Applied Engineering
2017; 1(1): 20-31
http://www.sciencepublishinggroup.com/j/ae
doi: 10.11648/j.ae.20170101.13

Measuring Soil Loss and Sediment Deposit on Low Volume Rural Roads in Mt. Elgon Sub County, Trans-Nzoia and West Pokot Counties

James Okinyi Manyara*, Elias Ucakuwun, Thomas Munyao

Department of Environmental Earth Sciences, University of Eldoret, Eldoret, Kenya

Email address:
jomsmanyara@gmail.com (J. O. Manyara), Ucakuwun@gmail.com (E. Ucakuwun), munyaothomas@gmail.com (T. Munyao)
*Corresponding author

To cite this article:
James Okinyi Manyara, Elias Ucakuwun, Thomas Munyao. Measuring Soil Loss and Sediment Deposit on Low Volume Rural Roads in Mt. Elgon Sub County, Trans-Nzoia and West Pokot Counties. *Applied Engineering*. Vol. 1, No. 1, 2017, pp. 20-31.
doi: 10.11648/j.ae.20170101.13

Received: March 6, 2017; **Accepted**: April 8, 2017; **Published**: May 24, 2017

Abstract: Roads are key economic pillars for any economy, major low volume roads in Kenya are faced by a major problem of degradation and soil erosion. These roads have become of great environmental concern causing siltation and land degradation. The research is carried out in three counties of western Kenya and North Rift between High, mid and Low altitude areas. The research used purposive sampling to select the study roads and class E and D roads were selected for the study. Metered drop pins were used to estimate soil loss and soil deposition in the study roads, this was achieved by driving the peg into the ground and measuring the height in two weeks interval for a period of three months between November 2013 to March 2014. Side drain cross sectional areas were measured at specified intervals to obtain soil accumulation or soil loss. Soil movement and deposition was analysed and it was observed that a greater change occurred in the months of November and December 2013 with a deposition change of 11.1 cm compared to 8.80cm for the month of January and February 2014. Highest rate of erosion was recorded at -10.1cm in the rainy months and -6.64 cm in dry months. Total soil volume movement in three months was 8309.75 cm^3 where Mt. Elgon Sub County exhibited the highest change of 3284 cm^3.

Keywords: Low Volume Roads, Soil Loss and Deposition, Rural Roads

1. Introduction

Kenya has a road network of approximately 150,000 km out of which 63,805 km are classified, 14,000km unclassified urban roads and the rest approximately 73,000 km are unclassified rural roads including 9,000 km of roads in Game Parks and National Game Reserves. Out of the 150,000 km only 11,500 km are paved, the remaining 138,500 km are mainly unpaved low volume roads [1] The unpaved roads are much more susceptible to erosion.

While erosion is a natural process, human activities such as agriculture, road construction among others have greatly increased the rate at which erosion is occurring. Excessive erosion causes problems such as damage to infrastructural facilities, desertification, decrease in agricultural productivity, sedimentation of waterways, and ecological collapse due to loss of the nutrient rich upper soil layer. Industrial agriculture, deforestation, roads construction, anthropogenic climate change and urban sprawl are amongst the most significant human activities in regards to their effect on stimulating erosion [2]. For instance, Urbanization and road construction can have a number of effects on soil erosion processes-first by clearing the land of its vegetative cover, altering drainage patterns, and compacting the soil during construction; and next by covering the land with an impermeable layer of asphalt or concrete that increases the amount of surface runoff and increases surface wind speeds. Much of the sediment carried in runoff from urban areas is highly contaminated with fuel, oil, and other chemicals. This increased runoff not only erodes and degrades the land that it flows over, but also causes major disruption to surrounding watersheds by altering the volume and rate of water that flows through them, and filling them with chemically polluted sedimentation [3].

Soil erosion, which is the removal and transportation of soil material from one area to another, has been a problem to man ever since he first settled and started to cultivate land some 10,000-15000 years ago [4]. Traditionally, accelerated soil erosion has been associated with soil loss from agricultural land. According to [5], the study of soil erosion on roads and the erosion impacts resulting from road drainage has not received much attention, especially in developing countries. However, there has been a number of erosion control measures put in practice along roads since the creation of roads and include scour checks and check dams in drains and protection of outfalls from culverts and bridges; stabilization of drains and embankments by using suitable vegetative material. In the lower catchment areas- below the road servitude, there must be a plan for safe disposal of water either to nearest natural waterway or, if there is a demand, to water harvesting and water conservation structures. In the latter case, runoff is led to infiltration ditches/pits or storage ponds for watering animals, irrigation or domestic use [6].

Road construction is a change in land use which increases run-off coefficient. It also concentrates the run-off from the upper stream of the road alignment and discharges into farms, fields and natural waterways downstream.

1.1. Study Area

The study covered three counties that included Mt. Elgon sub-county (in Bungoma County), West Pokot and Trans Nzoia Counties. The study area is located in both low and high altitude areas. The areas were chosen because of their varying physical characteristics and climatic conditions. Mt. Elgon lies on latitude 1° 8' 41.55" and longitude 34° 34' 44.2086" to its North, 0° 44' 3.5406", 34° 34' 29.3766" to its south, 0° 49' 0.1452", 34° 49' 4.4358"to its East and 0° 50' 58.7832", 34° 25' 40.386" to its west, it borders Trans Nzoia to its South west. Trans Nzoia is located between latitude 1° 16' 29.2152", 34° 49' 45.606" to the North, 0° 49' 3.1944", 34° 48' 56.1708" to the South, 1° 5' 7.1082", 34° 39' 32.5692" to the West and 0° 56' 33.0288", 35° 20' 59.3262" to the East and covers a total area of 2,470 km² with an altitude that ranges from 1000 to 2400 m above mean sea level. The terrain is generally flat. West Pokot covers a total of 8402 km^2 lying on latitude 1° 16' 29.2152", 34° 49' 45.606" to the south, 2° 41' 56.382", 35° 9' 23.8428" to the North, 1° 38' 32.406", 35° 47' 8.127" to the East and 1° 38' 22.5198", 34° 58' 51.0312" to the West on GPS it lies towards the north of Trans Nzoia county.

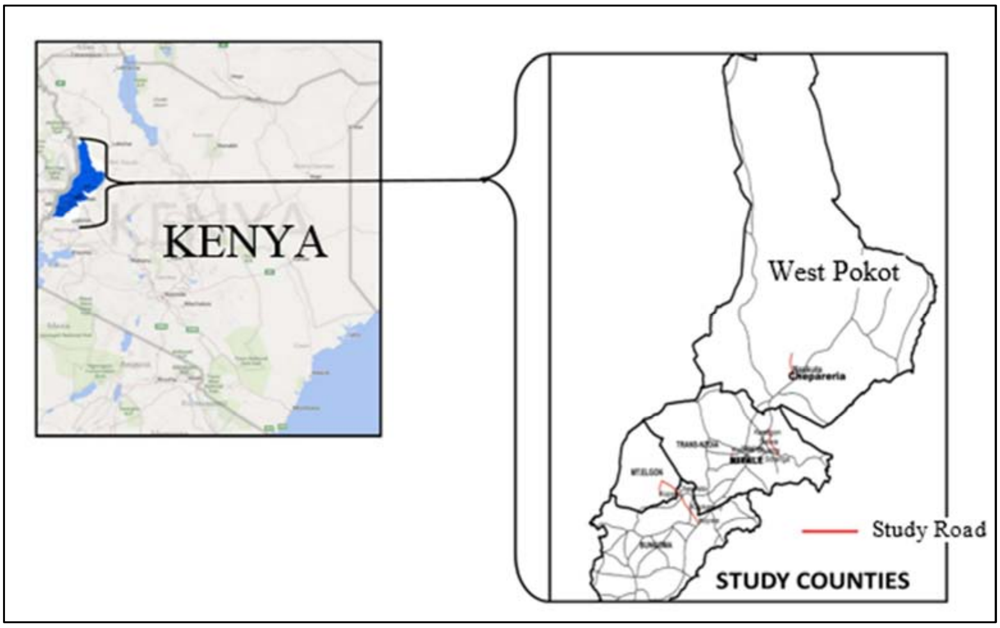

Figure 1. *Study area.*

1.2. Scope

The study was undertaken on two classes of rural roads, class D and E roads. Chepareria-Priokwo (class D) road was selected in West Pokot County, a stretch of 8 km. This road was chosen to represent arid and semi-arid Zone. Trans Nzoia which is a mid-latitude zone was represented by two roads a class D (Sikulu-Kinyoro) 8.5km and E (Sibanga-Kesegon) 20km. A class D road was selected in Mt. Elgon sub-county, a 24 km class D road was picked that traverses through Kapkateny to the slopes of Mt. Elgon via Cheptonon, Kipsikirok, Chebiuk and ends at Kopsiro. The road rises from 2000m ASL to 3000m ASL in Kipsikirok.

The study was based on data acquired from satellite images that were analysed using ARCGIS, data was also obtained from ILRI. Scientific methods already available in literature were used and this included mathematical methods like the cooks method and Universal Soil Loss equation.

2. Materials and Methods

Reconnaissance field studies were done between the months of September and November 2013 on all the three counties. This was done to ascertain the ground location of the roads to be studied and the suitable locations for pegging.

During the field visits a Garmin GPS was used to map the specific roads and identify areas where pegs for soil erosion control would be mounted.

2.1. Sampling Design

The study was carried out in four different phases. In the first phase, selection of geographic study clusters using secondary data (Maps) obtained from (Kenya Rural Roads Authority) KeRRA Kitale were used; reconnaissance visit; establishing accessibility; identification of roads in selected geographic clusters; establishment of status in each cluster-classes of roads, types of surfacing material, type of traffic loading, topography, vegetation cover, rainfall intensity, geomorphology of the area, geological and soil formation of the study area and social-economic activities were done. The first phase was meant to collect pre-sample the roads and check on study roads suitability. This was conducted for a period of one and half months [September to December 2013]. Various roads were identified and divided into several segments. The human activities -Farming and vegetation cover- within the road network were studied by observation and use of field study checklist.

2.2. Sample Selection

According to Kenyan roads classification, rural roads are classified as classes D and E. Purposive sampling of the selected study roads was used in the three regions whereas stratified sampling was used to obtain locations for peg placement to facilitate data collection and readings. This combined various factors –terrain, gradient, type of road, soil type, altitude and general climatic conditions of the area- were considered and factored in, in order to get a good comparison sample. The comparison sample was to represent the three zones that include mountainous areas, relatively flat areas with high rainfall intensity and flat areas with low rainfall intensities and also consider the soil types in the sampled counties. Rural roads were the sampling frame which comprises of class D and E roads. Two class D roads and two class E roads were purposively chosen for the study counties and this represented a class D and E road from Trans Nzoia, E from West Pokot and D from Mt. Elgon sub-county.

2.3. Estimation of Soil Loss from Roads

The amount of material removed from the entire length of the road by surface runoff was estimated by calculating the amount of sediment deposited or eroded at the various sedimentation points on the road and the side drainage at 2-weeks interval for three (3) Months.

The measurements were done on both sides of the road where necessary on areas marked for pegging covering 50% of the entire road network on each segment. The pegs were placed at 500 m interval on areas with a rapid change in relief and 500 m-1.2 km on areas with no major change in relief. Pegs were placed strategically at the highest point on a road to measure erosion and at the lowest point to determine deposition of sediments.

In measuring soil erosion and deposition on the roads a widely-used method consisting of driving a pin into the soil so that the top of the pin gives a datum from which changes in the soil surface level can be measured was used, this method is adopted from [7]. The pins are alternatively called pegs, spikes, stakes or rods. The pins can be of wood, iron or any material which could not easily rot or decay and was readily and cheaply available. Iron, steel pins or nails could not be used since they could easily be stolen. In the study area, cedar, bamboo and other wood pins/pegs were locally available and were more suitable for the function [8].

The pins were of standard average length of 70 cm which were driven into the soil to give a firm stable datum: 20 cm was typical, less for a shallow soil, more for a loose soil approximately 30-45 cm driven into the ground. The pins had an average diameter of 50 mm; thick pins could interfere with the surface flow and could cause scour. A total of 86 pegs were driven into the ground (see Table 1 for peg distribution per road). Rock and tree roots painting was also done in sections of West Pokot on areas with rocky road surface and zones were pegs could probably be plugged out or infested by pests like termites.

Figure 2. *Peg placement at 0+500 on Kuywa-Kopsiro Road.*

The first readings were done after the pins had been driven to the ground and this was taken to be the datum for consequent readings. To obtain the volume of sediments and soil deposited or eroded on the road side drain in each sedimentation point, the length and width of area covered by sediment was estimated by direct measurements. The average depth of sediments was calculated after taking five successive readings for a period of three months, during the rainy and dry seasons of December 2013, January and February 2014 respectively. The average readings were then used to calculate the volume of soil eroded or deposited by measuring the length of the back slope to the slope and multiply by the total length of the road to the next peg. The volume of sediments covering an area was calculated from the formula:

$$\text{Total soil loss volume} = \text{A} \times \text{D} \ [1]$$

Where:
D- Distance to next peg
A- Is the Area covered by the sediments calculated as:

$$\text{Area} = \frac{1}{2}(a+b)h \ [2]$$

Where *a* is the length from back slope to slope (standard) *b* is the length from current sediment deposition height to the back slope and the slope while *h* is the height of the sediments deposited or eroded.

Table 1. *Road distribution of pegs.*

Road	Class	Pins
Chepareria-Naskuta	D	21 Pins and Rock painting
Sikulu-Kinyoro	D	13
Kuywa-Chemisto-Kopsiro	E	28
Sibanga-Saiwa-Kesegon	E	24
TOTAL		86 Pegs

3. Findings

3.1. Soil Loss and Deposition

Soil movement was determined by both anthropogenic and natural factors. The rate at which erosion and deposition occurred in the regions was different due to natural factors but human factors could accelerate this in areas where erosion could be slow.

A combination of factors were considered on the research and they included, terrain, land cover, soil type, climatic conditions which comprises of surface run off rates.

3.2. Soil Types

Soil types and infiltration rates were determined by obtaining information from images adopted from ILRI [9]. Soil texture and types were obtained by observation in the field through texture and secondary review of data. The soil descriptions of the study zones are shown below (Figure 3).

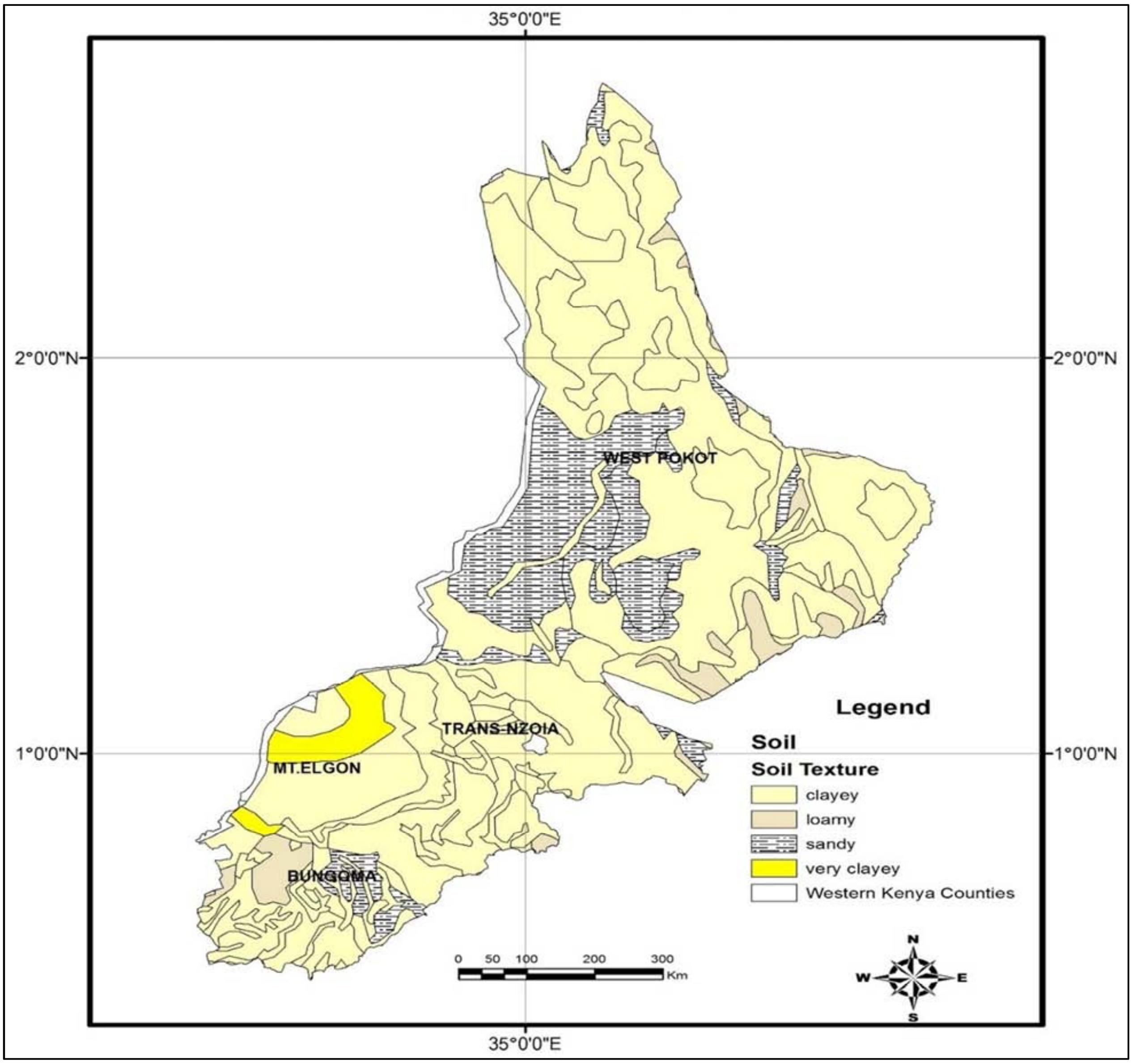

Figure 3. *Distribution of soil types in the study area.*

3.3. Weather Conditions

Precipitation accelerates debris movement and in the process causing massive erosion down slope when combined with terrain and nature of the catchment area. The research was conducted in December 2013 which was a rainy season and two sets of data were obtained while in January through to February a set of averaged two data readings were obtained.

In the month of December it was observed that there was higher erosion compared to other months January and February, where erosion was minimal. Mt. Elgon County had the highest rate of erosion in all the months while Sibanga-Kesegon a class E road in Trans Nzoia County had the highest rate of erosion in the county and the lowest during the dry seasons. This was due to the grassy surfaces formed after the rains ceased in the months of December, by February 2014 Sibanga Kesegon road had the lowest rate of erosion. At Mt. Elgon is a stiff terrain and this could be the reason behind its high rates of erosion and deposition.

There was high rate of erosion in the months of December and this was due to the heavy rain during the months of December, the rains act as agents of erosion transporting debris which causes abrasion and scouring of surfaces which caused further erosion. The highest change in erosion was -10.1 cm and the highest deposition occurred in the month of December with a maximum value of 11.1 cm, erosion in the month of January 2014 had a maximum value change of 8.80 cm and a minimum of -6.64 cm, this was due to minimal effect from agents of soil erosion in the months of January, it was also observed that hardpan formed in areas where grass grew and in areas where marshes existed in the month of December.

There was also a great disparity of readings in the month of December with a standard deviation of 4.39 and January/February had a standard deviation of 2.62. The deviation in the month of December is due to high rates of erosion and deposition caused by rains unlike in the months of January where agents of erosion were minimal. Weather is an aspect that influence soil erosion. There was a significant correlation between sediments change and weather seasons and in the month of December (rs=0.472) and in January/February (rs- 0.267).

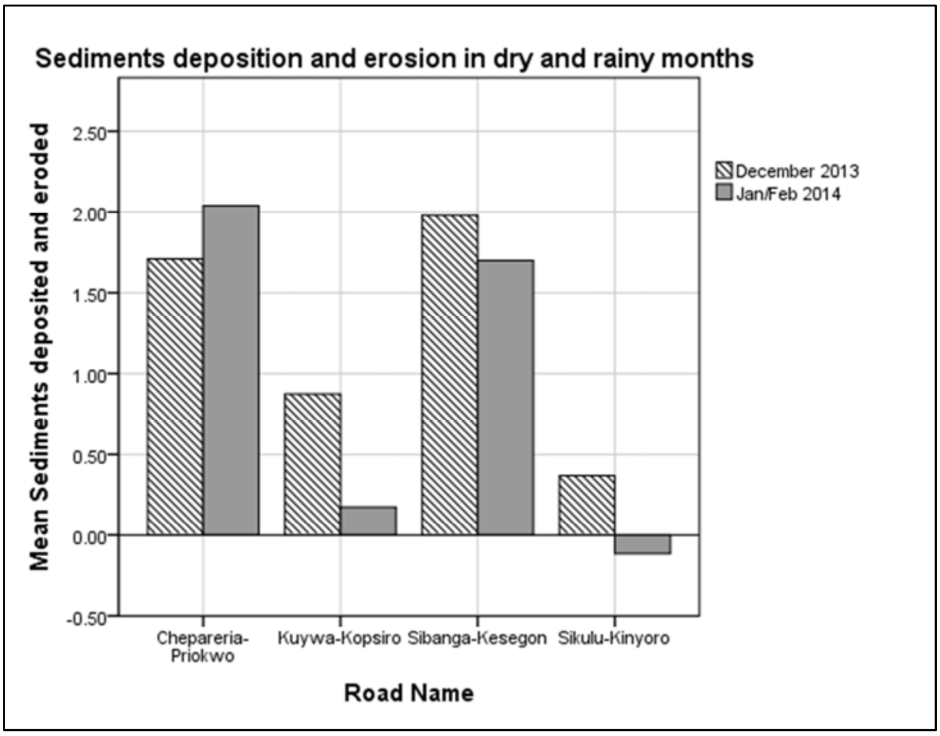

Figure 4. *Sediments deposited and eroded in December and January.*

3.4. Slope and Soil Erosion

Terrain is one of the factors that influences soil erosion, the study considered collected data for terrain of road by use of height above sea level. The correlation between height above sea level and sediments eroded or deposited was significant with an (rs=0.522). In West Pokot roads and Sibanga-Kesegon there was an insignificant relationship between sediments and terrain and this might be due to the undulating terrain and most of the erosion is due to climatic factors and human factors. In Mt. Elgon sub-county there was a significant relationship between sediment deposits and terrain (rs=0.530) whereas in Kinyoro-Sikulu road there was negative significance of (rs=0.032). Chepareria-Priokwo had a negative significance of r=-0.381, while Sibanga-Kesegon had a significance of r=-0.396, this shows that when height decreases in the roads sediment volume increase which also implied that when height reduces sediments volume increase.

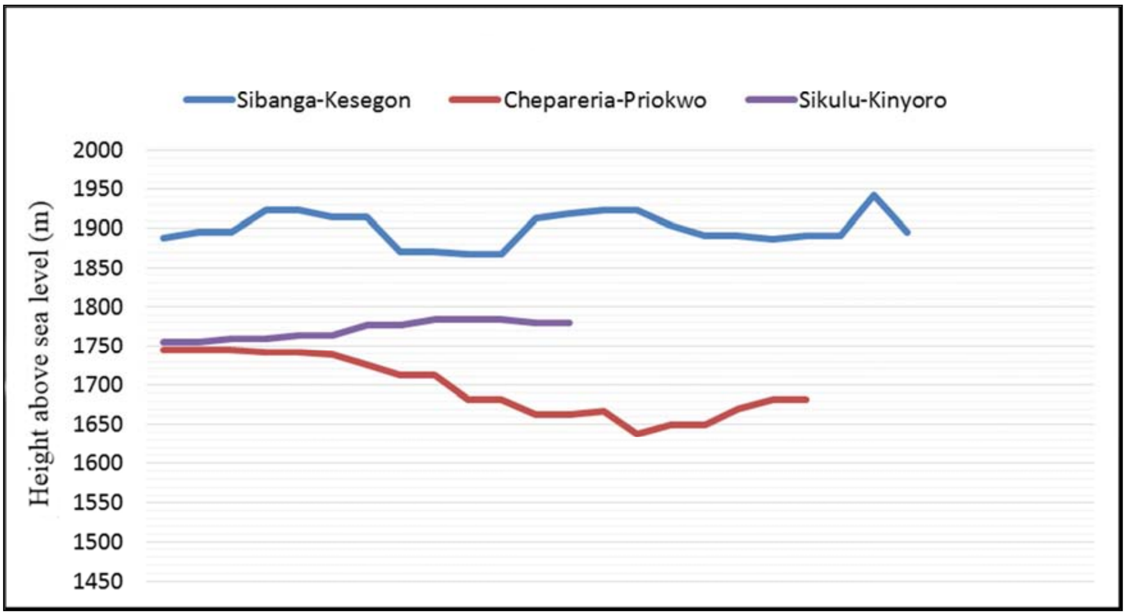

Figure 5. *Road terrain simulation using height above sea level (m).*

3.5. Sediments Volume Movement

Eroded sediments per road in all the three counties were calculated and this included sediments from both erosion and deposition. Sediments loss or gain was calculated at intervals of placed pegs. The final data was computed and Mt. Elgon County had the highest loss in sediments, 3284.64 cm^3 of sediments moved and deposited. West Pokot-Chepareria-Priokwoi road- had the lowest volume of sediments at 1004.124 cm^3. In Trans Nzoia county Sibanga had the highest number of sediments moved at 3009.512 cm^3. Mt. Elgon county road had the highest number of sediments this could be due to lack of soil control work in the areas.

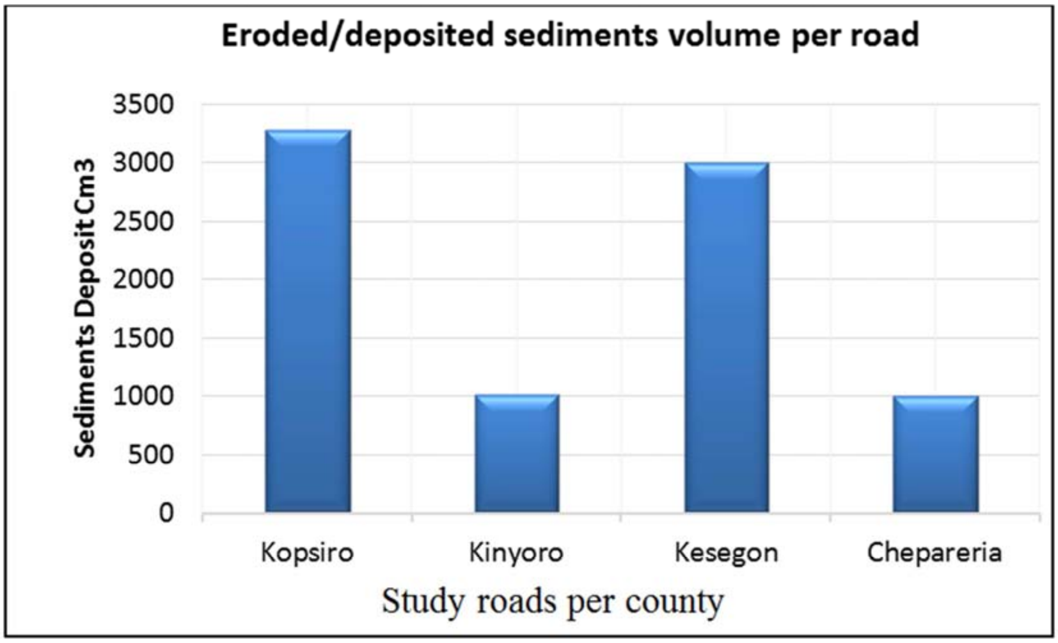

Figure 6. *Total sediments volume (deposited and eroded) per road.*

Sediments eroded and deposited were also plotted against height above sea level and grouped per road class for each study road. High sedimentation levels were recorded in Kuywa-Kopsiro area with sediments rising above 200 cm^3 after 2260 m above mean sea level. This was also experienced in parts of the lower lying road section which range between 33 cm^3– 98.7 cm^3 being deposited in three months period this is was as a result of a newly redone road with deep ditches and loose soil along its slopes and back slope which became source of sediments during rainy season.

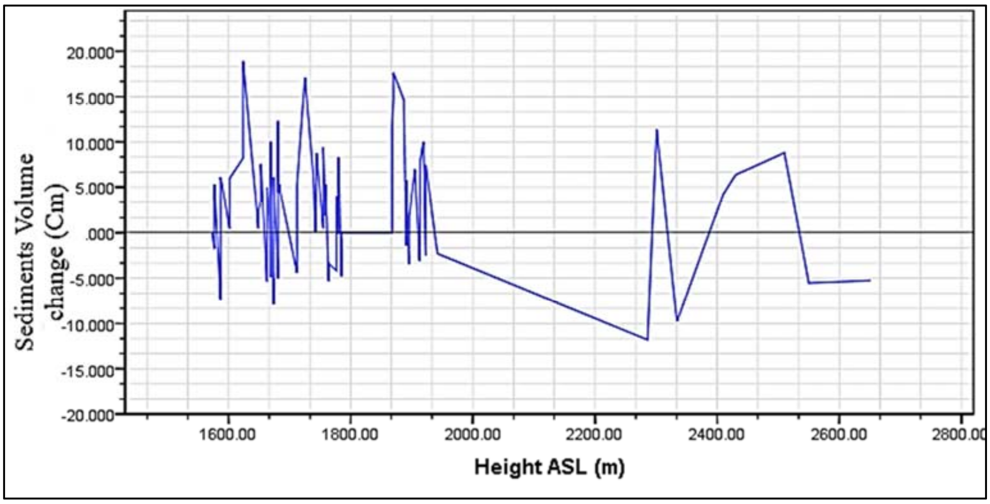

Figure 7. *Graph of sediment loss and deposition versus Height above sea level.*

3.5.1. Kuywa-Kopsiro

The road stretches 26+100 km from 1573 m-2651 m ASL, the road traverses through steep terrain with gradients greater than 50^0. The above graph (Figure 7) shows variation of soil erosion and sedimentation along all the roads, the negative value signifies erosion while the positive shows deposition. It was observed that between 2300-2400 m ASL there was a drastic increase in erosion, this area signifies the slopes of Mt. Elgon which covers 2 km of the road section and it recorded -11.1 cm change in sediment movement. The area is characterized by steep slopes with no soil control structures and scanty vegetation. Between 1800 m-2200 m ASL the area was not studied in Mt. Elgon region because of the terrain and inaccessibility of the road, the inaccessible part is 2 km from Kapkateny River to Chemisto Primary school in C51 road leading to Kapsokwony, this in the (Figure 8) below is represented by the missing values after 1800 m to 2200 m.

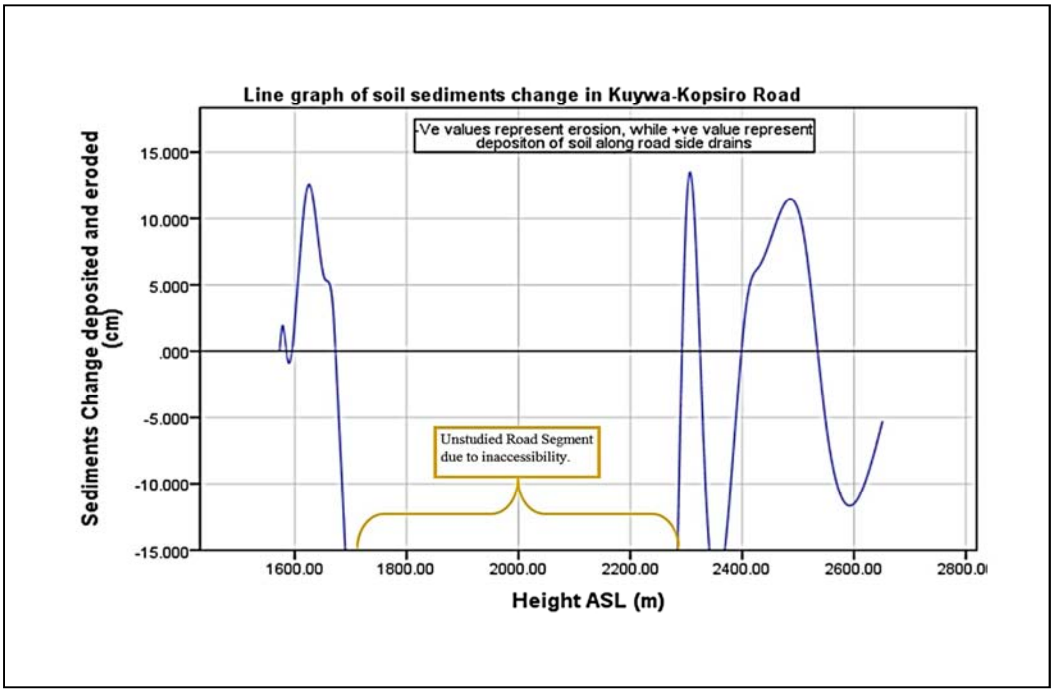

Figure 8. *Sediments change deposited/eroded in Kuywa- Kopsiro road.*

3.5.2. Chepareria-priokwo

In West Pokot County the terrain ranged from 1650 m-1725 m ASL and the highest deposition was recorded at 1725 m ASL which was at 2+800 km mark. The high rate of sand sediments was attributed to transportation by water from 0+500 km, the relief could be a factor contributing to the sedimentation, despite the availability of a mitre drain in the side drain and a cross culvert, their functionality was impaired by the massive transportation and deposition of debris.

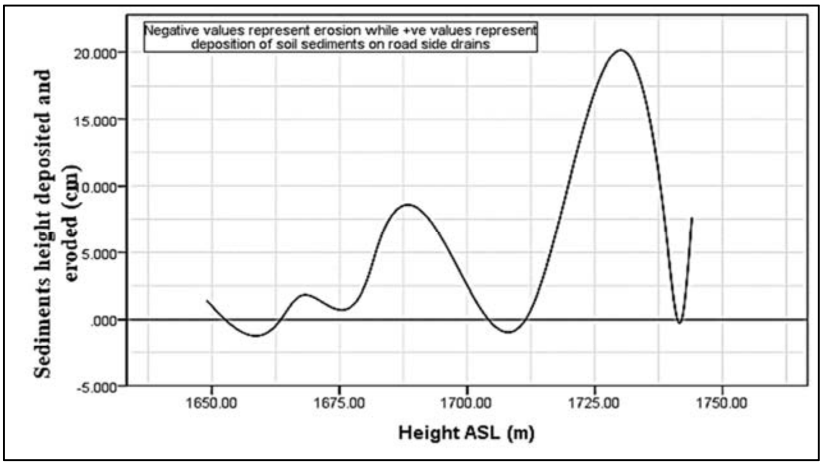

Figure 9. *Sediments change versus Volume in Chepareria-Priokwo.*

Erosion in West Pokot was not that intensive but it was a progressive and widespread across the road system, with maximum value of -5.4 cm. The erosive level was persistent in all seasons from dry to rainy seasons with a Standard deviation of (4.50541) in rainy season and (11.99954) in the dry months of January. The erosion in the roads occurred on side drains and in areas with descending profile leading to either a dry river valley or a river.

The average deposited sediments in west Pokot was higher than the eroded sediments from the road see (Figure 10 below). The volume of eroded sediments was less at 202.41 cm^3 compared to deposited sediments which was 356.11 cm^3. The general trend of west Pokot roads was deposition, while erosion accounted for less than 40% of soil movement and deposition was higher on lower sides of the road and along dry river beds. The probable source of sediments could be from adjacent farms or transported from distant locations by water action. The sedimentation materials were deposited on the roadside damaging road soil control works and blocking culverts, shattering drifts and bridges in the area.

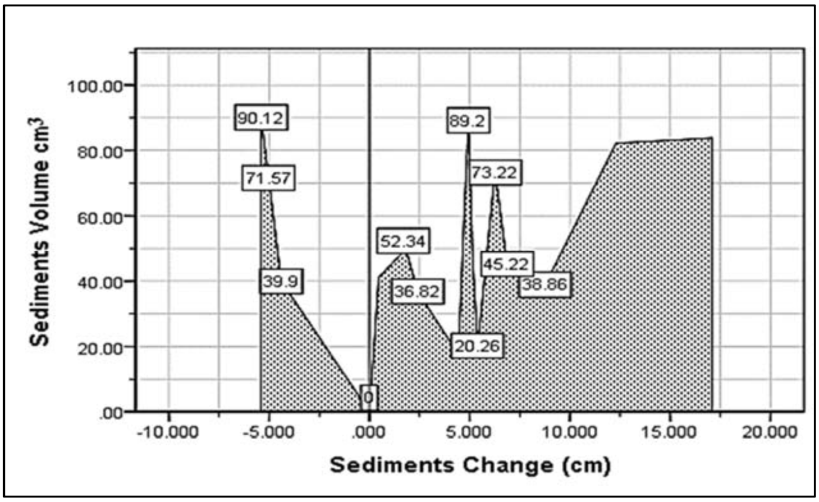

Figure 10. *Sediment volumes in West Pokot.*

3.5.3. Sibanga-Kesegon

Sibanga-Kesegon lies on the slopes of Cherangani hills along Kapkanyar Forest through Kapchorwa tea factory. The road ranges from a rolling terrain to undulating land. The road ranges from 1867-1943 m ASL and the studied road was 19+200 km with a total of 24 pegs. The general trend of the road was erosion. Erosion was higher at 3+100 km with an average high of 17.63 cm and low of -3.467 cm at 18+200 km (see Figure 11), and this was due to anthropogenic activities in the area. The road between 2 km-5 km was being redone during the third and fourth reading of the study, the high rate of sedimentation was also attributed to the rolling terrain and newly done side drains which retain much debris. The high rate of sediments at 12 km is due to poorly placed of soil erosion control works (scour checks) from 6 km to 12 km which caused a high run off rate causing accumulation at Saiwa swamp.

The total soil moved in Sibanga-Kesegon was 3009.512 cm^3, a total of 2476.484 cm^3 of debris were deposited along the road while 694.148 cm^3 was eroded. The general soil movement trend in Sibanga-Kesegon road is deposition. The deposited soil came from adjacent farms, this was evident by the inconsistency from eroded and deposited sediments.

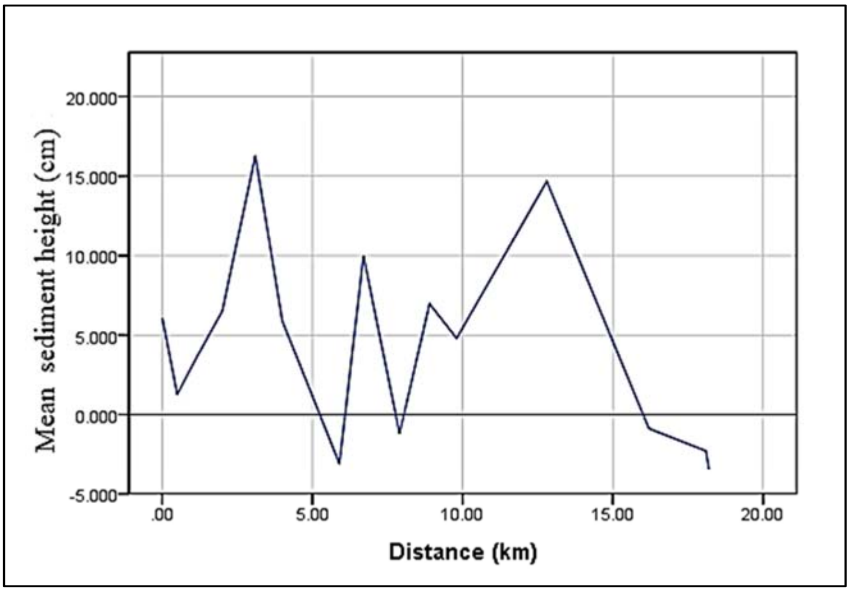

Figure 11. *Mean sediments height versus road distance (Sibanga-Kesegon).*

3.5.4. Sikulu-Kinyoro

Sikulu-Kinyoro lies on a rolling plain and it covers 8+200 km from Saboti Junction to Kitalale Junction in Kinyoro centre. The road rises from 1755-1809 m ASL at Kinyoro centre. The road is generally covered with vegetation. At 5.6 km to 6 km on height of 1768-1773 m above sea level there was no data recorded due to large existing gullies.

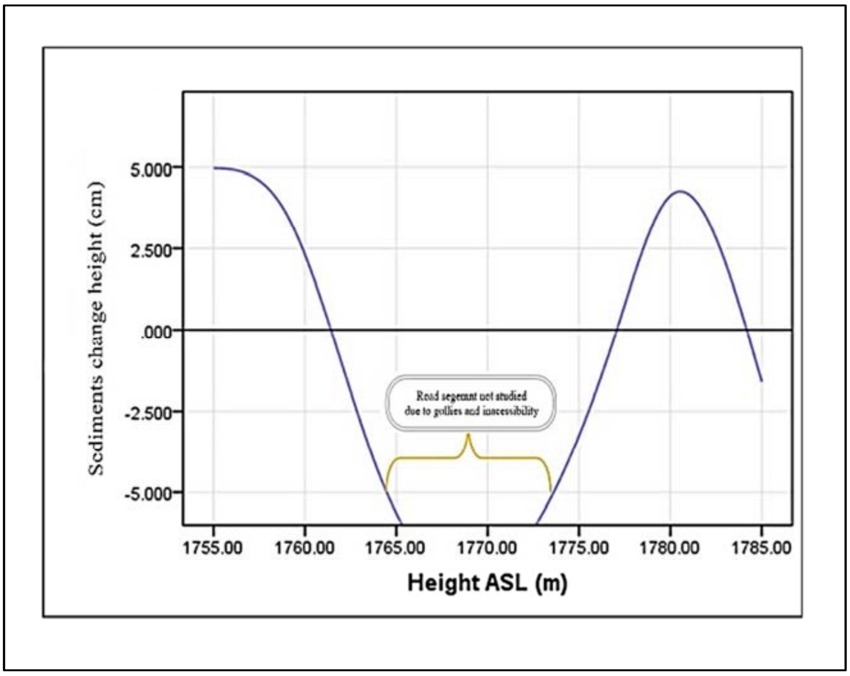

Figure 12. *Line graph of eroded/deposited sediments change versus ASL in Sikulu-Kinyoro road.*

The total sediments change in the road was 1011.47 cm^3. The total sediments deposited was 574.34 cm^3 while eroded sediments was 437.14 cm^3, the sediments eroded in the road reserve and the sediments deposited were almost equal. At 5+600 km of the road stretch from Saboti Junction there were large gullies that could have been caused by cumulative storm waters for a 2 km stretch.

3.6. Road Run-off Rates and Soil Deposition

Runoff rates for the road network were computed by cook's method, which factored in catchment characteristics of the catchment areas. A Pearson product-moment correlation coefficient was computed to assess the relationship between the sediments volume accumulated along roads and runoff rates along the study area. There was a positive correlation between the two variables, r =0.281, n = 82, p = 0.011. Generally, there was significant correlation between sediments volume and runoff rates in the study roads.

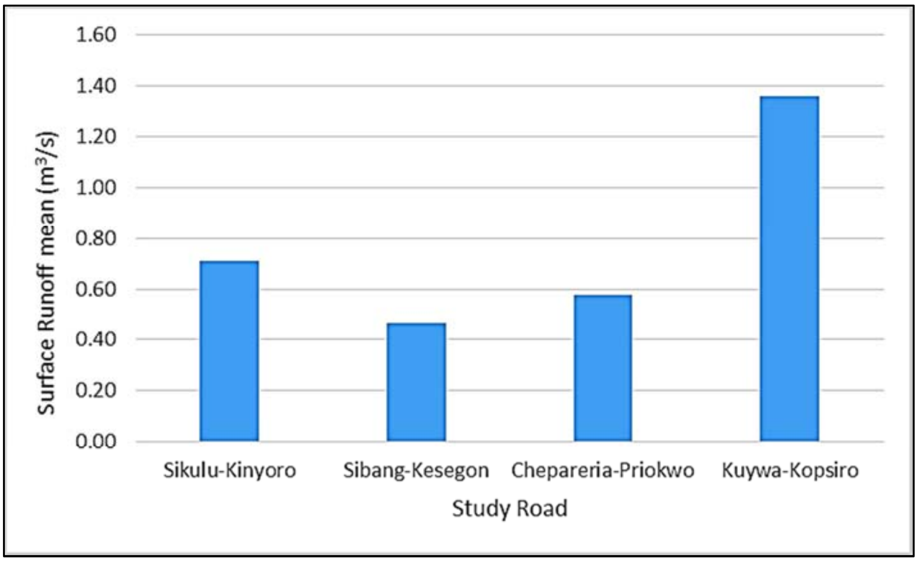

Figure 13. *Bar graph of study roads run off rates in (m^3/s).*

Plotting the data on a scatter plot- see a scatter plot that summarizes the results in (Figure 14)- exhibits a general concentration rate below 1 m^3/s.

The run off rates in all the roads concentrate on a mean of 1 m^3/s with volume sediments of less than 100 m^3. The corelation between run off rates and sediments volume in the roads shows a positive corelation of r=+0.079.

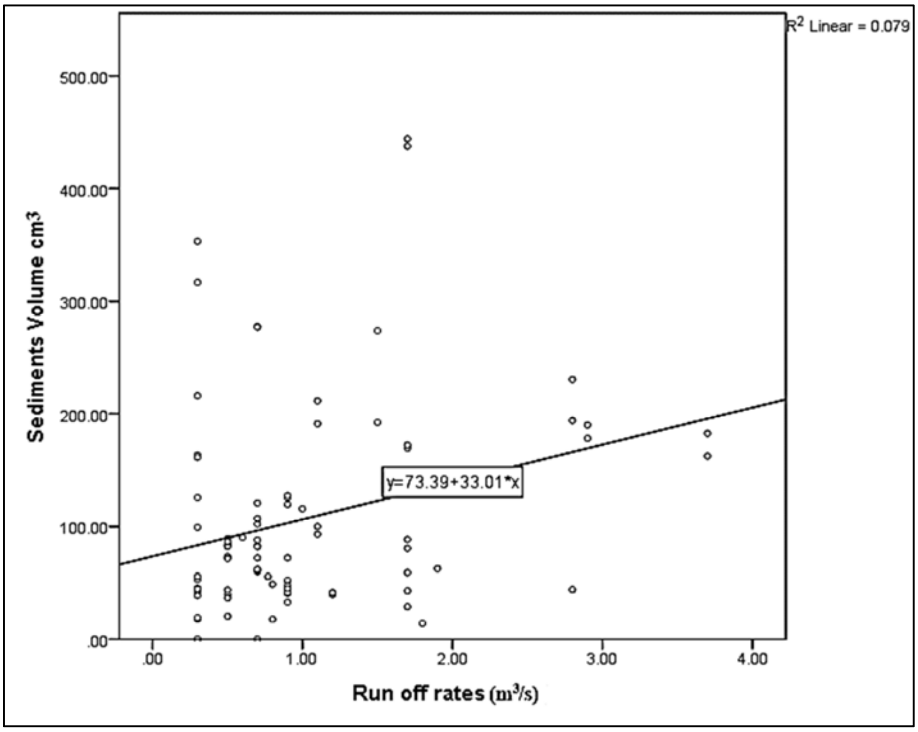

Figure 14. *Scatter plot of sediments total volume versus run off rates.*

3.6.1. Chepareria-priokwo

The drainage description of Chepareria area –West Pokot County- was rated as well drained zone [9], with deep and very deep soil columns. The area is on a plain land and the soils are sandy.

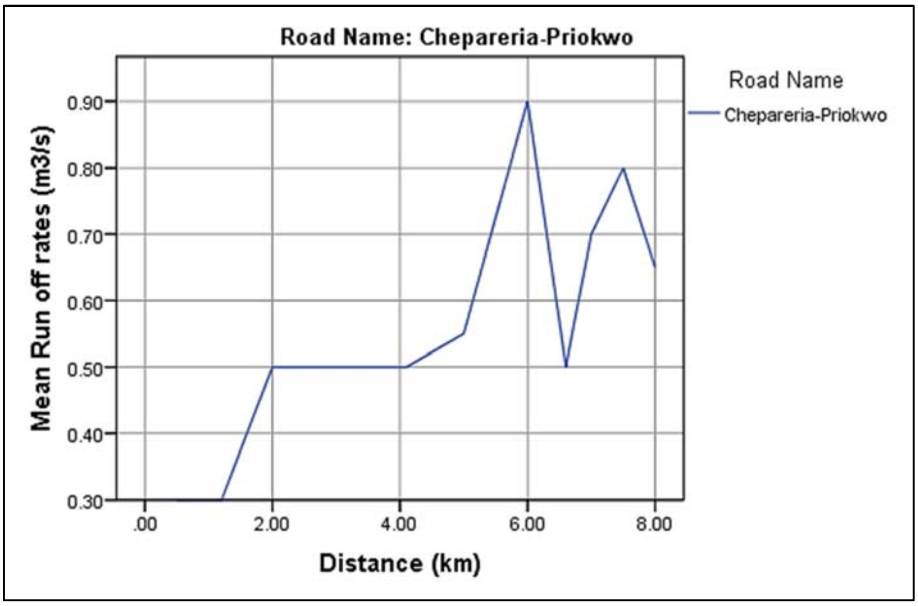

Figure 15. *Mean run off rate versus distance (Chepareria-Priokwo).*

The run off rate in Chepareria at 0+00 km is at 0.30 m^3/s, this was the lowest speed because of the terrain and vegetation cover at the area, the surrounding had a heavy shrub growth and this helped in reducing runoff water speeds, this has also been documented by [10]. The rate increased and at 2km the speed of water was at 0.50m^3/s and this was maintained until at 4 km. The stretch from 1.5 km-2 km was sloping towards the west and it featured large gullies and high rate of deposition. The slope could contribute to the increased surface run off within a 500 m stretch. A correlation of sediments volume versus run off rates were drawn, r=0.155, n=20, p= 0.515, there was significant difference between run off rates and sediments volume in the study road, this has been supported by [11] who indicated that surface runoff and sediments flow are directly proportional to the amount of runoff. From the above interpretation it is interpreted that surface run off is not responsible for the sediment deposits or erosion in the area and so others factors contributed to it and this included anthropogenic factors- human activities upslope or on the sides of the road.

3.6.2. Kuywa-Kopsiro Road

In Kuywa-kopsiro road the signifacnce between run off rates and sediments deposition was, r=0.339, n=26, p= 0.091, there was a positive significance between the two variables with a r=0.339 the significance was not so strong and conforms with [12] which indicated that an increase in run off rate caused an increase in soil movement or deposition.

3.6.3. Sibanga-Kesegon and Sikulu-Kinyoro

In Trans Nzoia County the two roads -Sibanga-Kesegon and Sikulu-Kinyoro- had a positive correlation of r=0.049 and r=0.251 respectively, this could be explained due to the ground cover on all the two roads, there was a higher percentage of grass cover. The correlation coefficient for Sibanga-Kesegon was lower than for all other roads, this could be because its sediments volume were determined more by anthropogenic activities rather than runoff rates, a report by [13] on the Yellow river indicated that the sediments downstream have significantly reduced in 30 years despite increased river surface runoff upstream. The Sikulu-Kinyoro road had weak positive correlation significance.

4. Conclusion

The road in Mt. Elgon was majorly influenced by climatic factors, it was also observed that erosion and deposition of soil was influenced by terrain and there was a relative significance in Mt. Elgon roads. In west Pokot the roads were in good conditions but the major threat to them delivering was erosion upslope. There was high rate of erosion upslope and this was evident with the road of Sibanga-Kesegon where there was immense cultivation upstream, causing high runoff rates and increased soil erosion which blocked culverts, mitre drains and cut-off or relief drains diverting the waters to the road camber and breaking it rendering the road unusable.

Recommendations

The paper recommended the following solutions for low volume rural roads to reduce and avert the soil erosion and deposition challenge.

a) Road reserve should be left uncultivated and the grass be kept short to enhance soil compaction and protect the back slope of the roads from erosion, this will also protect the side drains from silt/debris accumulation.
b) Soil control works should be built to expected standards for effectiveness and reduce overworking of other structures. This was observed in west Pokot where the drifts were built on bends which gets the side apron damaged before next road maintenance cycle.

c) Cut-off drain and relief culverts should be encouraged in zones of Mt. Elgon at distance of 10km apart and in Sibanga-Kesegon roads, these roads receive a high rate of precipitation resulting to high run off rates and unbalanced hydrology levels breaking road camber and blocking side drains.

Acknowledgements

Sincere thanks to the Dean School of Environmental studies Prof. Vincent Sudoi. Special thanks goes to the Ministry of Transport and Infrastructure for their financial support especially the Principal Secretary and Head of Department Eng. Martin Ontomwa and fellow staff at Kisii Training Centre. Specific recognition to the following; Regional Managers KeRRA and their technical staff in – Bungoma, Trans Nzoia, West Pokot enabling environment to carry out the research, ILRI, KMS (Kenya Meteorological Services) and Survey of Kenya's for provision of data, script editing and recording data.

References

[1] Ministry of Roads and Public Works- Roads 2000 (May 2005). Roads 2000 contract management manual, improvement works.

[2] BBC. (2014). Surface and interior erosion.

[3] Montgomery, David (2008). Dirt: The Erosion of Civilizations (1st ed). University of California Press. ISBN 978-0-520-25806-8.

[4] Dayton, Leigh; (1992) "Pacific Islanders Were World's First Farmers," (New Scientist).

[5] Jungerius, P. D., J. Matundura, and J. A. M. Van De Ancker. "Road construction and gully erosion in West Pokot, Kenya." *Earth Surface Processes and Landforms* 27.11 (2002): 1237-1247.

[6] Eriksson. A, Kidanu A (2010). Guidelines for prevention and control of soil erosion in road works. International Labour Office, CH-1211 Geneva 22. Switzerland (2012).

[7] Hudson, N. (1981). *Soil conservation*. Cornell University Press. USA, New York.

[8] Hudson, N. (1993). *Field measurement of soil erosion and runoff* (Vol. 68). Food & Agriculture Org.

[9] International Livestock Research Institute (ILRI), 2014.

[10] Whipple, K. X., & Tucker, G. E. (1999). Dynamics of the stream-power river incision model: Implications for height limits of mountain ranges, landscape response timescales, and research needs. *Journal of Geophysical Research: Solid Earth*, *104*(B8), 17661-17674.

[11] Lotfalian, M., Parsakhoo, A., Kavian, A., & Hosseini, S. A. (2013). Runoff and sediment concentration of different parts of a road in Hyrcanian forests. *Forest Science and Practice*, *15*(2), 144-151.

[12] Ajayi, Ayodele Ebenezer. "Ecology and Development Series No. 18, 2004.

[13] Jiongxin, X. (2004). Effect of human activities on overall trend of sedimentation in the lower Yellow River, China. *Environmental Management*, *33*(5), 637-653.