Universal Journal of Environmental Research and Technology
 eISSN 2249 0256
Available Online at: **www.environmentaljournal.org**
2018 Volume 7, Issue 1: 19-37

Open Access **Research Article**

Prediction And Estimation Of Sediments Discharge From Kangimi Dam Reservoir Catchment, Kaduna, Nigeria

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Abstract:
Sedimentation has been found to be a major future threat to water shortage and scarcity, as human activities and animal rearing aggravate its sources. There is need to provide the tools to predict and measure sediments, hence, this work aimed at providing a model to predict and estimate quantitatively sediment inflows for an area with herds' activities. The work applied Global Information System to derive the catchment feature characteristics for various sub-catchments. Soil samples were randomly collected for particle size analysis using Bouyoucos method for soil erodibility determination, while water samples were collected from surface runoff for suspended sediment concentrations using filtration and drying methods. The sediment load was obtained by multiplying the discharge and suspended concentration, and then converted to kilogram per day/tones per day. A rating relationship between the sediment loads and discharges on slope, drainage areas and herds' column, were used to determine the effects of sediment discharge characteristics. The prediction and estimation was done using Multivariate Universal Soil Loss Equation, thus, model formulation. The parameters of Universal Soil Loss Equation were evaluated from the standard in conjunction with global information system tool. However, the research provide the drainage areas, slope and four indices of soil erodibility to regressed against measured sediments from herds' column, for determining the extent and severity of sediment generation from the catchment, hence, the model. The soil particle size indicated that soil aggregates were not stable and prone to sediment and erosion wash if agricultural land use, animal herdship and human activities, persist. The model predicted well with Modified Clay Ratio with coefficient of determination, R^2 = 0.83 and coefficient of correlation, R= 0.91 at 0.01 (p<0.01). The study shows that herds' activities contributed to sediment yields as model reasonably matched with the measured data and moderately predicted within the data without deviation, and recommended the use of the model for the Kangimi dam reservoir sediment inflows among others compared.

Keywords: Sediments, Herds', Catchment, Discharge, Soil erodibility indices and USLE

1.0 Introduction:
The transportation of sediments by the flowing water in the watershed, rivers and channels is an important factor in the planning, design, and operation of reservoir and impounded water-management projects. Sedimentation affects the reservoir storage, water structures stability, channels conveyance efficiency, as well as the suitability of the water for various uses. In reservoir systems, persistent organic and inorganic chemicals are accommodated into sediments deposit (U.S. EPA. 2001). These sediments metamorphosis into toxic chemicals that are introduced into surface waters when settled and reduce interstitial oxygen concentrations that caused suffocation in benthic invertebrates, alleviants and fish eggs (Bjornn and Reiser, 1991, McDonald *et al.* 1991). United States Environmental Protection Agency's National

Sediment Inventory (NSI) (USEPA, 1998) reported to Congress on sediment quality in the United States, that sediment contamination exists in every state of the country and represent a hazard to aquatic life, wildlife and human health through direct toxicity. Sediment movement from the watershed is associated with environmental and engineering issues that are includes agricultural topsoil loses, high sediment loads to reservoirs, organic and inorganic chemical contaminants, silts and clays, silting of fish spawning beds, and channel instability when dredged in case of environmental issues. Engineering issues includes channel sedimentation leading to instability, loss of allowance, loss of river and reservoir capacity, navigation and flood control.

The rapid reduction in the storage capacity of reservoirs due to sedimentation is a world-wide sediment inflows problem. This condition is conflicting to water supply objectives in the effects of increment in world population. Research shows that, about 1% of total reservoir storage capacity of the world reservoirs is lost every year to sedimentation (Mahmood, 1987; White, 2001). Moreover, the water supply for irrigation and animal pastoralist in Africa leads to more intensive land use and soil aggregation disturbance. These effects may also be exacerbated by desertification, whether anthropogenic or climatic in origin (Petkovsek and Roca, 2014). The enrichment of reservoir storage with sediments materials that arise from agricultural and pastoral areas increase sedimentation originating from the water column after decaying plankton or littoral zones, decaying macrophytes. Consequently, the sedimentation rate of reservoir is often greatly exceeds that predicted during design (Morris and Fan, 1997), therefore, calls for monitoring data for sediment movement into reservoirs for accurate estimation of sediment inflows and its deposition, for effective reservoirs management to curb water loss and economic resources. This requires knowledge of the processes of sediment erosion, transportation, and deposition, and of their interaction with the hydrological processes in the catchment. Thus, the system requires a model which can predict future behavior and response of catchment material movements.

All models are concept of thought and depend on the situation and available resources. They may grow in complexity, numerical simulations, and physical scale modeling. The real-world hydrologic systems are complex, but can be illustrate with models which are simplified, though did not reproduce exact system behavior, but to a certain level of acceptance. In reservoir and dam engineering design, safety of factors are incorporated into analysis of the uncertainty, to approximate results of the model for acceptable design parameters to achieve a viable design that reduce sediment inflows, and hence, provide a good management planning. Construction of the dams across the natural channel of a river alters the natural balance of water ways and sediment, to a certain extent. The state-of-the-art system of conventional concept of managing reservoir sedimentation for a predetermined useful life of 50 to 100 years allocation is no longer fashionable since the structure in most of the world reservoirs and dams has been override by sedimentation. However, in the planning and designing new reservoirs, engineers should incorporate sustainable concept and management based on the expected catchment sediment generations. And for existing ones, engineers should provide appropriate remedial measures to prolong their useful functions within economic, social, political, and environmental constraints, or resolve issues for existing projects which have ability to forecast sediment inflows. This research therefore aimed at providing a model for forecasting and quantitatively estimates sediment inflows under the influence of agricultural land used and herds' activities .

1.1 Reservoir and Sediment:

Water harvested into reservoirs serves different functions that include domestic, industrial uses, hydro-power, agriculture and flood control (Palmieri *et al.*, 2003). These prevent the losses during excess and can be stored for years until the useful time, given the dams the strategic importance for the man civilization and economic strengths (Beebo and Bilal, 2012). However, these man-made structures caused imbalance to the natural water flow and associated problem of which is sediment production and transport. Reservoirs are designed for assumption of 50 - 100years life span, after which depleted by sediment deposition over time. The amounts of sediments inflows from overland often make the useful life of a dam shorter because sediments directly discharged into the dam and settled down as velocity of water reduces near dyke as observed by Morris and Fan (2008).

Palmieri, *et al.* (2003) revealed that an estimated of 0.5% - 1.0% is been lost to sedimentation, annually, about 45 km^3/year storage volume losses. The sediments generation and its transportation is highly depends on the magnitude of the various active and passive forces within the catchment. On continental and subcontinent basis, the major determinants are climate and relief (Syvitski *et al*., 2003), geology (Mclennan, 1993), soil types (Bartholic, 2004), vegetation (Jansen and Painter, 1974), drainage characteristics (Milliman and Syvitski, 1992), and land use pattern (Verstraeten and Poesen, 2001).

There are many models for use in simulating sediment discharge, transport and associated sediment yields. In general, models are into three main categories, depending on the physical processes, the model algorithms that describing the processes and model data dependence. These are Conceptual, Physics based and Empirical or Statistical, but no "best" model for all applications.Empirical models are simple and convenient to other three model types. They are based field observations and analysis responses from the data (Wheater *et al*., 1993). The parameters may be obtained by calibration, but often transferred from calibration at experimental sites and particularly useful as a first step in identifying sources of sediment production.Though, empirical models are often criticized for employing unrealistic assumptions about the system, neglecting the catchment heterogeneity, but despite the weaknesses, it has outperformed other model types (Govers 2011). For soil loss and sediment yields, the empirical models are based on the Universal Soil Loss Equation (USLE) despite conceptual flaws (Kinnell, 2004), the USLE has still been widely used in Europe to estimate soil loss on regional (Tetzlaff *et al*., 2013), and continental scales (Podmanicky *et al*., 2011). To predict the sediment yield, many empirical relationships between the sediment yields and catchment properties have been suggested, while the common power equations to forecast sediment yields from the catchment varied enormously between regions.

A simple regression model has been developed for prediction of sediment loads (Hicks and Shankar, 2003). In regression modeling standard, two variables called independent variable (X) and dependent variable (Y) are correlated. The variable to be forecasted (dependable variable) is expressed as a mathematical function of the independent variable. The analysis can be done by computer, while the expected regression equations were either: Linear, Power, Natural logarithms, and Polynomial functions. The sediments as dependent variable and catchment features as independent variables. Sediments sampling methods such as fraction collectors are suitable for small catchments, and one suited for large drainage basins, involves sediment sampling techniques. In the absence of frequent samples other samplers such as grab samples, point integrating samples or depth integrating samples, are used and a resort is usually made to the sediment rating curve technique of estimating sediment yields (Knighton, 1998). This technique is primarily applicable to the suspended load and involves deriving a generalized relationship between sediment discharge and flows, which can be used to predict sediment from a continuous record of discharge. The relationship is usually presented as a straight line graph on logarithmic coordinates (Yusuf, 2013). The sediment sampling is therefore required to derive and check the relationship curves and it is possible to tentatively extend the relationship to period when no data is available, but for which discharge records are available.

Grab method is mostly recommended in used where problems of tools for sediment sampling, lignin resources and with an unguage catchment site. Many authors (e.g. Yusuf, 2013; Tyagi *et al*., 2014) have used it and/or with conjunction with other methods, it is most preferred in such environments and sampling is directly related to conditions exist in the catchment.

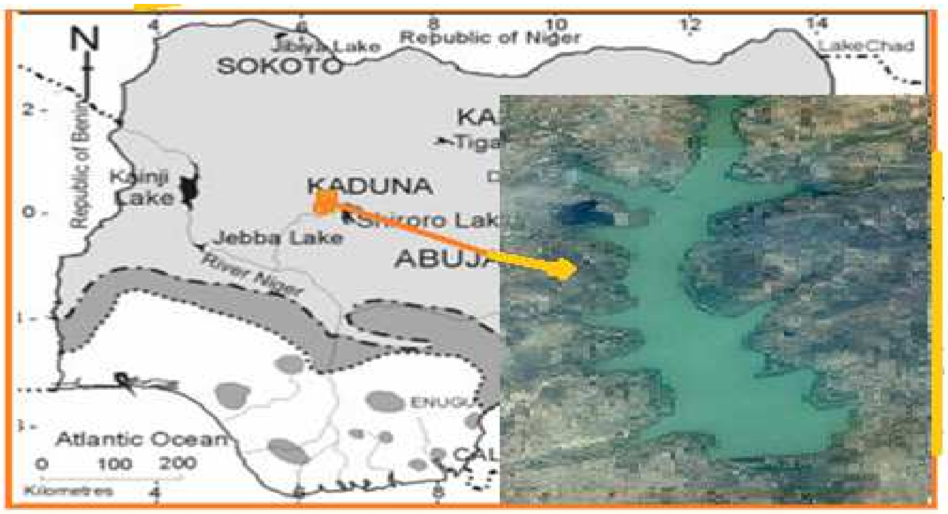


Figure a: Kangimi Dam Reservoir Catchment in Kaduna, Nigeria

2.0 Materials and Methods:

2.1 Study Location:

Kangimi earth dam reservoir (KDR) was constructed across Kangimi River approximately 3.22km on upstream of Kaduna River confluence (Figure a). It located on the Savanna region, between Latitude 10°46'N and Longitude 7°25'E. The reservoir has a total volume of 59.8Mm^{3}of water and covered surface area of about 12km^2 with about 9.63km in length and a maximum depth of 12.92m.

The water impounded is to be use to augment the existing water supply to Kaduna Metropolis during periods of low flow on the Kaduna River and to irrigate about 1,619ha of land on the North bank of the Kaduna River upstream.

2.2 Sampling Strategy:

The sampling design focused on existing natural channels, referred to as sub-catchments that formed the main contributories into the reservoir, ten (10) majorly, as seen in Fig. a. From the sub-catchments, soil and water samples were collected from representative fields during dry and storm events which were assumed to be the main sediment sources. Runoff water (as water samples) was collected using grab method for determining suspended sediment concentration (SSC). In this work, however, herds' columns were identified for probable sediment source. Here herds' columns were considered because of the resultant effects of their activities on the catchment leading to breaking and grinding of soil structures within columns. Many authors have used human population density (e.g. Xixi, 1998) that did not satisfactorily answer many questions related to sediment yield. These samples are to be analyzed for various physical properties, particle size distribution and erodibility indices for the identification of sediment production source and severity, while the controlled field as reference on the catchment was identified.

2.3 Sampling Procedures:

To provide background information on the behavior and sediment production on the catchment basis, specific locations were chosen for sampling collections.

2.3.1 Soil Sampling:

Soil samples were collected randomly based on land use and cover characteristics from sub-catchments at depth of about 20cm in twenty (20) places using core sampler. For easy handling and cost effective, the samples were mixed together, as partly assumed that top-soil depth is only around 15cm below that are partly weathered parent materials. The guide to the mixed was done by considering adjacent samples homogeneously; the mixed formed ten samples for every sub-catchment. The easy removals of fine/silt particles of topsoil by erosion resulted in high sediment yield, the condition that caused deliberate removal of soil through farming operations, herds' activities and rainfall erosivity actions. Under these circumstances, it is enough to judge the patterns of sediment production and transportation into the reservoir from the catchments

2.3.2 Herds' Columns Influence on Sediment Yield:
In this work, herds' column is assumed and considered to influence the breaking, detaching and grinding of soil structure into sediment material as shown in Figure b**.** Soil samples were collected before the raining season along the herds' column at 5cm depth of topsoil on the interval of 50m.
The hypothetical conclusion here is that, herds' activities influence topsoil as impact leading to high susceptible to erosion as matching, breaking, and grinding progresses.

Figure b**:** The surface reference point of herds' activities and route

2.3.3 Water and Sediments Sampling:
The elevation, length and slope formed the bases of where the water and sediment samples were collected for suspended sediment load (SSL) determination. Before the sampling exercise, two closest sub-catchments were treated as homogeneous by their drainage; hence, samples were mixed as one, and reduced to five (5) for easy handling of data. Water and sediment samples were collected by grabbing method after 3minutes pre-determined time as minimum time recommended (USSD, 2015) from the maximum elevations for determining the initial sediment loads, along the length and on minimum elevations, for specific differential. The volume of the mixtures collected at this 3minutes time were measured and recorded as discharge, Q.

2.3.4 Application of Geographic Information System (GIS) and Data Analysis for Land Use and Cover:
Global positioning satellite (GPS) was used to capture the coordinate points around the reservoir and other relevant positions. This served as the basis data for digital elevation model (DEM), topography map, and for generating influencing variables such as length, elevations, slopes, and catchment areas.

2.4 Data Analysis:

2.4.1 Rainfall Distribution Analysis:
Monthly rainfall data depths were obtained from Nigerian Meteorological Agency (NIMET) Kaduna, spanned between 1995-2015 (20years). From the data, descriptive and plot statistic analysis was performed on Microsoft Excel Software while Intensity-Duration-Frequency analysis (IDF) was developed using procedure in Gupta and Gupta (2008)

2.4.2 Estimation of Suspended Sediment Load (SSL):
Temporal extrapolation was required for a reasonable prediction (Painter, 1976). The condition is usually achieved through the relationship between suspended sediment concentrations, suspended sediment load (SSL) to catchment runoff discharge, based on a limited number of sediment. Thus, SSL (mg/s) was given as a product of discharge, Q and concentration, C_s and then converted to kg/day and tons/day, respectively as

$$Q_{SSL} = \frac{QC_S}{1000} \times 60 \times 60 \times 24 \text{ (Kg/day)} \quad (1)$$

$$Q_{SSL} = \frac{QC_S \times 60 \times 60 \times 24}{1000 \times 1000} \text{ (Tons/day)} \quad (2)$$

Where, Q_{SSL}= Suspended Sediment Load in Kg/day or Tons/day, respectively; Q= flow discharge in m^3/s; and C_S= Suspended Sediment concentration in mg/s.
The continuous record of suspended sediment discharges provide the estimation of sediment yield throughout the year for each of the sub-catchment (Ferguson, 1987; Thomas, 1983).

2.4.3 Laboratory Analysis:
The soil samples were analysed for particles distribution using Bouyoucos Hydrometer method. The amounts of particles size distribution dictate the susceptibility or erodibility indices of the soil of a catchment. To determine the indices three (3) methods were adopted as proposed in Mallo and Mgbanyi (2013) for clay ratio (CR); dispersion ratio (DR) and critical level of soil organic matter (CLOM). The suspended sediment concentration, C_s, was determined using method in Yusuf (2013) and for soil organic matter (SOM) estimation wet digestion method of Walkley and Black was adopted.

2.4.4 Predicting and Estimating Sediment Yields:

The method employed here was sediment-rating curves which have been widely used by many authors, for instance, Strand (1975), Gray and Simoes (2008), and Fathizad *et al,* (2014). The empirical relation between surface water discharge and sediment concentration or discharge can be expressed graphically as a single relationship. The curve is usually developed using logarithmic transformation data with surface water discharge as independent variable and sediment concentration as the dependent variable. The curve relation is defined by power function (Glysson, 1987)

$$SS_Q = aQ^b \qquad (3)$$

Where, SS_Q is the suspended sediment yields, kg/s or tons/day; Q is the surface water discharge, m^3/sec; and *a, b,* are the intercept and slope gradient respectively.

The solution to the function was given as

$$Log\ SS_Q = bLog\ Q + Log\ a \qquad (4)$$

In predicting and estimating sediment yields, many authors have used Universal Soil Loss Equation (USLE) (e.g. Gatwood *et al.,* 2000; Pak and Lee, 2008; Fathizad *et al.,* 2014), among all, no one has related herds' activities. The case study is favored with animal pastures, water, and conductive climate, the conditions favourable to cattle rearing and concentration, given large formation of herds' columns. The USL equation is given by Renard *et al* (1997) as

$$A = (R \cdot K \cdot L \cdot S \cdot C \cdot P) \qquad (5)$$

Where, A is Expected Annual Soil Loss in tones/ha/year; R is Rainfall erosivity in MJ mm/ha/h/year; L and S are topographic factors, hill slopes length and steepness (dimensionless), respectively; K is Soil erodibility in Mg ha h/ha/MJ/mm; C and P is Cover-management practices and support practices factors that describe land use, respectively.

For this research however, drainage area (A_d), Drainage density(D_d), Relief ratio (R_r), Slope (S_p) and Herds' column density (H_d) were incorporated into USLE to predict sediment discharge. The formulation is expected to help in overcoming the limitations of the use of USLE in an area where herds' column is prevalent and relevant on catchment sediment generation. Thus, equation (5) become

$$SS_Q = (R.K.L.S.C.P.A_d.D_d.S_p.R_r.H_d) \qquad (6)$$

The USLE variables in equation (6) were estimated using standard formula in Brown and Foster (1987); Panagos *et al* (2016); Vemu and Pinnamanen, (2012); McCool *et al* (1987); Van der Knijff *et al*. (2000); European Soil Bureau; Scott and Williams (1978); and outcome of the research GIS survey.

2.4.4.1 Drainage Area (A_d)

The Pacific Southwest Inter-Agency Committee (1968) procedure of area classification that gives each drainage basin characteristics of a subjective numerical rating was employed. This study conducted collection of the suspended sediment concentration during storm events for the individual sub-catchment classifications. Empirical equation of power function (3) was developed strictly as a function of drainage area, $A_{d,}$ based on catchment basin sediment survey as independent variable and sediment concentration as dependent variable.

2.4.4.2 Slope Influence (S_p)

During the process of drainage area classification, each feature of slope degree was identified on the classified areas. Based on this, suspended sediment concentration was abstracted and related to the slopes. An empirical equation of power function was developed, with the slope as independent variable and sediment concentration as dependent variable.

2.4.4.3 Herds' Column Influence (H_d)

To measure the effect of the susceptibility of catchment to sediment wash using herds' influence, various erodibility indices were proposed as earlier mentioned. The study tested three indices, CR, MCR and CLOM, for extent and severity of susceptibility, then used the best measure that gives good coefficients of correlation, R and determination, R^2. The measure reflects the change in soil erodibility in the catchment due to breaking and grinding, to sediment concentration, which is expected to have increase in sediment yields. The average products are then regressed as linear and log exponent function to sediment loads.

3.0 Results and Discussions:

3.1 Soil Particles Size and Erodibilty Indicies:

Generally, the soil particle distribution revealed average percentage Silt plus Clay, 34.46% - 75.13% and Sand, 3.05% - 65.54%. The average organic matter (OM) is between 2.89% - 4.67%, the condition that defined the soil catchment OM as moderate. Soil erodibility indices include CR with the average values range from 1.63 - 4.08, high by standard. The soils with DR > 0.15 are classified high, thus, the study revealed high average values range from 0.71 - 1.54. The CLOM average values range from 0.037 - 0.109, while MCR range from 1.36 - 3.57, all classified high. These results suggest that, the soil erodibility of the study area is high, making the catchment unstable and could face the risk of soil surface wash.

3.2 Rainfall Distribution:

Figure c present annual rainfall distribution of the Kangimi catchment for the period of 1995 – 2015 (20years), while Tables 1 present the Intensity-Duration-Frequency models for log and power models, respectively.

The rainfall distribution characteristics shown five years partition for the 20 years dataset on which the fitted line represents five years grouped, 1995 – 1999; 2001 – 2006; 2007 – 2011 and 2012 – 2015 as shown in Figure c. It can be seen and suggest that 2007 – 2011 was the driest period, while 2011 – 2015 revealed wettest. The rainfall intensity estimated for the period is between 19.707mm/hr – 1346.103mm/hr with the mean intensity of 591.63mm/hr. This suggests that, the maximum rainfall intensity will be expected to play a significant role in the hydrological process over the catchment. For design rainfall intensity of a large catchment of up to 212km^2, Gupta and Gupta (2008) suggested 10years-24hours storm events peak flow rates.

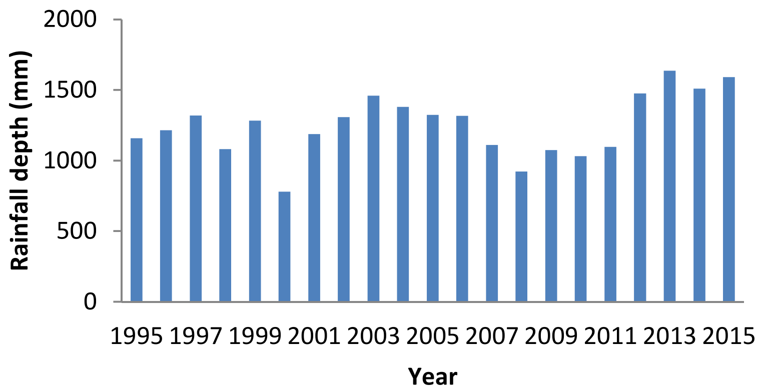


Figure c: Rainfall distribution of study area

Table 1: LOG and Power Models of the proposed IDF

Return Period (yr)	MODELS			
	LOG	R^2	POWER	R^2
2	113 - 34.74LN(Tr)	0.9117	$131T_r^{-0.67}$	1
5	125.94 – 38.76LN(Tr)	0.9105	$145.96T_r^{-0.67}$	"
10	139.59 - 42.98LN(Tr)	0.9096	$161.73T_r^{-0.67}$	"
25	152.67 – 47.04LN(Tr)	0.9088	$181.65T_r^{-0.67}$	"
50	169.60 – 52.29LN(Tr)	0.9079	$196.43T_r^{-0.67}$	"
100	182.29 – 56.22LN(Tr)	0.9074	$211.11T_r^{-0.67}$	"

3.3 Topography, Digital Elevation Model (DEM) and slope characteristics:

Figure d (a & b) present topography feature and DEM of the catchment as revealed in GIS

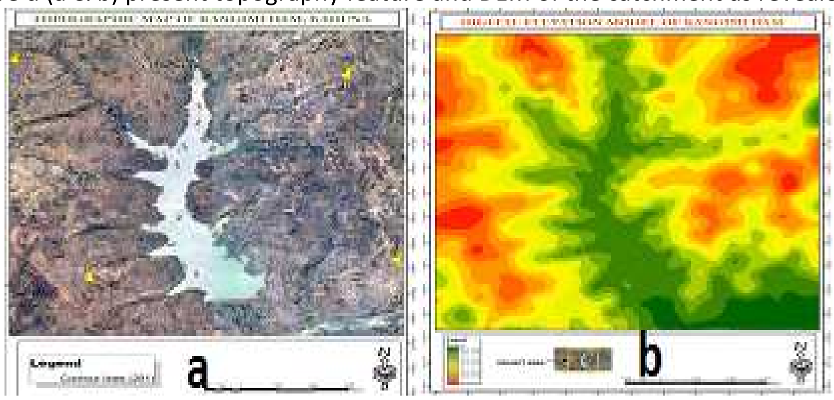


Figure d (a & b): Topography and Digital Elevation Model of the study area

The elevations revealed range values of 583.67m above sea level (asl) to 673.19m asl as shown in Figure d (a), while, the DEM features are represented in three (3) major colour in Figure d(b). The highest elevation was illustrated by deep orange color to faint orange with classification values of 628.58 to 673.15m, middle elevations of 618.08 to 628.57m, indicated in deep yellow to faint yellow, while the lighter green to deep green colour represent the lowest elevations and illustrated reservoir area. The slope classes is measured in degrees, and the values ranged between 0 – 0.66; 0.67 – 1.15; 1.16 – 1.63; 1.64 – 2.24 and 2.25 – 4.94, and classified as flat, gentle, and moderate. Generally, the site is slope moderate with upper slope ranged from 2.25 – 4.94, the middle, 1.62 – 2.24, and the lower ranged from 0.67 – 1.61, while the mean, minimum and maximum are 1.17, 0 and 4.94, respectively.

The major land use and land cover types were vegetation covered of 156.5Mm^2 about 59.6% of total area. The farmland of an area of 38.97Mm^2 (14.83%), Waterbody of about 27.79Mm^2 (10.58%), Bare-land 15.1Mm^2 (5.75%), while unclassified and settlement were, respectively, covered 14.20Mm^2 (5.41%) and 10.15Mm^2 (3.86%) (Table 2).

3.4 Land Use and Land Cover

Table 2 presents catchment Land Use and Land Cover classifications as revealed from GIS results

Table 2: Classes of land use and land cover

Land use	Area Covered (m^2)	Percentage (%)	Rating
Vegetation	156, 514, 099.0000	59.570	1
Farm land	38, 972, 195.0000	14.833	2
Waterbody	27, 789, 988.0000	10.577	3
Bare land	15, 110, 165.0000	5.751	4
Unclassified	14, 203, 713.0000	5.406	5
Settlement	10, 149, 638.0000	3.863	6

3.5 Relief Features of The Sub-Catchments

The extracted relief features of the various sub-catchments from the topography and DEM maps are presented in Table 3.

Table 3: Relief characteristics of the various Sub-catchments

Sub-catchment	Elevations (m)		Length (m)	Drainage Area (m^2)	Average Slope (^{0})
	Maximum	Minimum			
Loko-Koro	624	613	2700	1,590,594.23	0.0040
Loko-Hali	640	611	2190	929,934.50	0.0132
Loko- Balbela	643	608	2400	1,075,922.18	0.0145
Bahago	653	609	3500	4,208,315.95	0.0125
Kangimi Main	644	607	7900	16,593,262.74	0.0046
Rafin Kurmin Zaria	616	609	5500	7,475,734.56	0.0012
Rafin Gora	647	615	5900	3,062,416.13	0.0054
Rafin Jagiwa	653	614	4300	1,544,647.78	0.0091
Loko- Hadamshi	644	613	8300	1,322,987.30	0.0037
Loko-Danyaro	643	611	2300	216,701.31	0.0139

The lengths range between 2,300m - 8,300m and the drainage areas between 216,701.31m^2 - 16,593,262.74m^2, while the average slope ranged from 0.0012 to 0.0145 (Table 3).

3.6 Discharge-Sediment Load (mg/l) Relationships of The Various Sub-Catchment

Figures e, f and g present linear trends of sediment load (mg/l) against discharge at various points on pre-determined length for various sub-catchments.

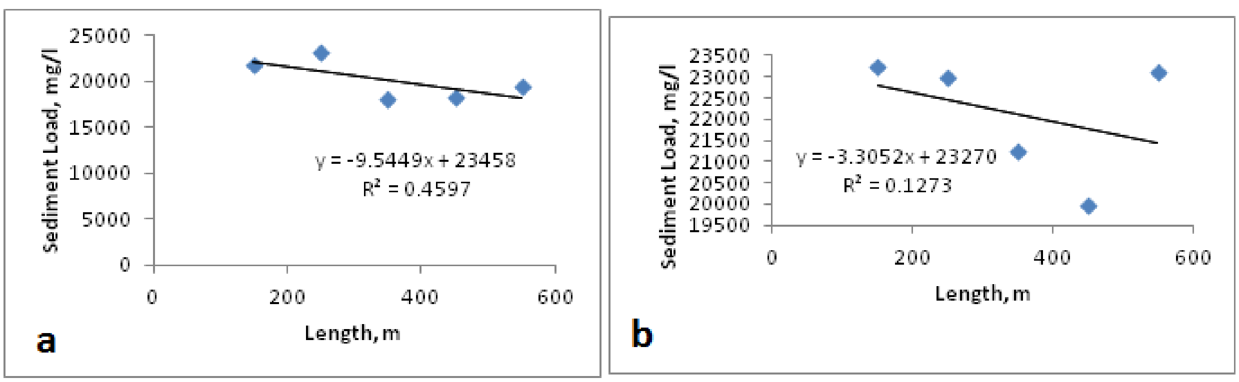


Figure e: (a) Loko Koro/Ali and **(b)** Loko Balbela/Bahago Discharge –Sediment load (mg/l) relations

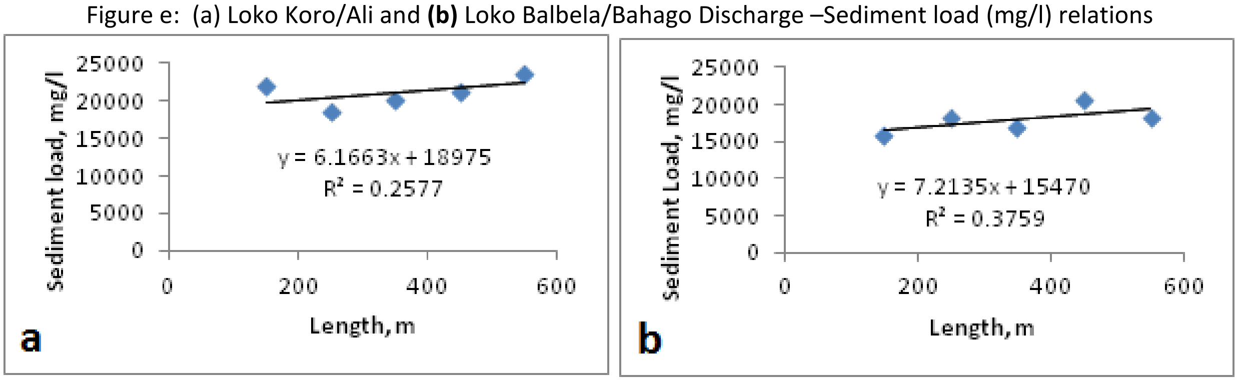


Figure f: (a) Kangimi Main/Rafin Kurmin Zaria, (b) Jagiwa/Hadamshi Discharge-Sediment Load relations

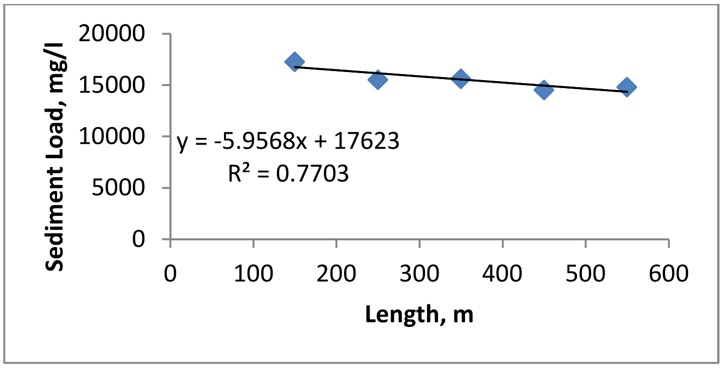


Figure g: Loko Gora/Danyaro Discharge-Sediment Load relationship

The results shown the downward trend with coefficient of determination, R^2 = 0.46, 0.13 and 0.77,for Loko Koro/Ali, Loko Balbela/Bahago and Loko Gora/Dangora sub-catchments, respectively, while, the Kangimi main/Rafin Kurmin Zari and Jagiwa/Hadamshi sub-catchments indicated upward trends with R^2 = 0.26 and 0.38, respectively, see figures e (a & b), f (a & b) and g. This shows that at Loko Koro/Ali, Loko Balbela/Bahago and Loko Gora/Dangora, sub-catchments, the sediment discharge were negatively predicted by the variation of 46%, 13% and 77%, respectively. Those of Kangimi main/Rafin Kurmin Zari and Jagiwa/Hadamshi sub-catchments were positively predicted by 26% and 38%, respectively. The results of Correlation and multiple regression analyses indicated that there is good positive correlation between the variables at Loko Koro/Ali, Kangimi main/Rafin Kurmin Zaria, Jagiwa/Hadamshi and Loko Gora/Danyaro with coefficient of correlation R= 0.59, 0.69, 0.71, and 0.82, at $p>0.05$, respectively. The extent of correlation in Loko Balbela/Bahago revealed weak correlation with R= 0.12, though positive. An independent-samples t-test was conducted to further confirm dependence of sediment discharge on drainage features. There is a significant dependence on conditions $t(5)=2.57$, n=5, p-values ranged from 0.31 to 0.98, and calculated t-value ranged from 0.26 to 2.52. These results suggest that sediment discharge really does have dependence on all sub-catchment features.

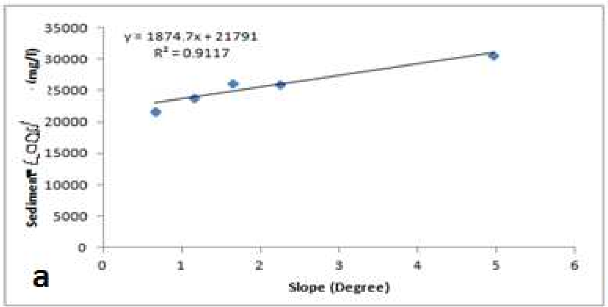
3.7 Slope and Sediment Load Relationship From The Sub-Catchments

Table 4 present statistical values of both linear and Log regression analysis of various sub-catchments, while Figures 7 – 9 present linear relationship plots

Table 4: summary statistics for grouped sub-catchments slope-sediment load relation

Sub-catchment	Factor	Coeff.	Std. Error	t-value	P-value	R	R^2	Mean	Median
Loko Koro/Ali	Constant	21790	876.29	24.87	0.00	0.95	0.91	25773	26123
	LOG	10.00	0.039	255.01	0.00	0.94	0.88	-	-
L.Balbela/Bahago	Constant	23220	307.21	75.58	0.00	0.97	0.94	24968	24596
	LOG	10.05	0.012	830.02	0.00	0.97	0.94	-	-
Kangimi/RK Zaria	Constant	20593	462.51	44.52	0.00	0.96	0.92	22829	22680
	LOG	9.94	0.012	474.87	0.00	0.95	0.91	-	-
Jagiwa/Hadamshi	Constant	15288	460.07	33.23	0.00	0.97	0.96	18423	17065
	LOG	9.65	0.026	375.43	0.00	0.98	0.95	-	-
L. Gora/Danyaro	Constant	14543	988.41	14.71	0.00	0.93	0.86	18053	17254
	LOG	9.61	0.056	170.73	0.00	0.92	0.84	-	-

The statistical coefficient values of the slope versus sediment load in Table 4 show that, there is a direct positive relationship between slope and sediment load for all the sub-catchments, at statistical significant level of 0.05. The results therefore suggested that there is a strong relationship between the slope and sediment load. The coefficient of correlation, R and coefficient of determination, R^2 in the results were high. Although the values are high, 0.93 to 0.97, inference on these values cannot be made without checking the statistical significance of the R^2 computed, as their high values do not conclude that the slope is a good determinant of the sediment load. For further confirmation, the F-ratio (ANOVA) test revealed the regression coefficient of determination, R^2, 0.86 – 0.96, was found to be statistically significant at the 0.05 level, indicating that slope is a good determinant of the sediment load (Table 4). The strongest relationship, R^2= 0.96, was experienced at Loko Balbela/Bahago and Jagiwa/Hadamshi sub-catchments, while the lowest, R^2= 0.86, was at Loko Gora/Danyaro, (see Figures h, i, and j).



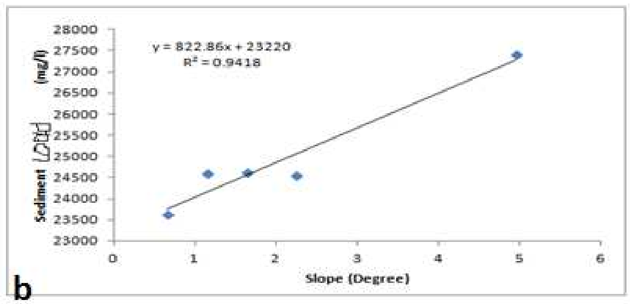
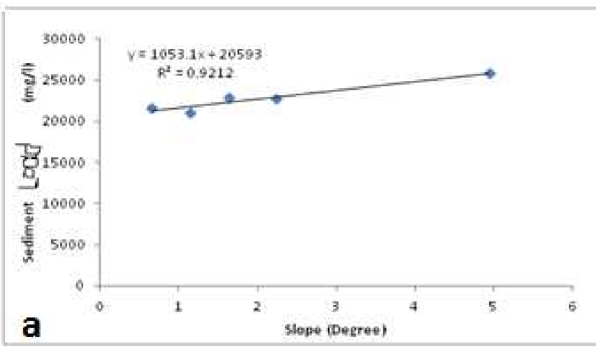


Figure h: Slope and Sediment load relationship of (a) Loko Koro/Ali and (b) Loko Balbela/Bahago



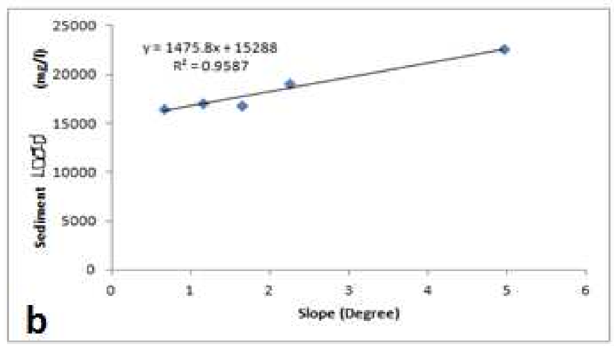


Figure i: Slope and Sediment load relationship of (a) Kangimi Main/Rafin Kurmin Zaria and (b) Jagiwa/Hadamshi

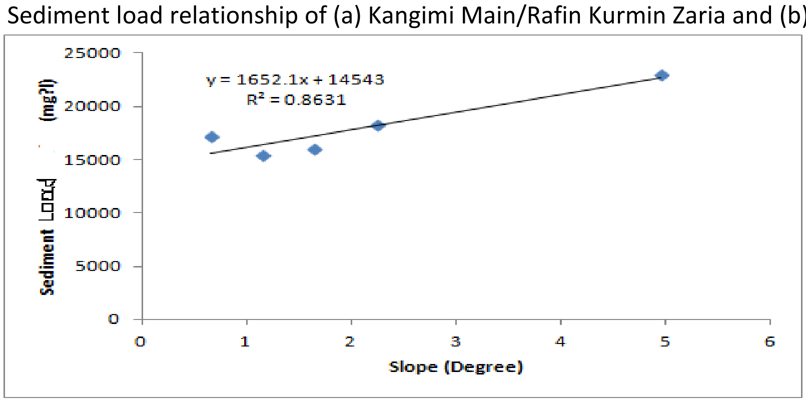


Figure j: Slope and Sediment Load relationship of Loko Gora/Danyaro

3.8 Drainage Area and Sediment Load Relationship:

As observed in Figure d, a large proportion of the sub-catchment in the catchment are located in areas <1,000,000; 2,000,000 – 3,000,000; 3,000,000 – 4,000,000; 4,000,000 – 5,000,000; 5,000,000 – 6,000,000; and >6,000,000, thus given the entire catchment six data points, though must be treated with caution. The regressed drainage areas versus sediment load for linear and log exponent were illustrated in Figure k (a & b). The coefficients of the drainage area and sediment loads relationship indicated that there is a positive direct relationship for the entire catchment as exhibited in Figure k (a & b). In order to check for the significance of the regression, intercept and slope, output, the ANOVA test was conducted and was observed to be statistically significant (0.003) at 0.05 level of significance. The coefficient of correlation, R and coefficient of determination, R^2 was also high. However, the log exponent summarized that there is a direct relationship between drainage area and sediment loads as demonstrated in the Figure k (a & a). For the significance of the regression coefficients, the ANOVA test was observed to be statistically significant (0.001) at 0.05 significant level. Therefore, it is concluded that there is a strong relationship between the variables. The t-statistic test under the conditions for linear analysis indicated, R=0.92, t^*= 5.21, p= 0.11, $t_{(0.025,7)}$ =2.37, while log indicated R= 0.95, t^*=1.46, p= 0.000. The results suggested that log exponential model is stronger and statistically significant at 0.01level, thus accepted for proposed model.

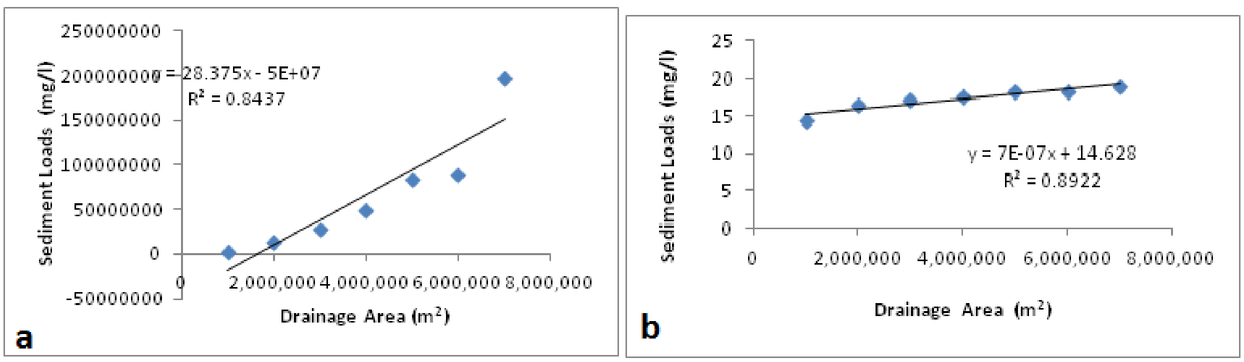
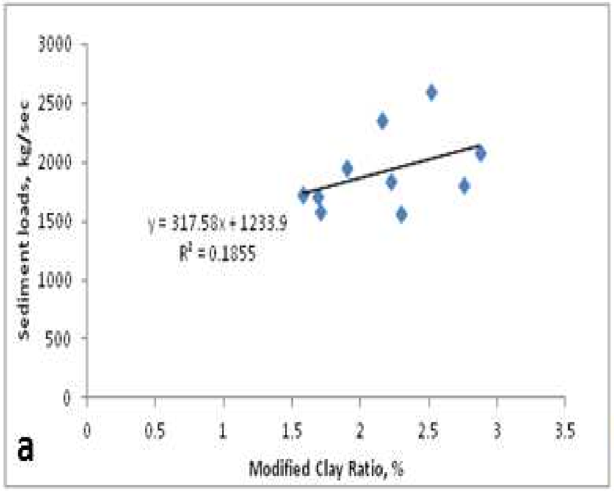


Figure k: (a) Linear and (b) LOG relationships between drainage area and sediment loads

3.9 Herds' Column Influence on Sediment Yields:

The influence of herds' column on sediment generation on the catchment, the instantaneous suspended sediment loads was regressed against soil erodibility indices from the herds' column using linear plots in Figures l (a & b), m and log exponent.

Generally, the values of coefficient of determination, R^2 ranged between medium to low. Correlation and multiple regression analysis were used to further determine the relationships. The linear results shown that MCR of herds' influence revealed R= 0.43, n= 10, p= 0.04, t^*= 1.35, $t_{(0.025, 9)}$= 2.23, while CR , R= 0.15, n= 10, p= 0.03, t^*= 0.44, $t_{(0.025, 9)}$= 2.23, and CLOM, R= 0.77, n= 10, p= 0.08, t^*= 0.22, $t_{(0.025, 9)}$= 2.23. The results suggested that there is statistical significant between the sediment discharge and all the indices as t^* is less than $t_{(0.025, 9)}$ at 0.05 level, excluding CLOM with p= 0.08. The log results revealed MCR with R= 0.46, n= 10, p= 0.000, t^*= 1.46, $t_{(0.025, 9)}$= 2.23; CR, R= 0.16, n= 10, p= 0.000, t^*= 0.45, $t_{(0.025, 9)}$= 2.23; and CLOM, R= 0.09, n= 10, p= 0.0001, t^*= 0.25, $t_{(0.025, 9)}$= 2.23, shows that all the indices were statistically significant at 0.01, but MCR value is stronger and will be consider for proposed model.



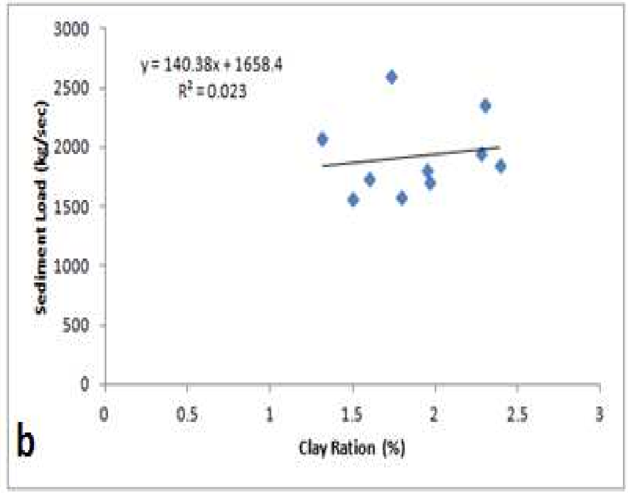


Figure l (a & b): Scatter plot relationships of (a) Modified Clay and (b) Clay Ratios and sediment loads

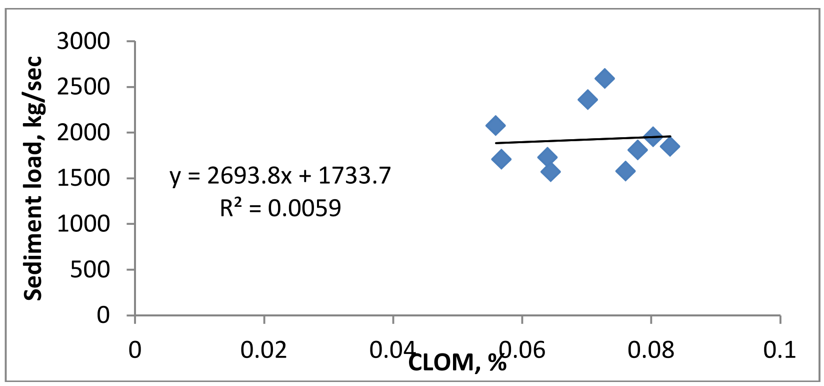


Figure m: Scatter plot relationship of CLOM and sediment loads

3.10 Rainfall Erosivity Factor:

The estimated R factor values range between 1627.81 - 717.17MJ/mm.ha^{-1}hr^{-1}year^{-1}, while the mean is 1082.06 MJ/mm.ha^{-1}hr^{-1}year^{-1}. This indicated that the rainfall was high for the period of dataset.

3.11 Extracted Drainage Parameters Values:

The drainage features in Table 5 was derived from topography and DEM maps in Figures d (a&b).

Table 5: Estimated values of Drainage features

Sub-catch	Length (m)	Area (m^2)	Max. height (m)	Min. height (m)	Change in Elev. (m)	Drain. Density (m)	Relief ratio	Slope Length Fac., L
Loko Koro	2700	1590594.23	624	613	11	0.0017	0.004	11.05
Loko Ali	2190	929934.5	640	611	29	0.0024	0.013	9.95
L. Balbela	2400	1075922.18	643	608	35	0.0022	0.014	10.42
Bahago	3500	4208315.95	653	609	44	0.0008	0.012	12.58
Kangimi/RK	7900	16593262.74	644	607	37	0.0005	0.004	18.91
Raf K/Zaria	5500	7475734.78	616	609	7	0.0007	0.001	15.78
Jagiwa	5900	3062416.13	647	615	32	0.0019	0.005	16.34
Hadamshi	4300	1544647.78	653	614	39	0.0028	0.009	13.95
Loko Gora	8300	1322987.3	644	613	31	0.0063	0.003	19.38
Danyaro	2300	216701.31	643	611	32	0.0106	0.013	10.20

3.12 Land Cover Practices, C

Table 6 presents six classifications according to land use with C values from the catchment

Table 6: Land cover and respective C-factor

Land use	**Area Covered (m^2)**	**Percentage (%)**	**C-factor**
Vegetation	156, 514, 099.0000	59.570	0.7669
Farm land	38, 972, 195.0000	14.833	0.1153
Waterbody	27, 789, 988.0000	10.577	0.0001
Bare land	15, 110, 165.0000	5.751	-0.0593
Unclassified	14, 203, 713.0000	5.406	0.0150
Settlement	10, 149, 638.0000	3.863	0.0118

Vegetation was higher with 59.6% of total catchment area, farmland 14.8% and water body 10.6%. It is obvious since NDVI increases as rainfall increases (Xixi, 1998), crops growing follow the pattern of rainfall periods, while vegetation present, fresh or dry.

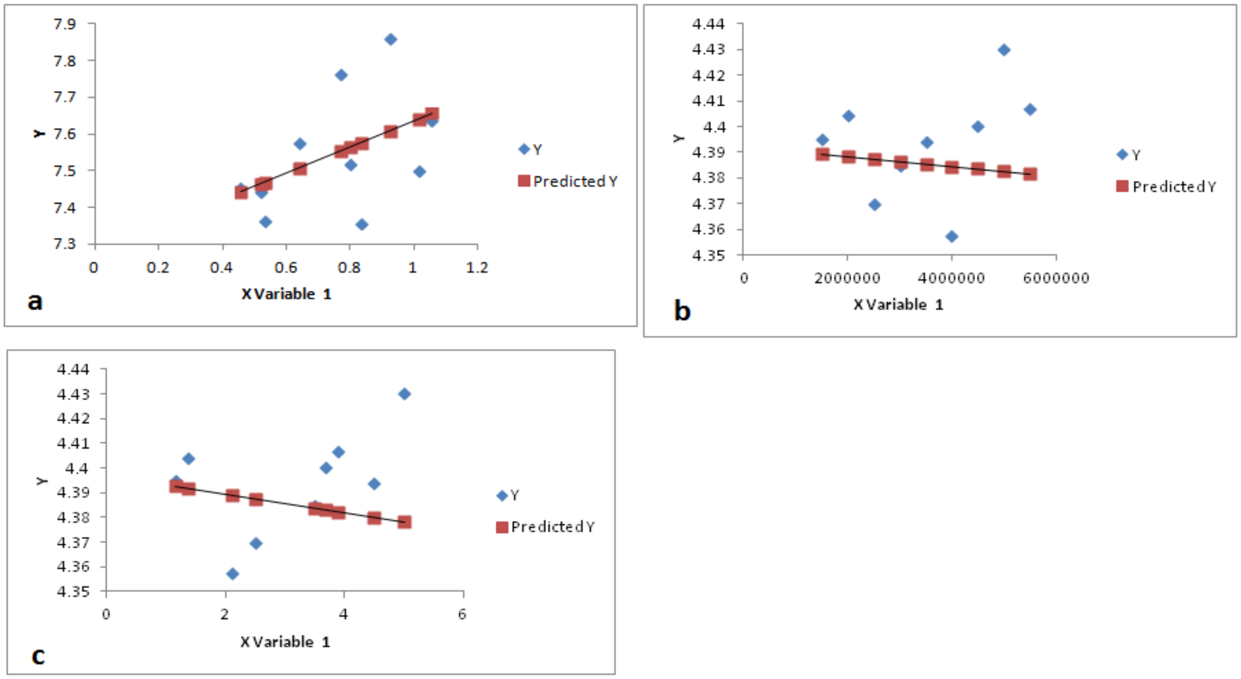
3.13 Model Development:

The development of the model follows equation (3) (4) and (6) with variables estimated and, thus,

$$LogSS_Q = Log0.067 + Log14.63 + 6.75E-07LogA_d + Log10.05 + 0.021LogS_p + log7.474 + 0.152LogMCR \quad (7)$$

3.14 Model Calibration and Evaluation:

The model was calibrated using measured data from the catchment. The predicted and observed data were plotted as partial shown in Figure n (a, b, & c)



Figures n: Partial plots of (a) Herds' influence (b) Drainage Area (c) Slope, of sediment predicts

The model positively predicted well with herds' influence having coefficients of determination, R^2= 0.83 and of correlation, R= 0.91 at p=0.000. The partial plots in Figure n (a) shows positive linear trends between variables and moderately predicted within the measured data. The predicted values with drainage area impacts were predicted within the measured data though very weak R^2= 0.13 and R= 0.11, but statistically significant, p=0.000 and on downward trend Figure n (b). The slope effect was also within the measured values as shown in Figure n (c), at downward trend, with R^2= 0.05 and R= 0.23 indicated weak correlation, but statistically significant (p=0.000).

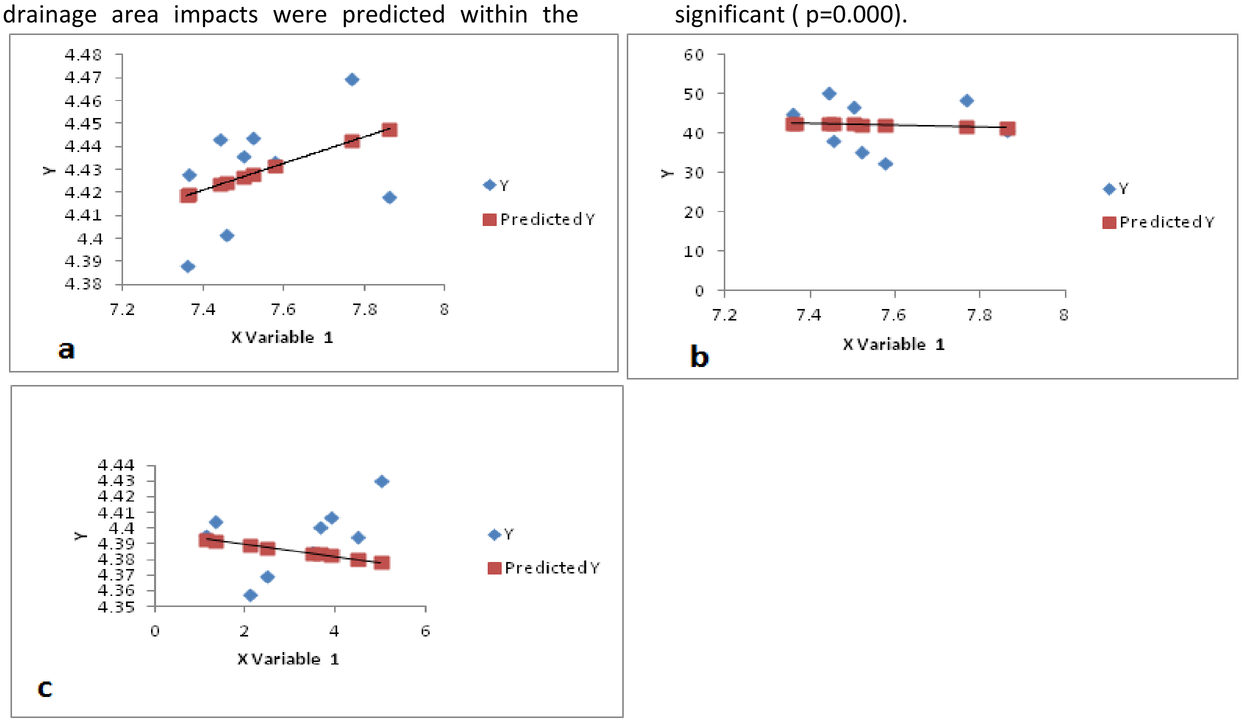


Figure o: Models compared (a) Owned (b) Gartner *et al*. (2008) and (c) Flaxman (1974)

3.15 Comparison and Assessment of the Models:

Figure o (a, b, c) presents the comparison of partial plots of the developed and existing models

Generally speaking, the developed model will perform best in the study catchment than the two compared models. The model shows coefficient of determination, R^2= 0.67 and of correlation, R= 0.71 at p= 0.000 (1.14E-05) meaning, the result is statistically significant at 0.01 level of significance. Looking at Figure o (a), the model predictions is moderately predicted and remain within the measured data, this is an echo of the strength of the model over the compared ones. Gartner, *et al* model predicted with weak coefficient of determination, R^2= 0.004 and of correlation, R= 0.00, given a further weak indications of p= 0.58 greater than p=0.05. While, the Flaxman model predicted fair with R^2= 0.05 and R= 0.23, though weak, but statistically significant at 0.01 (p= 1.22E-14).

The research used information from herds' column, drainage area, and slope as major variables with Universal Soil Loss Equation parameters to develop and predict potential sediment yields model of the Kangimi dam catchment in Kaduna State, Nigeria. The model was evaluated using coefficient of determination R^2, coefficient of correlation, R, t-test and partial plots to predict sediment yields using a test dataset not used to develop the model for the three parameters and each of the variables have physical relationship with sediment yield.The developed model demonstrates the strongest predictive capacity with effect of herds' on the catchment. It produced the coefficient of determination, R^2 and coefficient of correlation, R of 0.83 and 0.91, respectively, at 0.001 level of significance (p= 4.24E-15). However, the effect demonstrated that a valuable contribution of the variable to the sediment yields in the catchment is very significant, and again the severity of herds' activities on soil structures trebling, breaking, and grinding has also demonstrated in soil particle size analysis. The effect of slope is more correlated with sediment yield than drainage area, which shows that slope play more roles in sediment yield than drainage area. From the result obtained, slope decreases as sediment yields increases as seen in Figure o (c).

4.0 Conclusion:

It was observed that the land use and land cover of the Kangimi dam catchment has vegetation covers of about 60% of the, while agricultural land use responsible for about 15%. The soil particle analysis generally revealed that the soil structure of the catchment is mostly sandy-clay and sandy-clay-loam and found to be unstable and likely prone to sediment and erosion wash. The increasing agricultural land development, and animal activities, in the catchment with increasing settlements, will seriously aggravate sediment wash and erosion risk in the catchment.

The model result reasonably matched with the observed data and moderately predicted within the data. However, herds' variable was significant and a good indication of its contribution to the production of sediment materials. The research compared the developed model with two existing ones, and found to performed better and could be recommended for predicting and estimating sediment yields from the Kangimi dam reservoir catchment. The Kangimi dam reservoir catchment has capability to store sediment and buffer the effects of increasing sediment supply due to ongoing agricultural land development, climate change, and herds' activities; hence, there is need to fully examine the sediments generation on individual sub-catchments basis. The variable of herds' column used in developed the model was originally initiated by the authors, the work on the variable is still on-going and open to constructive criticism. The outcome model is empirical and therefore do not necessarily account for all of the factors that may also adversely affect the catchment sediment yields.

5.0 Acknowledgement:

The authors appreciate the Managements of Kaduna Polytechnic and University of Nigeria, Nsukka, for enabling environment provided and to individual likes, Prof. S.M. Ibrahim, Cambridge University,UK and Dr. M.K.A Abdulrahman, for their efforts towards the research manuscript.

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