TO ASSESS THE IMPACT OF LANDUSE CHANGE ON NUTRIENTS FLOW AND TO ESTABLISH THE LEVEL OF KEY POLLUTANTS OF NYANGORES RIVER

F. K. Kigira [1] and P. G. Home[2] and J. M. Gathenya
[1] Department of Engineering, Meru university of Science and Technology, Kenya
[2] Department of Biomechanical and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3] Department of Biomechanical and Envioromental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: fkigira2004@yahoo.com

Abstract
This study was carried out with the aim of assessing the effect of riparian land use/ land cover change on the hydrology and water quality of the upper Mara River catchment specifically Nyangores River. The study incorporated remote sensing and GIS tools to prepare and analyze the data. It involved sampling of sediments deposits and water flows at various points of the river to quantify water quality parameters such as N, P, Ca and Fe. These parameters were tested in the laboratory.
Land cover change was analysed from dry season LandSat MSS, TM and ETM images of 1976, 1980, 1985, 1990, 1995, 2003, 2006, 2010, and 2014 respectively. Digital image analysis for the riparian zone showed that between 1976 and 2003, crop land increased by about 100%, other vegetation and forests have reduced by 32% and 34% respectively with the river line decreasing by 50%. Comparatively high percentages of N, P, Ca and Fe i.e. 0.07meq/100g soil, 0.66meq/100g soil, 12meq/100g soil and 17mg/kg respectively were detected from soils collected along the cattle tracks and in the water directly below the animal tracks. Grass strips along the rivers were found to filter sediment and nutrients and soil from the urban set up and tested high for Fe=46 mg/kg, N= 0.03meq/100g soil K=0.21meq/100g soil caused by channelized flow. Soil composition of 89% sand, 3.4% clay and 7.5% silt which is sandy soil forms the downstream banks of river Nyangores and this is the main cause of the river banks erosion and subsequent sedimentation. Channelization should be controlled and a lot more of grass should be planted along the riparian zone also deep rooted trees should be planted at the downstream of river Nyangores to control river bank Erosion.

Key words: Riparian zone, landuse/landcover, water quality, hydrology

1.0 Introduction

A riparian zone is the interface between land and water bodies, including streams, rivers, lakes and estuarine marine shores. Riparian zones can therefore be considered as a transitional belt between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes and biota (National Research Council, U.S, 2002).

Gregory,S.V,*et al*., (2005) defined riparian zones as transitional semi-terrestrial areas regularly influenced by fresh water, normally extending from the edges of water bodies to edges of upland communities. It is important to note that the riparian vegetation acts as a buffer zone along rivers and lake shores in various ways. It may minimise the effects from river spates, e.g. the water flowing from upstream reaches downstream through absorption, hence causing stability in the water flow. Furthermore, the vegetation usually traps sediment and therefore influences sedimentation downstream.

A riparian zone is often a habitat for rare species and it is also a breeding ground for aquatic fauna such as fish and invertebrates (Naiman *et al.*, 2005). Loss of riparian vegetation can decrease the amount of suitable habitat for riparian and aquatic fauna such as fish and invertebrates, thereby reducing stream productivity and fish carrying capacity (Ahearn,D.S 2005). Riparian vegetation has many critical functions; it provides resistance to flowing water as well as to runoff during floods. The vegetation provides protective cover which helps to absorb the forces exerted by flowing water (Mitch W.J and J.W Day, 2006). Riparian plant canopies intercept, store and evaporate a portion of precipitation and have an important role in influencing stream temperature and the health of aquatic species (National Research Council, U.S., 2002).

Soils found in riparian zones have pronounced spatial variability in structure, particle size distribution and other properties, not only across the riparian area but also vertically within the given soil profile. This is dependent on soil geological formation and the landscape of the area. Soil properties and the microtopography of the valley floor affect the biotic composition of the riparian community (Naiman, Bilby & Bisson, 2000) and hence their biodiversity.

The structure and function of the riparian zone are highly influenced by climate through temperature, precipitation, evaporation and runoff. Floods play a significant role in determining regeneration from seed as well as long term seedling survival. Soil moisture and depth to the water table also influence the composition of the riparian plant communities (Naiman *et al.*,2005).

Riparian areas supply water for domestic and agricultural uses, forage, and browse for native herbivores, livestock and recreational opportunities. The riparian areas are so important that they have been extensively and intensively used for decades by humans for a variety of purposes that range from providing well-vegetated sites for grazing to places of beauty and solace that renew the spirit of visitors (Chambers & Miller, 2004).

Degradation of riparian zones is a result of complex interrelated responses from geomorphic, hydrologic and biotic processes to climate change and natural and anthropogenic disturbances (Chambers & Miller, 2004). The disturbances can alter the hydrological or sediment regime of the river/stream system and produce changes in the physical properties of riparian ecosystems such as stream channel characteristics, and surface and ground water interactions. Human activities such as agriculture, harvesting of riparian flora and hunting of riparian fauna, grazing and industrial discharges have a great impact on riparian ecosystems. Direct discharge of untreated waste from industries, domestic and urban sources into lakes contribute to various forms of pollution, eutrophication, suspended solids, sedimentation and pesticide residues leached from soils and agricultural plantations (Odadal *et al.*, 2003). Human impact such as dams, deforestation and water use practices pose serious threats to water availability to downstream populations (United States Agency for International Development, 2008). Degradation of riparian zones not only affects the riparian area but also the surface and ground water resources and the aquatic fauna and flora; and the terrestrial ecosystem. Thus, the riparian zone is increasingly seen as ecologically important in landscapes, and identification of the boundaries of such areas is important and has clear management significance (Nally, Molyneux,Thomson, Lake & Read, 2008).

2.0 Materials and Methods

2.1 Reconnaissance Survey

A two days reconnaissance survey was carried along the whole stretch of Nyangores River to establish the point and nonpoint source of pollution. This involved mapping the locations that were found to be sources of pollution by the use of geographical positioning system (GPS).

2.2 Image processing and Classification

Land cover classification based on image segmentation was used. The land cover classes were needed for monitoring the progress of the depletion of the riparian zones. Availability of time series high quality and fine resolution images was key to success in obtaining accurate land cover classes within the River catchment. Land sat imageries for 1976, 1980, 1985, 1990, 1995,2003,2006,2010 and 2014 were used. The images were down loaded from the data office at Regional Centre for Mapping of Resources for Development (RCMRD) Kasarani.DEM (Digital Elevation Model) was obtained for larger 30m shuttle Radar Topographic Mission (SRTM) also facilitated by RCMRD. 500m distance from the river line was used as the riparian zone and this dictated the size and extent of the DEM that was to be used as the area of interest for extracting the land cover layers from the Landsat image.GPS coordinates of the area of interest and photographs were obtained by ground visit which was done during the reconnaissance survey.The images were processed to the following Land Cover classes.

- Built up and bare ground. These are areas with build-up structures like roads and settlements, as well as areas with no vegetation cover as at the time of image capture. (NB: Crop land that has no crop at the time of image capture is not considered as bare)

- River line: The vegetation that follows the water line. In some instances water along the river line is visible.
- Crop land: Cultivated land. With or without crop at the time of image capture.
- Other vegetation: All other vegetation apart from forest, crops and River line.
- Forest: Trees canopy cover of over 30% and extending area coverage of 5 hectares

2.3 Stream Water Sampling

Grab water samples were collected in 500ml high density polyethylene (HDPE) bottles from respective river gauging stations at approximately mid depth of the river. For each station Ph, Ec, N, P, TSS and Fe were analysed in the laboratory.

2.4 Soil Analysis

Table 2.1: Shows Laboratory method used for soil/water chemical analysis

S/NO	PARAMETER	METHOD OF ANALYSIS
1	Fe mg/kg	Atomic Absorbtion Spectrometer (AAS)
2	Ca meq/100g in soil	Atomic Absorbtion Spectrometer (AAS)
3	K meq/100g in soil	Flame photometer
4	P ppm	Colorimetry at 400 nm OR Uv-Vis-spectrometer
5	NO_3ppm	Colorimetry at 400 nm OR Uv-Vis-spectrometer
6	% TOC	Walkley and Black rapid titration method
7	Soil Texture	Hydrometer Method and Textural triangle
8	Ph H_2O 2:5	Electric pH Meter Method
9	Ec H_2O 2:5	Electric Conductivity Meter Method

3.0 Results and Discussion

3.1 Landuse/Landcover Change Analysis

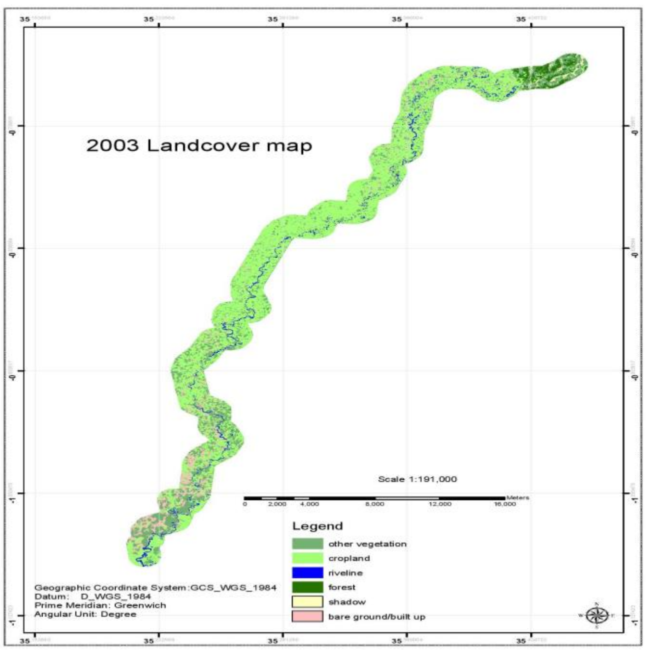
After the analysis of the landSat MSS,TM and ETM images of Nyangores River Riparian Zone landuse/landcover maps shown in figure 2 were used .The area of the catchment covered by each landcover type for the years are shown in Table..3.1

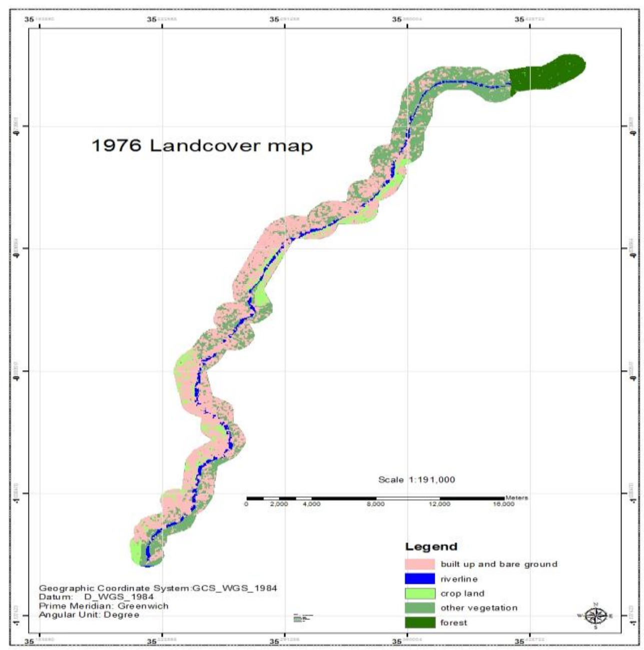
Table 3.1: Landuse/landcover area change statistics

	Area in km² 1976	Area in km² 1980	Area in km² 1985	Area in km² 1990	Area in km² 1995	Area in km² 2003	Area in km² 2006	Area in km² 2010	Area in km² 2014
Built up area	32.10	31.02	35.38	35.77	38.47	26.59	42.31	51.93	30.84
Other vegetation	64.78	65.36	57.45	54.35	48.37	56.28	42.39	40.86	48.51
Forest	8.02	7.29	6.42	6.12	4.45	6.06	4.07	5.64	7.06
Crop land	15.84	16.21	21.02	25.22	30.24	36.91	35.34	24.81	41.05
Shadow/clouds	0.00	1.00	2.49	1.65	1.93	1.00	1.65	1.64	0.06
River line	10.26	10.12	8.24	7.89	7.54	4.16	5.24	6.12	3.48
Class total	131	131	131	131	131	131	131	131	131

Digital image analysis for the riparian zone showed that between 1976 and 2003, crop land increased by about 100%, other vegetation and forests have reduced by 32% and 34% respectively with the river line decreasing by 50%. There is a continued decrease in the river line caused by declining quantity of water as a result of increased sediment in the river this is evident with figure 3.1 which shows accumulation of the sediment in the lower Nyangores River. The progressive increase in cropland and declining river line as shown in table 3.1 suggest that much of the natural riparian vegetation has been destroyed leading to sediment flow into the river.

Figure.3.1: Shows lower Nyangores River heavily loaded with sediment





3.2 Image Processing and Classification

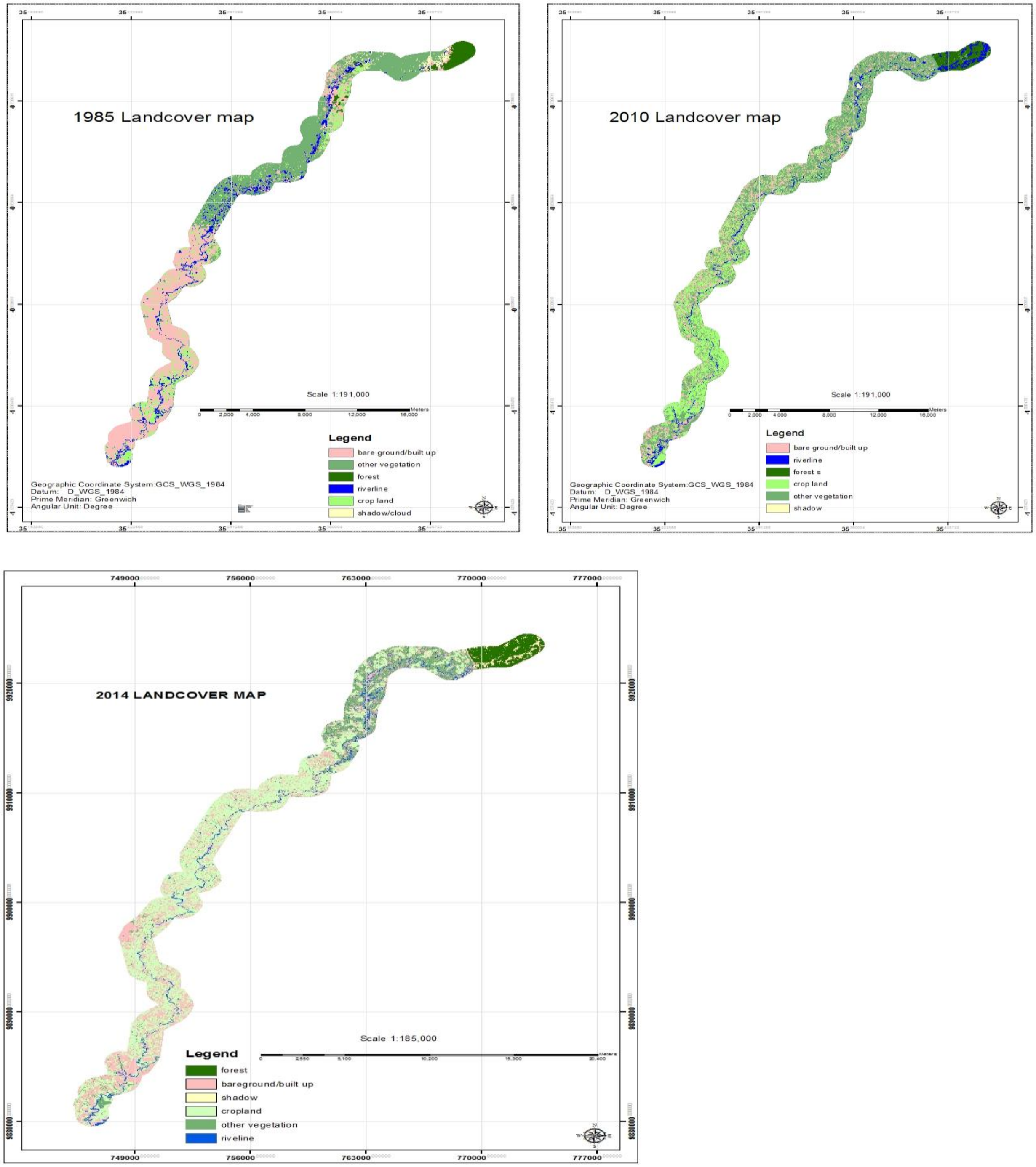


Figure 2: Land cover maps prepared for 20th January for the years.1976, 1985, 2003, 2010 and 2014

3.2 Soil Tests

3.2.1 Soil Chemical Analysis on Soil (Sediment) Deposit on Nyangores River Bed and Bank

Table.3.2 shows the values of Ph, EC, N, P, K, Ca, %TOC, and Fe of soil deposit obtained from the river bed as well as the bank of River Nyangores. Location 3 and 4 represents a cattle track which is intercepted by a well protected river bank growing with Kikuyu grass as shown in figure 3.4shown below. The soil shows a high Ph value of 5.4. P= 0.66, N=0.7, 6.4 %TOC and Fe=17mg/kg .This could be attributed to the channelization leading to urban areas as well as animal faeces. The Kikuyu Grass has a high trapping efficiency. Quarrying activities at location 7 as shown has a value of Fe = 27 mg/kg, Ca=22 meq/100 soil which is the highest of all other values. Cleaning of vehicles is major contributing factor to water pollution in Nyangores River. Water samples collected and analysed for this point (Olobutyo bridge) showed that the water pH was 7.3 , E_C 0.04 Ds/cm, NO_3 6.43mg/l, P 3.3 mg/l, K 0.31mg/l .

Table 3.3 shows the optimum nutrients for most soils in Kenyan.

Table 3.2: Soil Chemical Analysis on Soil (Sediment) Deposit on Nyangores River Bank

Location	**pH**	**EC Mil/mhos**	**N (meq/100) soil**	**P (meq/100) soil**	**K (meq/100) soil**	**Ca (meq/100) soil**	**%TOC**	**Fe mg/kg**
1	6.15	0.04	0.05	0.43	0.10	12	3.5	22
2	6.02	0.02	0.05	0.35	0.15	15	2	7.4
3	5.7	0.1	0.07	0.66	0.15	12	6.4	17
4	5.4	0.03	0.03	0.36	0.21	3.1	1.4	4.6
5	6.3	0.01	0.03	0.2	0.10	3.5	0.6	4
6	6.4	0.01	0.07	0.4	0.05	6	0.12	8.2
7	6.9	0.06	0.05	0.19	0.15	22	3.2	27
8	7	0.01	0.03	0.27	0.15	6.9	0.68	10.6
9	7.2	0.01	0.03	0.48	0.10	8.6	0.8	7.4
10	6.9	0.27	0.02	1.29	0.13	20	2.8	25.4
11	7.7	0.06	0.03	0.22	0.15	16	1.1	7.2
12	6.1	0.02	0.08	0.25	0.21	7	3	10.6
13	6.9	0.17	0.05	0.27	0.15	7	0.68	10

Table 3.3: Optimum Nutrients for Most Soils in Kenyan

1	**pH**	**5.5-6.8**
2	Ec	1ds/cm
3	K meq./100g soil	2meq/100g soil
4	P meq. /100g soil	0.01-0.4
5	N meq. /100g soil	>0.25 high
6		0.12-0.25 moderate
7		0.05-0.12 low
8		< 0.05 very low
9	Ca meq. /100g soil	4-10
10	Mg meq. /100g soil	1-4
11	Fe mg/kg	2000 to 100,000
12	% TOC	> 3 high
13		1.5-3 moderate
14		0.5-1.5 low
15		< 0.5 very low

3.2.2 River Bank of the lower Nyangores River

At the river bank elevation 1714m, S00^{0}59’417, E035015’634 existence of exposed tree roots was observed which is a sign of bank erosion. Table 3.4 Shows Soil collected at this point and tested for particle size analysis using hydrometer method and showed the following characteristics.

Table 3.4: Shows soil textural analysis of lower Nyangores River banks

% Sand	% Clay	% Silt	Textural Class
89.1	3.4	7.5	SANDY SOIL

Sandy soils has a poor cohesion and they are therefore prone to erosion and hence the appearance of uprooted trees and exposed tree roots at this part of Nyangores river which has lead to lose of riparian vegetation as shown in figure 3.3 below.


Figure 3.3: River banks of lower Nyangores River where trees have exposed roots caused by washing away of the poorly cohesive sandy soil.

3.3 Water Analysis at Various Points along the Nyangores River

Ph is a measure of how acidic or basic water is. A pH of 7.0 is neutral, values less than 7.0 are acidic, and those more than 7.0 are basic. According to table 3.5 the optimal pH range for aquatic life is 6.5 to 8.5. A pH less than 4.0 or greater than 10.0 is usually lethal to fish and other organisms. The average pH for the vegetated sites was 7.0 (neutral) which is perfect for aquatic life where as the non-vegetated site averaged at 6.0 which is slightly lower than the optimal pH range for aquatic life.

Table. 3.5: Shows results of water analysis of various points along the Nyangores River

S/N	POINT	Ph H_2O(2:5)	Ec Ds/cm	NO_3 Mg/l	P Mg/l	K Mg/l
1	A	7.7	0.03	7.34	1.28	0.26
2	B	6.5	0.04	6.14	20.32	0.26
3	C	6.9	0.03	4.84	22.10	0.26
4	D	6.9	0.03	4.03	18.59	0.26
5	E	7	0.04	5.04	6.27	0.26
6	F	7.3	0.04	6.43	3.3	0.31
7	G	7.2	0.05	9.58	6.27	0.31
8	H1NY	7.3	0.05	3.89	3.3	0.31
9	H2AM	7.5	0.33	5.18	1.64	1.03
10	Tributary	7.8	0.06	11.24	1.05	0.31
11	I	6.3	0.04	5.19	22.57	0.36

Key

1. Point A near a well protected river bank (elevation 2046m, S00^{0}42474, E035^{0}25.127
2. Point B (elevation 2002m, S00^{0}42.188’, E0350 23’ 531
3. Point C (i) well buffered area where sediments from a cattle track was trapped by grass and collected for analysis (elevation 1991m S 00^{0}42’869, E 035^{0}21’985 GLONAS 3m).
4. Point C (ii) well protected river bank sediment were collected trapped before reaching the river from agricultural land and tests carried out (Elevation same as above)
5. Point D at a bridge near Tenwek hospital there was a lot of cleaning of vehicles and

Washing of clothes going on (elevation 1957m S00^{0}44'341, E 035^{0}21'714 GLONAS 2m)
6. Point E at Nyangores River Bridge at Bomet town cleaning of machineries and human was observed (elevation 1899m S00^{0}47'395, E 035^{0}20'796)
7. Point F (OLBUTYO BRIDGE) already the riparian vegetation is destroyed and quarrying on the river banks is evident (elevation 1856m S 00^{0}51'482, E 035^{0}16'767).
8. Point G (KABOSON)The soils on the river banks were tested and found to sandy soil which are very unstable this has lead to river bank erosion exposing the banks roots, watering of animals and cleaning of humans is evident. (Elevation 1714m, S 00^{0}59 417,E 035^{0}15'634 GLONAS 2M).
9. Point H (i) at the confluence of Nyangores and Amala rivers .destruction of natural riparian vegetation to burn charcoal was evident and a lot of sediment deposit could be seen after the rains. (Elevation 1696m S 01^0 02'258, E 035^{0}14'511).
10. Point H (ii) River Amala 20m from the confluence elevation and coordinates as indicated above.
11. Point I Tenwek power house (Elevation1959m, S 00^{0}44'666, E035^{0}21'829).
12. A cattle track crosser to point A at (Elevation 2046m, S00^{0}42'474, E35^{0}25'127).
13. Point G River bank

Figure3.4: Shows sampling of soil sediments trapped by Kikuyu Grass along the river bank.

4.0 Conclusions/Recommendations

Trees and vegetation act as an anchor, holding the soil in place and consequently reducing the amount of erosion that takes place. By removing the vegetation, the loose soil is vulnerable to the elements, and will be eroded and transported to the river. Planting of indigenous trees with deep rooting system grasses like Kikuyu grass is highly recommended.

Channelization and the removal of riparian vegetation have a detrimental impact on water quality. Without the vegetation sources water cannot filter out pollution and sediment quickly enough and with concrete channels, water moves more rapidly downstream and deposits waste into Nyangores River. It is important to erect physical structures like retention ditches and bench terraces to reduce runoff velocity. The results of my tests show that areas of the river that is untouched and surrounded by riparian vegetation has better water quality than sections that have their vegetation removed. Making the public more aware of this problem could minimize removal of riparian vegetation and result in a change for the better in water quality.

The public can benefit from this research project by learning the benefits of having vegetation in the riparian zones as a way to promote water quality improvement that does not require any human labour or money. More sediment is deposited on the lower sections of the river where a lot of subsistence farming is taking place. The ability of buffer zones to attenuate pollutants will depend upon the mechanisms by which these pollutants reach surface waters. Three main transport processes can occur: Direct pollution e.g., stock access to streams and bank erosion. It is therefore important to fence off the river bank to stop the animals from destroying part of the riparian zone closer to the river because Buffer zones where stock have been excluded and where long grass or natural vegetation has been allowed to develop, or been planted, can reduce diffuse pollutant transport from agricultural land. Enhanced infiltration by riparian soils which reduce surface runoff thereby aiding the deposition of particulates like sediment and particulate nutrients.

References

Ahearn, D. S. 2005. Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California. Journal of Hydrology, pp 313, 234.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41: pp 540-551.

Mitsch, W.J., and J.W. Day, Jr. 2006. Restoration of wetlands in the Mississippi-Ohio- Missouri (MOM) River Basin: experience and needed research. Ecological Engineering 26: pp 55-69.

Naiman, R.J., H. Decamps, J. Pastor, and C.A. Johnston. 1988. The potential importance of boundaries of fluvial ecosystems. Journal of the North American Benthological Society 7: pp.289-306.

United States Environmental Protection Agency. 2009. National water-quality inventory: report to congress. United States Environmental Protection Agency, Office of Water. Washington, D.C

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137.

Appendices

Profile of a large woody tree within the Mara River Watershed illustrates the intricate root system that works to stabilize soil. Cleaning of vehicles is also observed (Photo by F. Kigira)

Sediment deposit downstream of Nyangores River reducing the River capacity

Burning of charcoal and destruction of river banks by livestock

Soil and water samples in the laboratory ready for analysis

Animal waste and chemical application in agricultural activities also contributes to decline in river water quality