion from a gully, wind, or culturing. Elwell (1981) describes how this disintegration display can be used in various pruning and administration frameworks, while on the other hand, it can also be used in conditions unrelated to horticulture, for example, building sites. Using the RUSLE, a soil misfortune rate from a field can be determined for a specific yield and management structure to create "middle of the road" soil loss rates. Elective management and product systems can also be assessed to determine the adequacy of protection policies when planning a farm (Kurt, 2002). Elective management and product systems can also be assessed to determine the adequacy of protection policies when planning a farm (Kurt, 2002).

The soil degradation at a given site can be evaluated using five main factors. Factors measure the severity of soil misfortune at a particular location based on their numerical values. Because of changing climatic conditions, soil misfortune can be reflected in these elements differently. Therefore, the qualities acquired from the USLE are especially relevant to long-term midpoints.

The RUSLE model is expressed using the equation:

A=RXKX LS X C X P…………………………………………………Equation 1

Where:

A is the average annual soil loss in mass per area (ton per hectare) or (megagram per hectare). This quantity depends upon the following:

R is the rainfall – runoff erosivity index factor

K is the soil erodibility factor

LS is the Length and Steepness factor

C is the crop management factor

P is the conservation practice factor

2.4 Rainfall Erosivity

Precipitation is one of the main thrust of water disintegration surface keep running off outcomes from raindrops which beat on the soil surface. Precipitation ace and time (Renard, 1994). The erosive capability of a rainstorm and its related spillover is an element of precipitation vitality, the most extreme delaerosivity is the potential capacity of the precipitation to cause disintegration which shifts in spyed power and their connection. The general soil misfortune condition erosivity file is yearly aggregate of every shower result of precipitation vitality and its greatest thirty moment managed force (De Roo, 1993). Weischmer and smith (1978) found that dirt misfortune expanded directly with a tempest add up to motor vitality times its most extreme 30 minutes power. To compute the R factor the following equation is used.

$R=0.0483P^{1.610}$ ………. when P is less or equal to 850mm……………. Equation 2

$R=0.004105P^2 – 1.249P + 587$………..where P is greater than 850

2.5 Soil Erodibility

A quantitative description of the inherent erodibility of a particular soil is referred as Soil e rodibility factor. It is a measure of the soil particles susceptibility to detachment and transpo d]y[proiuu7765rt by rainfall and run off (George 2005). Every particular soil has soil erodibility factor index. It reflects how different soils undergo erosion to varying degrees regardless of other factors such as infiltration rate, permeability, and water capacity. Texture and organic matter are the two most important factors that determine soil erodibility, but permeability, structure and organic matter are also important. Soil erodibility factor ranges in value from 0.02 to 0.69.In determining the K factor the following mathematic expression is used (Kurt 2002):

$K_{fact}=(1.292)\{2.1\times10^{-6}F_P^{1.14}(12-P_{om})+0.0325(S_{struc}-2)+0.025(F_{pem}-3\}$………Equation 2.3

Where $F_P=P_{silt}(100-P_{clay})$Where

F_P---------particle size

P_{OM}-------percentage organic matter

S_{STRUCT}-----soil structure index

F_{PERM}------profile permeability factor

P_{CLAY}-----percentage clay

Table 1: Soil Erodibility Facto rK_{fact}

	P_{om}(%)		
Textural Class	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21

	P_{om}(%)		
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay	0.2	0.13	

Source (Stewart *et al.* 1975)

2.6 Length and Steepness Factor

LS factor represent a ratio of soil loss under given condition. The steeper and longer the slope, the higher the risk of erosion (Garde, 1990).

The NN factor can be estimated by use of the following formula.

NN=[0.065+0.0456(slope)+0.006541(slope)^2]

Table 2 Slope factor

slope/steepness	less than 1%	1%-3%	3%-5%	**>5%**
NN	0.2	0.3	0.4	0.5

2.7 Crop Management Factor

In terms of soil loss prevention, crop management is used to determine how effective soil and crop management systems are. Essentially, the crop management factor compares the soil loss on a particular crop and management system with the corresponding loss from continuously fallow and tilled land, which has a value of 1. C factor is influenced by the type of crop grown, the timing of tillage, the use of winter cover, and solid manure application (Omwega, 1989).

C-Factor represents the effect of biomass below ground, plants in the soil, and activities that disturb the soil on soil erosion. The modules have been constructed for time-variant (cropping/rotation scenario) as well as time-invariant (average annual values) (Wesheimer, 1978).

2.8 The Support Practice Factor

The P factor compares the eroded soil from inclination to loss that results from conservation practices, for example, contour farming and strip-cropping. The strategy for deciding the P Factor is introduced by a diagram (Jabbar, 2003). The P-factor in USLE is the proportion of soil adversity with a particular help practice to the relating loss. For developed land, bolster hones incorporate molding (culturing and planting on or close to the shape), strip editing, terracing, and subsurface waste. On dry land or rangeland territories, utilization of soil exasperating practices situated on or close to the shapes that store dampness and lessen spillover is additionally utilized as help rehearses. The P-factor does not consider enhanced culturing practices, for example, no-till and other protection culturing frameworks, turf-based yield turns, trim buildup administration, and surface roughening. Such disintegration control rehearses are considered in the C-factor (Kurt 2002).

2.9 Conceptual Framework

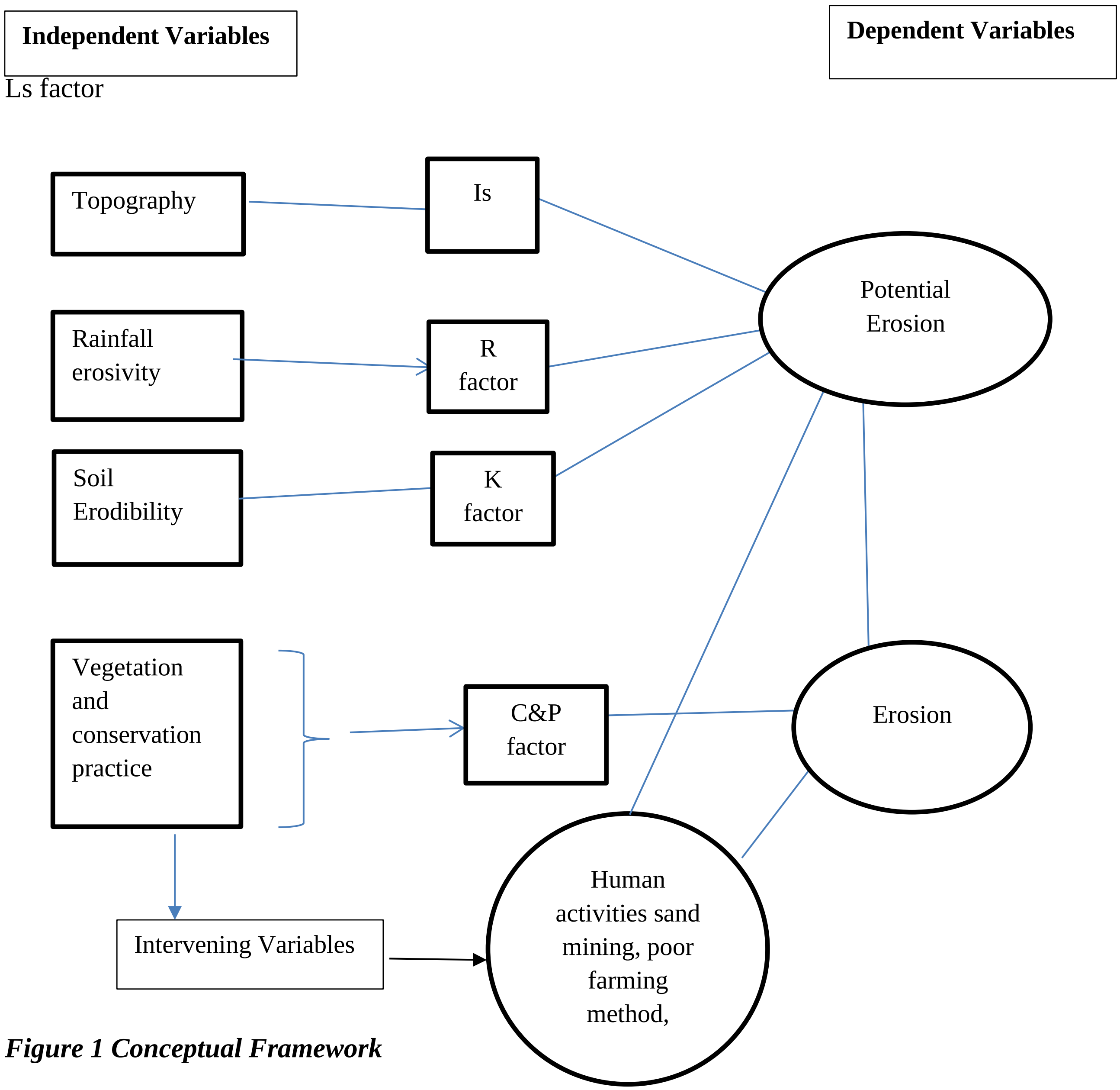

Figure 1 Conceptual Framework

From the above (fig 1) Rainfall erosivity (R factor), length of slope (LS factor), slope steepness, soil characteristics (k factor), land cover and conservations measures (CP factor) are the main variables for erosion to take place as per the RUSLE model.

3.0 Research Methodology

3.1 Study Area

Kambiti sub catchment area is in Murang'a south sub county of Murang'a. The region is located between 0°450' and 0°550'South and 37°20' and 37°100' East longitude. The place is characterized by ridges and valley (District Environment Action Plan, 2014). Some of the valleys in the sub catchment area are separated by rivers which drain to river Tana that is Maciana stream,sabasaba Kambiti stream and Matheng'eta stream and many channels. Kambiti has a population of 21,195 and an area of 77.80km² (Kenya National Bureau of Statistics, 2017). Kambiti sub catchment is characterized by challenging topography, rivers carry heavy sediment loads due to soil erosion and deeply eroded gulleys (Waruru, 2002). The valley are highly dissected by erosion mostly from the runoff. The region is dominated by Tertiary and Pleistocene volcanic, which is overlain by black cotton soil, lateritic soil and Basement System pediments which is overlain by variable sandy soil and black cotton soil towards the end of section.

Kambiti sub catchment has a tropical climate. The average annual temperature is 20.7 °C. The average annual rainfall is 983 mm. Soil erosion is exacerbated by sand mining which makes the soil loose hence easily eroded by water. The area is densely populated because of the agricultural potential. Agriculture and livestock keeping constitute the major socioeconomic activities in the project area. Plantations are limited to small-scale farms with very few large-scale farms. 39% of the population lives in absolute poverty (District Environment Action Plan, 2014). Since agriculture began, soil erosion has been a major threat to soil quality primarily due to wind and water erosion. Consequently, sufficient food production has been hampered due to soil erosion (Soil erosion has been a major threat to soil quality since the dawn of agriculture). Sand mining has also led topsoil erosion. Youth today participate in these practices in large numbers. Environmental ignorance and lack of awareness have trapped society in a cocoon that does not even understand the purpose of its existence (NEMA, 2005). Understanding soil erosion is a prerequisite in the broad understanding of the environmental hazards

3.2 Methodology and data collection

Modeling soil erosion process based on Rusle equation intergraded with arc view GIS and it is the primary method of the study.

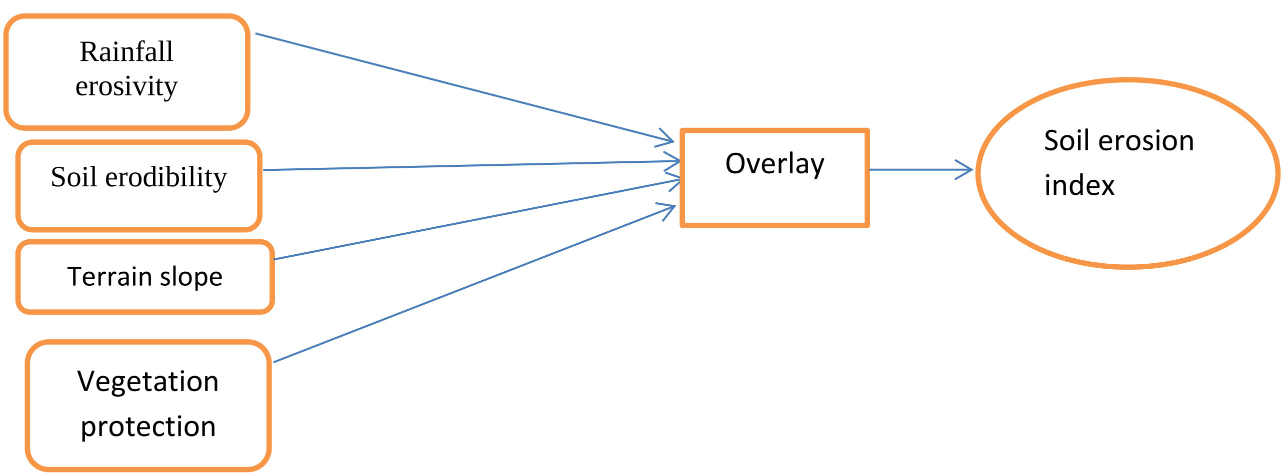

Figure 2: **Summary of Modelling Approach**

3.2.1 Rainfall Erosivity

Rainfall erosivity is the potential for soil erosion caused by rain falling on a surface (Lal, 1990). Several researchers have suggested that the R factor is the most important parameter in estimating erosion from RUSLE and is strongly correlated with soil loss at many regions and worldwide stations (Fu *et al.*, 2006; Millward and Mersey, 1999; Renard and Freimund, 1994; Wischmeier and Smith, 1978). Generally, researchers use historical rainfall data to determine the erosion factor, as well as applying a variety of formulas specific to the area. It is more difficult to estimate R factor in data-poor areas or when climate stations are very few. This method was used to determine the mean annual precipitation. Mean annual rainfall was gotten from Kenya meteorological for Murang'a County. By use of arc GIS Inverse distance weighted (IDW) interpolation was run for the whole county and then Kambiti sub catchment was clipped from county.

Table 3 Mean annual rainfall

Lon	Lat	Alt	ID	Station Name	Annual
37.2	-0.88	7200	9037018	PUNDA MILIA CO-OP SOCIETY LTD - MAKI	938.5
37.18	-0.9	4465	9037143	DISTRICT OFFICE - MAKUYU	941.5
37.18	-1.03	5000	9137000	MITUBIRI;NANGA ESTATE	854.3
37.07	-0.98	5080		KALRO AGROMET STATION	936.2
37.32	-0.97	4150	9037192	ITHANGA CHIEF'S OFFICE	948.5
37.17	-0.88	1939	9037044	KARATINA ATHARA ESTATE - MAKUYU	1063.3
37.17	-0.72	4200	9037007	DISTRICT OFFICE - MURANG'A	1108.3
37.3	-0.98	1928	9037016	KITITO COFFEE ESTATE - MITUBIRI	1054.7
37.32	-0.95	4250	9037223	MITHINI MARKET (ASST. CHIEF'S HOME)	897.7
37.1	-0.63	4900	9037181	MUGEKA CHIEF'S CENTRE	1490.4
37.15	-0.73	4300	9037109	MURANG'A WATER SUPPLY	1290.2
37.03	-0.72	5000	9037042	KAHUHIA GIRLS' HIGH SCHOOL - MURAN	1403.2
37	-0.9	5300	9037210	KANDARA AGRICULTURE OFFICE	1200.5
37.03	-0.75	5000	9037063	MUGOIRI GIRLS' SECONDARY SCHOOL -	1428.6
37.02	-0.72	5531	9037136	KIROGO HIGH SCHOOL - MURANG'A	1786.8
37	-0.75	5382	9037204	KAHURO D.O.'S OFFICE	1560.2
36.78	-0.83	1966	9036283	KIMAKIA FISHING CAMP	1746.7
36.93	-0.7	1970	9036302	GITHIGA W. MACHARIA FARM	1659.3
36.9	-0.85	1978	9036329	KIGORO CHIEF'S CAMP	1715
36.9	-0.68	6600	9036100	KANYENYAINI - MURANGA	1924.9
36.9	-0.65	6448	9036293	KIHOYA CHIEF'S CAMP	1993.8
36.75	-0.77	8080	9036233	KIMAKIA FOREST STATION	2040.8
36.93	-0.8	6228	9036347	KENYATTA FARMERS TRAINING CENTRE	1712.8
36.83	-0.7	7400	9036292	ICHICHI KARURA VILLAGE	2100.3
36.8	-0.75	7010	9036248	NJIRIS HIGH SCHOOL	2040.2
36.85	-0.75	7000	9036212	KINYONA GITUAMBA EXP. FARM - MURAI	2219.1
36.77	-0.72	8500	9036259	GATARE FOREST STATION	2332
36.83	-0.67	6900	9036315	TUSO CAMP	2567.3
36.83	-0.68	7700	9036330	WANJERERE FOREST STATION	2304.1

Spatial location of rain gauges in Muranga and interpolation by I.D.W

3.2.2 Soil erodibility

K factor measures how erodible soil is as a function of soil properties. According to Fu *et al.*, (2006) and Millward and Mersey (1999), soil long-term reactions to heavy, erosive precipitation events are described by this term. Wischmeier and Smith (1978) developed a simple method of measuring five soil properties, namely the organic matter content (OM), soil structure, soil permeability, and sand content. Researchers typically use existing maps of soil in areas where they can obtain hard copy soil maps from government agencies in order to create a vector coverage map. The soils are then classified according to their properties based on sources such as the Agricultural Handbook as recommended by Shamshad *et al.*, (2008), or the FAO soil classification system as used by Millward and Mersey (1999). The k factor is a function of soil texture. A shape file for Kenya soil was gotten from Kenya agriculture research institute. By use arc GIS clipping was done for the county and narrowed down to sub-catchment. The k factor attribute was added as a new attribute depending on the type of soil was used to obtain the k factor.

3.2.3 Slope Factor

The length and slope factors in the RUSLE model characterize how topography affects erosion. The slope length, as commonly defined by researchers in the field of soil erosion, is the distance between the point of origin of overland flow and the point where deposition begins (Renard *et al.*, 1997; Wischmeier and Smith, 1978). In their study, Haan *et al.*, (1994) found that as slopes are widened, erosion occurs as water flows faster. As a result of this, soil loss increases proportionately to slope length and slope inclination (McCool *et al.*, 1987The slope length and slope incline combined give a good estimate of soil erosion rate. There are mainly two types of erosion, namely rill and inter-rill erosion, which is caused by surface runoff toward the direction of slope. The latter happens when rain falls on the ground. The RUSLE encompasses both types of erosion and does not discriminate between them. In general, researchers calculate both factors (Land S) together in order to compute the topographic effect on erosion. Slope factor was analyzed using spatial analysis, a raster format was gotten from STRM satellite. Hill shade attribute was also used for ground truthing. This was useful in computing digital elevation model (DEM).slope factor model from arc GIS was computed in terms of percentages. This aided in computation of slope factor in terms of LS in the attribute table. The formulas used was $LS=[0.065+0.0456(slope)+0.006541(slope)^2]$

3.2.4 Crop protection factor

Cropping protection factor for erosion control should be based on USLE and RUSLE, as crop patterns affect erosion process (Vinay *et al.* 2015). Based on the land use-land cover map of the study area, a C factor map was prepared. The C factor was derived from Geo processing by use of unclassified classification in arc GIS tool box. To obtain the vegetation cover from the raster data. Ground trothing was done to identify the vegetation in the sub catchment and an attribute table obtained which enabled classification of the vegetation.

Table 4 Sampled Vegetation

1 D	Long	Lat	C_Factor	C_Value	P_Factor	P_Value
1.0	37.20241800	-0.9140720	Planted Forest	0.001	Planted Forest	0.7
2.0	37.21406700	-0.8996000	Water Body		Without Practice	2.689
3.0	37.22646700	-0.8943320	Mangoes	0.35	No Practice	1
4.0	37.23094500	-0.8310570	Buildings	1	Buildings	1
5.0	37.22651700	-0.8301620	Banana	0.35	Strip Cropping	0.35
6.0	37.22434300	-0.8303580	Maize	0.38	No Practice	1
7.0	37.21831700	-0.8207300	Mangoes	0.35	No Practice	1
8.0	37.21829200	-0.8172900	Buildings	1	Building	1
9.0	37.21893300	-0.8149170	Schrubs	0.25	No Practice	1

10.0	37.2230750 0	-0.8022680	Mangoes	0.35	No Practice	1
11.0	37.2181700 0	-0.8011420	Schrubs	0.25	No Practice	1
12.0	37.2170730 0	-0.8005750	Schrubs	0.25	No Practice	1
13.0	37.2138570 0	-0.7989250	Maize	0.38	Contouring	0.6
14.0	37.2129230 0	-0.7975630	Schrubs	0.25	No Practice	1
15.0	37.2124170 0	-0.7955430	Banana	0.3	Strip Cropping	0.35
16.0	37.2088630 0	-0.7872580	Schrubs	0.25	No Practice	1
17.0	37.2078520 0	-0.7805200	Maize	0.38	No Practice	1
18.0	37.2087320 0	-0.7786700	Buildings	1	Buildings	1
19.0	37.2202900 0	-0.7821000	Maize	0.38	No Practice	1
20.0	37.2633830 0	-0.8040280	Banana	0.3	Strip Cropping	0.35
21.0	37.2504750 0	-0.8142500	Bare Land	1	Bare Land	1
22.0	37.2422130 0	-0.8154270	Oranges	0.35	No Practice	1
23.0	37.1910000 0	-0.8150000	Shrubs	0.25	No Practice	1
24.0	37.1890000 0	-0.8380000	Shrubs	0.25	No Practice	1
25.0	37.1750000 0	0.8350000	Bananas	0.3	Contouring	0.6
26.0	37.1810000 0	-0.8660000	Planted Forest	0.001	Planted Forest	0.7
27.0	37.1830000 0	-0.7730000	Bananas	0.3	Contouring	0.6
28.0	37.1830000 0	-0.7910000	Maize	0.38	Strip Cropping	0.35
29.0	37.1640000 0	-0.7880000	Banana	0.3	No Practice	1
30.0	37.1600000 0	-0.8240000	Planted Forest	0.001	Planted Forest	0.7
31.0	37.1850000 0	-0.9080000	Mangoes	0.35	No Practice	1
32.0	37.1710000 0	-0.8860000	Bare Land	1	No Practice	1

3.2.5 Protection factor

The conservation and management practice factor (P) is a dimensionless ratio that accounts for soil loss under certain management practices (Renard *et al.*, 1997; Wischmeier and Smith, 1978). Millward and Mersey (1999) state that contouring and tillage practices can have a significant effect on soil erosion. Plowing up and down without contouring, strip cropping or terracing is the general practice of farmers in the agricultural sector, resulting in higher P values. The p factor was obtained from sub county agricultural officer and also through observation. This will consider various conservation measures that are being undertaken in the region. These will include contouring (tilling and planting along the contour), strip cropping, terracing, and subsurface drainage. From observation and secondary data from agricultural office each of them will be labeled with its P value.

3.2.6 Strategies form management of soil and water conservation

Four variables were analyzed that is awareness, economic, farming method and sand mining. Questionnaires (appendix one) was administered to the sampled population of fifty residents in the catchment area.This was based on the five sublocation in the catchent. This was obtained using by purposive sampling. Descriptive statistics were used to analyze the data.

3.3 Research Instruments

The study used questionnaires and interviews as research instruments. To collect primary data for the study, a set of questionnaires was distributed to respondents. Respondents had the option of answering a short question or checking a suggestion from the list of possible answers on the questionnaire. The collected instruments were analyzed and edited for better analysis after they were checked for proper scoring. Secondary data was also used to obtain parameter in RUSLE equation. This includes rainfall data, soil type and elevation. Field observation was used to derive plant cover and protection factor

3.4 Ethical considerations

The principle of voluntary consent stipulates that participant must wish to participate in the research according to Mugenda and Mugenda (2003). Consent should be based on the following: the purpose of the research study, identification of the researcher, and any benefits that may be derived. Mugenda (2008) notes that research participation is voluntary, and subjects may withdraw from any study at any time without consequence. Prior to administering questionnaires or conducting interviews, the researcher made sure that the names of the respondents were not on the research instruments. Before respondents filled out the questionnaires, the purpose of the study was explained to them. Research participants were not compelled to participate in the study, and the researcher assured them that all information collected would remain confidential and used only for academic purposes.

4.0 Results and Discussion

4.1 R FACTOR

The R-Factor values of the Kambiti Sub catchment were included in the legend of the thematic map as fig 3 The R-Factor represents the ease with which soil particles can be detached from the parent rock as a result of splash effect and sheet wash erosion. Going by the legend, the R-Factor values ranged from 938 to 1161 mm. The R factors are based on mean annual precipitation. It is easier for the soils in the upper course of the Kambiti Sub-catchment to be eroded, an observation largely attributed to the high amount of rainfall experienced within this region and other factors such as surface cover(plate 1).

***Figure 3**: Plate 1: long 37.242392, Lat -0.819085*

Captured on 5th July 2020 by Daniel Githinji

As we move the southern region the R factor is low. Since rainfall is the best catalyst for the process of soil erosion, it is understandable to comment that higher rainfall regions experience higher R-Factor values while lower rainfall regions experience lower-Factor values on the same note. Seemingly, there is a direct-forward relation between rainfall values and the R factor values in that region, due to the direct equation that is applied to convert rainfall values into R-Factor values.

4.2 The K-Factor

The K-Factor values the ease with which soil particles can be detached due to the soil characteristics. The K-Factor values take into consideration the grouping of soil into attributes that relate them with others such as clay-loamy, sandy-silt etc. since this classification is so diverse, K-Factor values ranged from 0.13 to 0.41. Higher K-Factor values are reminiscent of soils such as sand (plate 2) and silt which are easily washed away even by low velocity sheet erosion. On the same note, low K-Factor values indicate high level of compaction and resistance to erosion, as displayed by sandy clay soils at the lower course of Kambiti sub-catchment.

***Figure 4:** Plate 2: long 37.207852, lat –0.780520*

Captured on 5th July 2020 by Daniel Githinji

Moderate K-Factor values represent soils such as sandy loam, which is an aggregate mixture of both clayey and sandy soils. Such K-Factor values are found within the middle course of Kambiti sub catchment. However, the legend was not properly developed due to the nature of the values in the attribute table. The Arc Gis software treats such continuous data as strings, which must be accorded unique values in the legend, instead of being grouped. On that note, symbols ended up getting duplicated or even tripled such that the legend couldn't lend meaning to the thematic map. From the above map, south eastern part have got a higher r factor hence susceptible to erosion. Northern part and southern part of the catchment have a lower r factor

4.3 The LS-Factor

Soil erosion is a phenomenon that is highly dependent upon the gradient of land, given other factors constant. Higher values of the LS-Factor where attitude is 1457metres preserve of the high-altitude regions of Makuyu region. The LS-Factor was lowest in most of the region comprising 1049 metres. The lowest LS-Factor values were found at low altitude regions especially where the terrain assumed an almost flat nature. Given the nature of the result, it was noticeable that little variation exists in the altitudes of most regions within Kambiti sub-catchment. However, calculated as a single variable, the LS-Factor is sometimes treated as a variable with two factors: The L-Factor and the S-Factor. The L-Factor depicts the length the eroded load travels before being deposited. In this case, at the mouth of the Tana River, the LS-Factor turns to is low, which is nearly an average of the values for the entire region.LS factor was computed as a percentage. The entire region has a low gradient especially on the lower side. The southern part has got high gradient. This clearly indicates there is some siltation on lower region near river Tana. However in terms of slope percentage which is the key driver of soil erosion the northern and southern region have got a lower percentage hence less susceptible to soil erosion. On the middle portion of sub-catcment that is Karia ini and Marajau there are very steep slopes hence the area will have a higher LS factor.

Table 5 NN factor

slope/steepness	less than 1%	1%-3%	3%-5%	**>5%**
NN	0.2	0.3	0.4	0.5

There is clear indication that most of the parts have a got a higher NN hence susceptible to soil erosion and there is likelihood of siltation at the mouth of river tana. The kambiti subcatchment generally have a got a higher NN value.

The C-Factor values ranged from 0 to 0.38, having been accorded depending on the land cover types in the Kambiti sub catchment. The conservation practice factor of value 0.25 covered most of the catchment, owing to the extensive land area under shrubs.

The forested regions such as Kakuzi had a conservation factor of 0.001. Such forests were fewer in geographical expanse in comparison to the vast agricultural fields that stretched across the region. Plantations were usually accorded a C-Factor value of 0.38. This was evident northern region of the sub catchment, probably due to the extensive maize plantations within. On the same note, water bodies have a C-Factor value of 0,which was evident of the dams in Kakuzi.

The extensive C-Factor value stems from the fact that much of the region is covered by agricultural activities and bare land. This explains why the region is so vulnerable to erosion since most agricultural activities and bare land result into loss of the top soil and subsequent layers due to less compaction of soil.

4.5 Protection factor

P is the support practice factor. It shows the effects of practices that reduce runoff and erosion by reducing the amount of water and the rate at which it runs off. A P factor represents the soil loss caused by a support practice compared to the loss caused by a straight-row farm up and down a slope. Most of the land in the sub catchment does not have any practicing factor. This is attributed to the fact that most of the places is occupied by shrubs and mangoes plantation. Strip cropping is most prevalent along river Sabasaba. Planted forest is found on the west sides where Kakuzi have done the practice. This clearly indicate that most of the sub catchment will be prone to erosion since they are not subjected to prevention of soil erosion measures.

4.6 The Soil Erosion Risk Map

Annual Soil Loss (AASL) in the Kambiti sub catchment was classified from low to high. In the soil erosion susceptibility levels map, numerical values were replaced by quantifiers ranging from highest to lowest, in accordance with the parameters that tabled the results. The colour map also presents the areas thus making it easier to link the susceptibility levels to a given geographical region. This implies that there are regions that are greatly eroded, while some regions are least affected by soil erosion. This was inputted in terms of sub locations. Minimum soil loss was experienced on the western region of the Kambiti sub-catchment. However, being grouped data, it was impossible to point out the exact quantity of soil loss, which would otherwise be possible with point data. Higher rates of soil loss are experienced in the eastern regions of the sub catchment. This can be attributed to several factors emanating from RUSLE model. Most of the soil loss is experienced within agriculturally productive regions thus showing evidence of the fact that agriculture within the Kambiti sub catchment basically contributes to soil loss .This can be attributed to farmers not professionally managing their land.

4.7 Strategies form management of soil and water conservation

Four variables were analyzed that is awareness; economic, farming method and sand mining. The four were arrived after reconnaissance was done in the study area. Questionnaires were administered to the sampled population of fifty residents that were selected using purposive sampling in the catchment area. The data was be analyzed by use of SPSS**.** The sampled population comprised of 33 percent females and 67 percent males. This clearly that most of the house hold are managed by males. From the data obtained over sixty percent are primary school dropout. Thirty percent are secondary school leavers while less than 10 percent have post-secondary education. Majority of the residents in the sub catchment have lived more than twenty years. This clearly the vulnerability of soil erosion in Kambiti sub-catchment. Very few residents have resided in Kambiti for a short time (between one to five years). This can be linked to the extent to of soil loss within the period of stay of residents. Majority of the sampled population were not thoroughly sensitised about soil erosion by the various stakeholders. This leaves the community with little information about soil conservation measures. However, it was noted also that majority of sensitisation was done by farmers in their respective regions. Agricultural officers from Muranga County were least involved in the sensitisation of soil erosion in Kambiti sub catchment. Others include Non-government organisation i.e. upper tana project.

Lack of training programmmes was majorly the cause of low sensitisation.However lack of funds to conduct sensitisation programme and lack of personell is also a major hindrance.This clearly indicate that the county government need to increase allocation on soil conservation measures. It was also realised that 30 percent of the sampled population were trained on suitable farming method while us 70 percent were not trained on suitable farming methods. Suitable farming methods are the key factors to curb soil erosion. One of the key factor that leads to soil erosion in sandy preferential areas is sand mining. Kambiti sub catchment is of the major areas where sand mining is done especially during the rainy season. Majority of sampled population in the sub catchment portrayed a zone where sand mining is not regulated. This call for intervention from the county government to regulate sand mining.

5.0 Conclusion and Recommendations

5.1 Conclusion

Despite raindrop impact and runaway as the primary cause of the erosion damage in the Kambiti sub catchment, the severity of the damage was exacerbated by anthropogenic factors in the form of continual vegetation degradation and destruction of soil structure due to depletion of organic matter and routine shallow tillage. By protecting private property rights, it is possible to reduce or prevent vegetation degradation caused by open grazing patterns. The cost of controlling erosion in gullies and constructing physical soil conservation measures is extremely high, making it unaffordable for individual resource-poor farmers. Building community-based organizations and strengthening them can help reverse this trend, as these groups have been instrumental in mobilizing resources and building capacity in resource-poor areas in order to develop. Knowledge gaps regarding the integrated nature of erosion processes made timely intervention in erosion control impossible, which enabled land damages resulting from rill and inter-rill erosion to continue unnoticed. A lack of capital and poverty are the main reasons for abandoning degraded land. Land degradation and enhanced livelihoods in semi-arid agro-ecosystems in Kenya can be mitigated with identification and implementation of alternative off-farm income sources such as Beekeeping. If farmers are to accept responsibility and participate fully in resource management decisions, an integrated approach in land and water management for agriculture is necessary because of the multiplicity and interdependency of rural needs, including food security. Capacity building for farmers, specifically in reducing and eliminating knowledge gaps in land resource man inter-relationships, is of paramount importance.

5.2 Recommendations

Agricultural lands have become less fertile due to soil erosion, resulting in a loss of food supply to the ever-growing human population. In order to curb soil erosion, preventive measures such as intensive afforestation, dredging riverbeds, and constructing gabions should be prioritized specially in the southern regions. Therefore, the key to closing existing knowledge gaps would be the establishment of strategic educational campaigns, control on the mining of sand, and the promotion of strip farming. Participation of farmers at all levels of land resource use decision making would be inevitable, as this would accord agricultural resource users the recognition they require as equal partners in problem identification and solution design. Cooperation and participation among farmers become more efficient and effective when interventions are coupled with tangible short-term benefits and when their multiple needs, including food security, are considered.

It would be helpful to find alternative off-farm income generation sources in semi-arid environments to decrease pressure on land while also increasing farmers' ability to adapt to adverse conditions. Helping farmers realize that food security is not solely about production, but also about their ability to buy food is important. In addition to meeting pressing needs, increasing income will also allow for land improvement initiatives such as terracing and irrigation. Most externally driven initiatives to combat land degradation in rural Kenya lack a multi-purpose approach to sustainable land management. This explains the need for a comprehensive erosion management strategy. Taking part in the decision-making process in resource use and management allows farmers to appreciate the role such resources play in improving livelihoods, thus increasing their willingness to direct and manage their development needs.

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