

Application of GIS-Based MUSLE Model Approach for Sediment Yield Estimation in the Kubanni Drainage Basin, Zaria, Nigeria

Ezenwa, K. O.¹, Iguisi, E. O.² and Yelwa, S. A.³

¹Department of Geography, Nigerian Defence Academy, Kaduna.

²Department of Geography, Ahmadu Bello University, Zaria.

³Department of Geography, Usmanu Danfodio University, Sokoto.

Corresponding author's e-mail: ezenwako@nda.edu.ng

ABSTRACT

The rising prevalence of detrimental land use practices and population pressure is intensifying sediment yield, thereby exacerbating the sedimentation of the Kubanni dam in Zaria, Nigeria. This study set out to ascertain the response of Kubanni drainage basin to natural and anthropogenic factors with a view to evaluate its sediment yield status from 2010 - 2022 using geospatial technology. The research entailed an application of the MUSLE Model within the GIS environment to estimate the sediment yield of the Kubanni drainage basin. The study utilized Landsat OLI satellite images of the years 2014, 2016, 2018 and 2019, soil and rainfall data from 2010 to 2022, and a 30-meter resolution Digital Elevation Model (DEM) for the sediment yield investigation. The estimated sediment yield amount for the Kubanni drainage basin was found to be 13,206.692 tons $ha^{-1}yr^{-1}$ with the annual sediment yield amount for the entire basin reaching a value of 20,787.76 tons yr^{-1} . This study provides a crucial insight into the measure of the Kubanni drainage basin's susceptibility to sediment yield with implications for excessive sedimentation, thereby reducing the storage capacity and life cycle of the Kubanni Dam over time. Furthermore, the findings of the study are implicit for quality assessments of rivers and Kubanni Dam and the attendant impact on the aquatic ecosystems and the usability of water for various purposes.

Keywords: GIS-Based MUSLE, Sediment Yield, Soil loss, Watershed, Runoff Index.

1. INTRODUCTION

Sediment yield from soil erosion engendered by fluvial processes causes the siltation and sedimentation of water courses and dams. Sediment yield has been reported to be responsible for watershed degradation (Moges et al., 2018). As a natural process, sediment yield is complicated by anthropogenic acts of omission or commission thereby exacerbating channel aggradation and sedimentation, altering sediment transportation dynamics and as well as water quality degradation.

Ultimately, sediment yield is implicit in the depreciation of the safety and storage capacity of dams. Sediment yield from soil erosion can reduce the storage capacity of any downstream reservoir and can at the same time deteriorate the hydrology of basin (Sundara Kumar et al., 2018) thereby besetting it with environmental challenges. Nevertheless, the drainage basin is a unique physical feature recognized as a fundamental geomorphological unit which is frequently used as the primary landscape unit for hydrological and ecological investigations

and for land management activities (Horton, 1932). The watershed plays a dominant role in the development of landforms and therefore, the study of drainage basin has a great significance in geomorphological studies (Abdulrahman et al., (2015). Given its disposition as a fluvial cum hydrological entity, the drainage basin is thus a fundamental unit upon which Geographic Information System (GIS) based runoff, soil loss and sediment yield investigations can be based. The Kubanni drainage basin is one of such entities which is a vital component of our regional landscape and plays a pivotal role in water resource management and environmental sustainability. For instance, Ezenwa et al., (2022b) reported the viability of GIS based estimation of watershed runoff which is a precursor for sediment yield generation. Hydrologic models and modern improvements in GIS have made this technique a good choice for water resources, sediment yield and environmental assessment enterprises (Verma et al., 2022). Sediment yield assessment for sustainable development of watersheds is a worldwide concern for landuse planners (Balasubramani et al., 2015). The impact of rainfall on a drainage basin triggers processes which result in channel erosion and sediment yield generation. The abuse of the drainage basin/watershed landscape by anthropogenic interference promotes degradation which aggravates soil erosion and sediment yield thereby accelerating sedimentation of water courses and impoundment reservoirs. Sediment yield is facilitated by the composite influences of climatic and physiographic factors. The climatic factors which affect sediment yield generation include rainfall intensity, rainfall duration, rainfall distribution and direction of prevailing wind in a drainage basin (Ezenwa et al., 2022b). In the same vein, the physiographic factors which influence sediment yield are size, shape, slope of drainage basin, land use and soil type. Since watershed forms a natural boundary of its own, a systematic assessment of sediment yield within the watershed would provide reliable information to draw strategies for sustainable development of watershed resources (Balasubramani, et al., 2015). Drainage basin studies which aim at ensuring sustainable management and development of drainage basin resources have attracted the attention of researchers (Yildirim and Erkal, 2013; Kamaludin et al., 2013; De Carvalho et

al., 2014; Kumar et al., 2014; Biswas and Pani, 2015; Ganasri and Ramesh, 2016; Ezenwa et al., 2022a; Ezenwa et al., 2022b). Drainage basin studies have also been extended to the Kubanni drainage basin. Previous studies have attempted to investigate soil loss and sediment yield profile of the Kubanni drainage (Iguisi, 1996; Yusuf, 2006; Yusuf, 2009; Yusuf, 2013; Shehu et al., 2016) using different models. Numerous models and methods assess sediment yield in watersheds, these models vary from simple to complex and differ in their need for data and their ability to predict soil erosion and sediment yield by water (Chadli 2016). For instance, the work of Iguisi (1996) on soil loss investigations using USLE model focused on two sub basins of the Kubanni drainage basin, whereas the Kubanni drainage basin is made up of four sub basins namely: Goruba, Maigamo, Tukurwa and Malmo sub basins (Ezenwa et al., 2022a; Ezenwa et al., 2022b). Yusuf, (2013) utilized the 1200 and 900 v-notch weirs to investigate sediment delivery into the Kubanni reservoir. Shehu et al., (2016) utilized the velocity and cross sectional area (AV) to analyze dissolved sediment concentration (DSC), discharge (Q), relationship between dissolved sediment discharge (DSD) and discharge (Q) and estimated the dissolved sediment yield for the year 2014. Despite valuable contributions from studies by previous studies towards understanding the intricacies of this basin, it becomes evident that there exists a gap in its comprehensive analysis. This gap is the underutilization of geospatial technology in the study of sediment yield in the Kubanni drainage basin. Presently, the analysis of the Kubanni basin sediment yield profile relies on traditional methods (Iguisi, 1996; Yusuf, 2006; Yusuf, 2009; Yusuf, 2013; Shehu et al., 2016) which, while providing valuable insights, fall short of unlocking the full spectrum of geospatial data-driven possibilities. Conventional approaches often lack the precision, efficiency, and holistic perspective that geospatial technology can offer (Ezenwa et al., 2022a), whereas sediment yield estimation using MUSLE Model in geospatial environment has been carried out with success elsewhere in Nigeria (Ayinla and Jona, 2018; Mbajorgu and Adegede, 2019). Geospatial technology, encompassing Remote Sensing (RS), GIS, and advanced mapping techniques, stands as a powerful tool for sediment yield studies in the Kubanni drainage basin. By

integrating satellite imagery, topographic data, and mapping capabilities, geospatial technology can revolutionize our understanding of sediment yield dynamics of the Kubanni drainage basin. Bridging this gap requires a shift in approach by incorporating geospatial technology into the study of the sediment yield profile of the Kubanni drainage basin. The goal of this study therefore is to estimate the amount of sediment yield in the Kubanni drainage basin using the MUSLE Model in a geospatial environment. The achievement of this goal entails determining within GIS environment the Runoff Index (RI) Factor, Erodibility (K) Factor, Cover Management (C) Factor, Slope Length and Steepness (LS) Factor, and Support Practice (P) Factor for the Kubanni drainage basin.

2.0 MATERIALS AND METHODS

2.1 The Study Area

The study area (Figure.1) is situated in the Kubanni drainage basin in Zaria on Latitudes $11^{\circ} 05' 30''$ N to $11^{\circ} 10' 30''$ N and Longitudes $7^{\circ} 35' 15''$ to $7^{\circ} 38' 45''$ E. Taking its source from Kampaji Hill in Shika, near Zaria, Kubanni river dissects the study site and flows in a southeast direction through Ahmadu Bello University Main Campus, Samaru to empty into an impoundment – the Kubanni dam.

dam, the channel is incised into superficial materials and deeply weathered gneiss (Ololobou 1982). With the summits of the residual hills of Kufena and Kampaji at 820 m and 708 m respectively above sea levels, the Kubanni drainage basin which is characteristically enmeshed between these two prominent landmark features (Iguisi, 1996). The drainage system of the Kubanni River traces four tributaries upstream of the Kubanni impoundment reservoir, Ahmadu Bello University main campus, Samaru, Zaria (Figure 1). Zaria landscape is characterized by thorough and deep chemical weathering which has developed thick lateritic regolith of varying degrees of induration (Bello, 1973). The study is characterized by strong seasonality in rainfall and temperature distributions (Oladipo, 1985). Seasonality in climatic conditions is caused by the oscillation over the study area of two air masses, the maritime tropical air mass (MTS) and the tropical continental air mass (CTS). The natural vegetation of the study area belongs to the northern Guinea savanna type which has been altered by human activities such as deforestation, construction, overgrazing, among others (Aminu, and Jaiyeoba, 2015). The dominant tree species found in the Zaria region are the *Isoblerlinia doka*, *Terminalia*

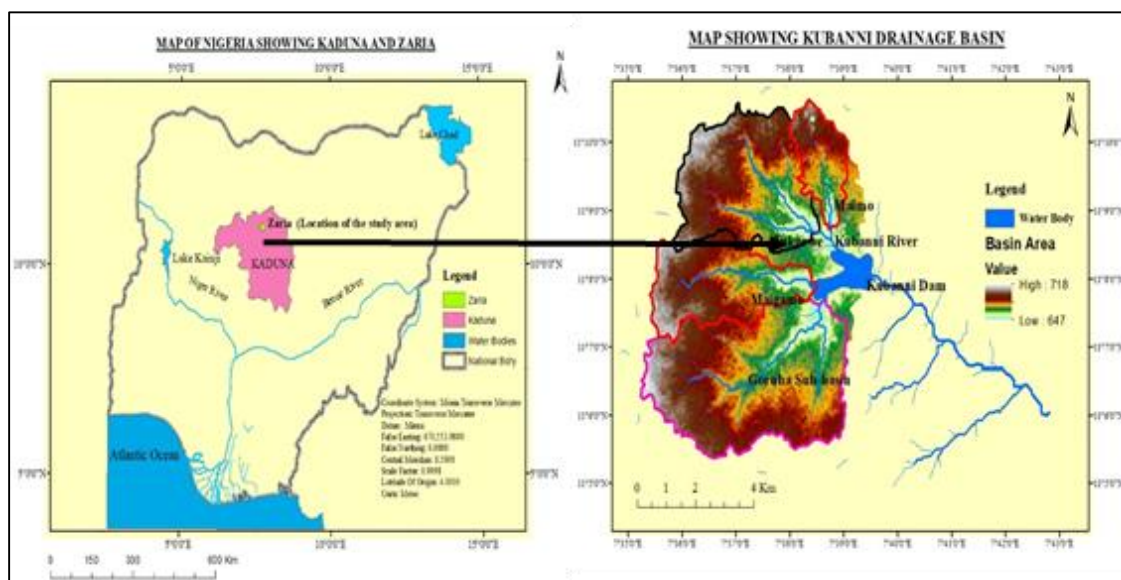


Figure 1: Kubanni Drainage Basin in Zaria Kaduna State, Nigeria

Geologically, Zaria is underlain by differential pre-cambrian Basement complex formation which comprises igneous and metamorphic rocks (Wright & McCurry, 1970). The study site which is the upper Kubanni is developed on the old granite while the downstream of the

avicennioides, *Stereospermum kunthianum*, *Nauclea latifolia*, *Annona senegalensis* and *Dichrostachys cinerea* (Jackson, 1970). Most of the soils have a sandy loam texture (Jaiyeoba, 1995) with poor infiltration capacity because of the high clay content (Iguisi, 1997).

2.2. Methods of Data Collection and Analysis

The data utilized for sediment yield estimation in the Kubanni river basin were obtained from both primary and secondary sources. Rainfall data of a period of 13 years (2010 – 2022) was obtained from the Institute of Agricultural Research, Ahmadu Bello University, Zaria. Soil data for the study was obtained from results of laboratory test conducted on soil samples obtained from the study site. The soil samples were obtained with soil auger at intervals of 1000 meters in the study area. A total of 55 soil samples were obtained and analyzed for the study. The secondary data were obtained from: (1) Landsat OLI images (189/82) of December 2014, December 2016, December 2018; February, July and November 2019. (2) Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) with a spatial resolution of 30 meters. The data were processed using the maximum likelihood classification technique of supervised image classification. The average sediment yield (Y) in the Kubanni drainage basin per unit area per year ($\text{ton ha}^{-1}\text{yr}^{-1}$) was quantified using the MUSLE Model in GIS environment. The MUSLE is a Model devised by (Wischmeier & Smith, 1978) is expressed as follows:

$$Y = 11.8 \times (Q \times q_p)^{0.56} \times K \times LS \times C \times P \quad (1)$$

Where, Y is the computed average sediment yield, $[11.8 \times (Q \times q_p)^{0.56}]$ is Runoff Index Factor which was computed as the product of surface runoff volume (Q) measured in m^3 , and the peak runoff rate q_p measured in m^3s^{-1} . K Factor is the soil erodability Factor ($\text{Mg h MJ}^{-1}\text{mm}^{-1}$); LS is the slope length (L) and slope gradient (S) Factor (dimensionless); C is the cropping management factor (dimensionless, ranging between 0 and 0.5) and P is the supporting conservation practice factor (dimensionless, ranging between 0 and 1). The quantitative evaluation of sediment yield by MUSLE is based on its component factors corresponding to each of the parameters of the equation. In this study, GIS plays a major role in the preparation of the thematic layers and the estimation of the sediment yield in the Kubanni drainage basin.

2.2.1 Runoff Index Factor (RI Factor):

The Runoff Index (RI) Factor is numerically expressed as $[11.8 \times (Q \times q_p)^{0.56}]$. The RI

Factor was computed as the product of Surface Runoff Volume (Q) measured in m^3 , and the Peak Runoff Rate q_p measured in m^3s^{-1} . The Surface Runoff Volume was determined using SCS Curve Number method while the Peak Runoff Rate was estimated using Rational Method. The Rational Method was proposed by Mulvaney, an Irish Engineer in 1851. The Rational Formula is represented by the relationship:

$$q_p = \frac{CiA}{36} \quad (2)$$

Where q_p is the Peak Runoff Rate in m^3/sec , C is the Runoff Coefficient (dimensionless), i is the Average Rainfall Intensity for a duration equal to the time of concentration and at desired frequency or return period in cm/h and A is the Watershed Area in (ha). The application of the Rational Formula was based on assumptions that rainfall is uniformly distributed over the watershed, rainfall is uniformly distributed over the storm period, the runoff rate resulting from any rainfall event is the maximum when the rainfall lasts for duration equal to or greater than the time of concentration, the return period of a peak runoff is the same as that of the rainfall intensity and the fraction of rainfall that becomes runoff is independent of rainfall intensity or volume.

2.2.2 Soil Erodibility (K Factor)

Soil Erodibility K -factor was obtained using relevant soil properties in accordance with the procedure outlined by El-Swaify and Dangler (1976) for tropical soils. The procedure uses the benchmark of percent-modified silt (0.002–0.1 mm), percent modified sand (0.1–2 mm), base saturation, percent unstable aggregates, and percent very fine sand. The units of the determined K factor were quoted in $\text{ton acre h[hundreds of acre ft tonf in]}^{-1}$. The result was therefore divided by 7.59 to obtain the equivalent value in SI units of $\text{Mg h MJ}^{-1}\text{mm}^{-1}$ (Renard et al., 1997). The values obtained from the measured soil properties were used to determine K Factor using the following equation:

$$K = -0.03970 + 0.00311X_1 + 0.00043X_2 + 0.00185X_3 + 0.00258X_4 + 0.00823X_5 \quad (3)$$

Where X_1 is percent unstable aggregates < 0.250 mm, X_2 is the product of the percent of silt (0.002 – 0.01 mm) and sand (0.1–2 mm) present in the sample, X_3 is percent base saturation of the soil, X_4 is percent silt present (0.002–0.050 mm), and X_5 is percent sand in the soil (0.1–2 mm). The percent organic carbon (OC) was determined following the modified Walkley-Black method, (Anderson and Ingram, 1993). The Cation Exchange Capacity (CEC) was determined following the ammonium saturation method (Anderson & Ingram, 1993). Percentage sand, silt and clay content in the soil and particle size distribution were determined by the Bouyoucas hydrometer method (Bouyoucas, 1962).

2.2.3 Slope Length and Steepness (LS Factor)

The LS Factor takes into account the influence of topography on sediment yield as computed from MUSLE Model. The combined slope length and slope steepness factors in MUSLE represent the ratio of sediment yield on a given slope length and steepness to sediment yield from a slope that has a slope length of 72.6 feet and a steepness of 9% where all other conditions are the same (McCool., et al., 1997). The LS Factor for the Kubanni drainage basin was extracted from DEM with ArcHydro tool within ArcGIS 10.1 environment. The GIS operation returned raster derivatives such as flow direction, flow accumulation and slope map which were used as input data for the generation of LS Factor raster map. The LS Factor for the Kubanni drainage basin landscape was computed in line with Morgan (2005). The computation of the LS Factor followed the relation:

$$LS = \left(\frac{x}{22.13} \right)^n (0.065 + 0.045S + 0.0065S^2) \quad (4)$$

Where x is the slope length, (m) and s is the slope gradient in percent and n is the slope length exponent. The value of n was varied in accordance with the steepness of the slope. Values were assigned to represent slope length exponent in commensurate measure to the degree of steepness of a given slope as indicated by (Wischmeier & Smith, 1978). The map algebra which is a function of the Spatial Analyst tool in ArcGIS 10.1 was used in the implementation of the formula for the LS Factor computation.

2.2.4 Cover management Factor (C Factor)

The C Factor which represents the effect of plants, ground cover, soil biomass, and soil disturbing activities on erosion (Renard, et al., 1997) expresses the ratio of soil loss from land cropped under specific conditions to the corresponding loss from tilled, continuous fallow condition (Wischmeier and Smith, 1978; Risse et al., 1993). The C Factor for the Kubanni drainage basin was obtained from Landsat image scenes of the study area. The C Factor values of the land use classes were extracted from the Landsat satellite images using the relation for the NDVI which is expressed by the relationship:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (5)$$

Where NIR is surface spectral reflectance in the near infrared band and RED is surface spectral in the infrared band. In accordance with Durigon et al. (2014), the extraction of C Factor for the Kubanni basin landscape was based on NDVI rescaling method suitable for application in tropical regions. Thus, Durigon et al. (2014) proposed the relation below which was adopted for the determination of C Factor in our study area.

$$C_D = \left(\frac{-NDVI + 1}{2} \right) \quad (6)$$

A C Factor raster map of the study area was created from GIS operations integrating the C-factor values and classified raster images of the Kubanni drainage basin. The raster images were classified using maximum likelihood classification technique and depicting five land use classes.

2.2.5 Support Practice Factor (P-Factor)

The support practice factor embodies all the soil erosion management attributes prevalent in the Kubanni drainage basin landscape. It represents the effects of those practices such as contouring, strip cropping, terracing, etc. that contribute to the prevention of soil from eroding by reducing the rate of water runoff (Parveen and Kumar, 2012). The P Factor for the landscape of the study area was determined cognizant of the prevalence of strip cropping farming practice in the Kubanni basin landscape and slope (Shin, 1999).

2.3 Geospatial Implementation of MUSLE Model

The geospatial implementation of the MUSLE Model represents a cutting-edge approach in

sediment yield studies harnessing the power of advanced spatial technologies to enhance precision and reliability of outputted results. The integration of GIS allows for a comprehensive characterization of key factors influencing sediment yield including topography, land use, and hydrological patterns within a spatial context. GIS facilitates the creation of accurate DEMs and the calculation of slope and slope length which are crucial parameters in sediment yield modeling. Additionally, geospatial techniques aid in the dynamic mapping of vegetation indices, enabling a robust assessment of the C Factor and its variations throughout the study area. The flowchart of the MUSLE Model Implementation in GIS environment is shown in Figure 2.

3.1 Runoff Index Factor (RI Factor)

The Runoff Index Factor (RI Factor) values for the Kubanni drainage basin varies between $311.03 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$ and $219.397 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$ while the average Runoff Index Factor (RI Factor) value was $265.214 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$. Such variation has implications in the estimation of sediment yield as the rate of sediment yield increases with increase in Runoff Index (RI) Factor and increase in basin slope steepness. Thus, the rate of sediment yield on the upstream district contributes the highest amount of annual sediment yield in the basin. Although the RI Factor values of the Kubanni drainage basin was found to be less than the global average for erosivity at

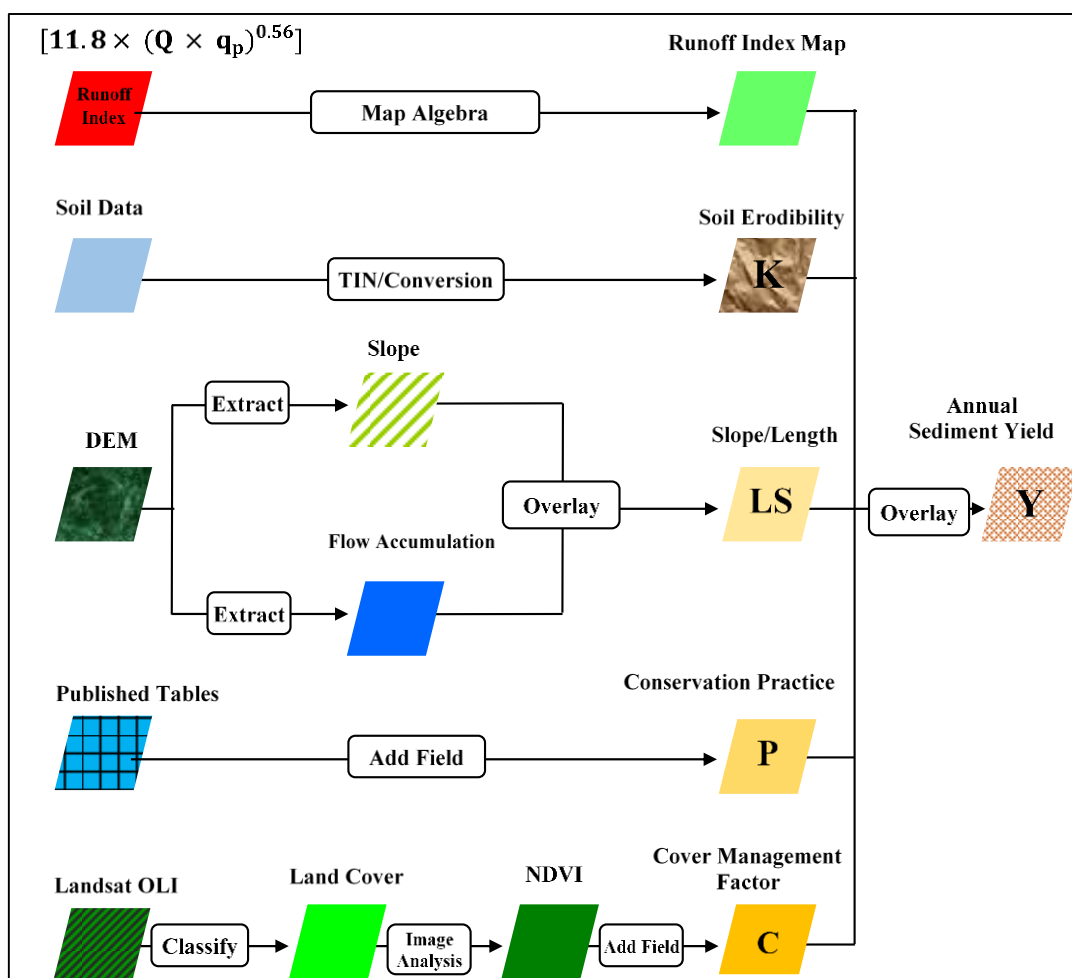


Figure 2: Schema for the Execution of MUSLE Model for Sediment Yield Estimation.

Source: Authors Field Study, 2023.

3.0 RESULTS AND DISCUSSION

The results of the analysis are presented in this section. The MUSLE factors presented in this section include RI Factor, K Factor, LS Factor, C Factor, and P Factor.

$2,190 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$ (Panos et al., 2017), the amount of sediment yield contributed by Runoff Index (RI Factor) is significant. The studies of Ganasri and Ramesh (2016) reported erosivity (R Factor) values

ranging from 2,948.16 MJ mm ha⁻¹h⁻¹ yr⁻¹ to 4,711.4 MJ mm ha⁻¹h⁻¹ yr⁻¹ which provides a rough clue as to the RI Factor obtainable in the study area. This is because in soil loss and sediment yield studies using RUSLE and MUSLE Models, erosivity and runoff index factor are somewhat remotely synonymous. In this regard, despite submitting R Factor values which are far higher than the RI Factor obtained for this study, Ganasri and Ramesh (2016) corroborated the notion that sediment yield is more sensitive to rainfall.

3.2 Soil Erodibility (K Factor)

The K Factor of the Kubanni drainage basin is depicted on a K Factor map shown in Figure 3. As evident in Figure 3, the K Factor values for the Kubanni drainage basin varied from 0.07 Mg ha h ha⁻¹MJ⁻¹ mm⁻¹ (0.535 ton acre h [hundreds of acre ft tonf in]⁻¹) to 0.13 Mg ha h ha⁻¹MJ⁻¹ mm⁻¹ (1.0 ton acre h [hundreds of acre ft tonf in]⁻¹). The K Factor values of the Kubanni Basin Landscape is shown in Table 1.

silt, sand, and the corresponding base saturation (El-Swaify and Dangler, 1976). The derived K Factor values for this study also coincide with the benchmark values of (Wischmeier and Smith, 1978) *K*-nomograph which is 0.018 Mg ha h ha⁻¹MJ⁻¹ mm⁻¹ (0.14 ton acre h [hundreds of acre ft tonf in]⁻¹). The *K*-factor values of the *K*-nomograph is applicable to tropical soils that have kaolinite as the dominant clay mineral (Wischmeier and Smith, 1978). The average K Factor value for the Kubanni drainage basin was found to be 0.1 Mg ha h ha⁻¹MJ⁻¹ mm⁻¹ per year. The result of this study is indicative of the dominance of sandy loam soil in the Kubanni basin. The sandy loam soil falls under HSG A. Parts of the Kubanni basin is equally prevalent with loamy soil, although sandy loam soil has preponderance over other soil types in the drainage basin.

3.3 Slope Length and Steepness (LS Factor)

The LS Factor of the Kubanni drainage basin which was obtained from the DEM of the study

Table 1: The Erodibility (K Factor) of the Kubanni Basin Landscape

Soil Sample ID	K Factor	Soil Sample ID	K Factor	Soil Sample ID	K Factor
A1	0.992653	A21	0.713558	A39	0.615556
A3	1.0	A22	0.859143	A40	1.0
A4	0.872207	A23	1.0	A41	1.0
A5	0.632667	A25	0.528604	A42	0.643902
A6	0.773499	A26	0.960093	A43	1.0
A7	0.735652	A27	0.686466	A44	1.0
A8	0.975179	A28	0.614659	A45	0.778374
A9	1.0	A29	0.834681	A46	0.870026
A12	0.999797	A30	0.684417	A47	1.0
A13	0.924349	A31	0.942555	A48	0.8397
A14	1.0	A32	1.0	A49	1.0
A15	1.0	A33	0.599602	A50	0.801187
A16	1.0	A34	1.0	A51	0.851356
A17	0.619283	A35	0.974064	A52	0.984521
A18	0.805125	A36	0.838341	A53	0.708524
A19	0.889404	A37	1.0	A54	0.777442
A20	0.715825	A38	1.0		

Source: Author's Field Survey, 2023.

A comparison of the K Factor value of the Kubanni drainage basin in Table 1 *vs-a-vis* the K-factor values reported by Ajibade, et al., (2020) reveals some similarities. The shared similarity between the K Factor values derived for this study and that of Ajibade, et al., (2020) is attributable to the fact that the determination of K Factor for tropical soils incorporate input data such as unstable soil aggregates, modified

area is summarized in Table 2. As shown in Table 2, the study found that the slope of the Kubanni drainage basin ranged from 0 to 13.47%. The LS value was estimated using slope contributing area approaches and it ranged from 0 to 49.4 which correspond to the topography factor of the study area as depicted in the LS Factor map for the Kubanni drainage basin shown in Figure 4. The distribution of the

slope values as evident in Table 1 is in perfect agreement with (Wischmeier and Smith, 1978). The LS Factor map is shown in Figure 4.

Table 2: Values for Slope Length Exponent for LS Factor

Slope Length Exponent (n)	Slope Gradient (%)
0.2	0 – 0.106
0.3	0.106 – 0.371
0.4	0.371 – 1.803
0.5	1.803 – 5.144
5 > n < 6	5.144 – 13.470

Source: Author's Field Survey, 2023.

3.4 Cover Management Factor (CFactor)

The values of C Factor for the Kubanni drainage basin were found to range from 0.26 to 0.55 as shown in Table 3. It is evident from the table that the C Factor values for built up area, water body, vegetation, farmland and bare land were discovered to be 0.41, 0.55, 0.26, 0.35 and 0.40 respectively. The finding of this study with respect to C Factor differed with previous studies especially with respect to the land use class of water.

Table 3: NDVI and C Factor for Land Use Classes

LULC Classes	NDVI	C Factor
Built Up Area	0.19	0.41
Water Body	- 0.1	0.55
Vegetation	0.48	0.26
Farmland	0.3	0.35
Bare Land	0.21	0.40

Source: Author's Field Survey, 2023.

The reasons for the variation between the C Factor of this study and that of Hlaing et al., (2008) are accounted for by the differences in the selected land use classes of the two study areas. While the land use classes for this study were built up area, water body, vegetation, farmland and bare land, that of Hlaing, et al., (2008) were closed forest type (0.048), opened forest type (0.08), scrub land (0.35), grass land (0.64), agriculture land (0.45) water body (0.00). Secondly, the C-factor derived in Hlaing, et al., (2008) were generalized C Factor values for specified crop that does not account for crop rotations or climate and annual rainfall distribution for the different agricultural regions of the study area. A C-factor raster map of the study area was created from GIS

operations integrating the C Factor values of the study area. The C Factor map is shown in Figure 5.

3.5 Support Practice (P Factor):

The P Factor values for the Kubanni drainage basin is shown in Table 4. From the table, is it evident that the P Factor values varied from 0 to 1; where 0 represents very good manmade erosion resistance facility and 1 represents non-manmade erosion resistance facility. The steepness parameters of the Kubanni drainage basin slope map were categorized into defined intervals of five discreet classes. The GIS operation for support practice factor returned a P Factor raster map. The generated P Factor map is shown in Figure 6.

Table 4: Support Practice Factor according to the Types of Cultivation and Slope

Slope (%)	Contouring	Strip Cropping	Terracing
0.0 – 7.0	0.55	0.27	0.10
7.0 – 11.3	0.60	0.30	0.12
11.3 – 17.6	0.80	0.40	0.16
17.6 – 26.8	0.90	0.45	0.18
> 26.8	1.00	0.50	0.20

Source: Shin (1999).

3.6 Results of MUSLE Model

Implementation

The implementation of MUSLE Model in GIS environment for this study returned “amount of sediment yield” and “total annual sediment yield” for the Kubanni drainage basin. The quantification of sediment yield for the Kubanni drainage basin returned outputs as shown in Table 5.

Table 5: Sediment Yield Profile of the Kubanni Drainage Basin

Scale of Sediment Yield	Spatial Extent	Quantity
Sediment Yield	Per Hectare	13,206.692 tons ha ⁻¹ yr ⁻¹
Total Sediment Yield	Entire basin	20,787.76 tons yr ⁻¹

Source: Author's Field Survey, 2023.

Results from the table indicate that the amount of sediment yield for the Kubanni basin is 13,206.692 tons ha⁻¹yr⁻¹, while the total annual sediment yield for the entire Kubanni drainage basin was found to be 20,787.76 tons yr⁻¹. The results of this study are in contrast to the findings of Iguisi, (1996) whose study of sediment yield in the Kubanni

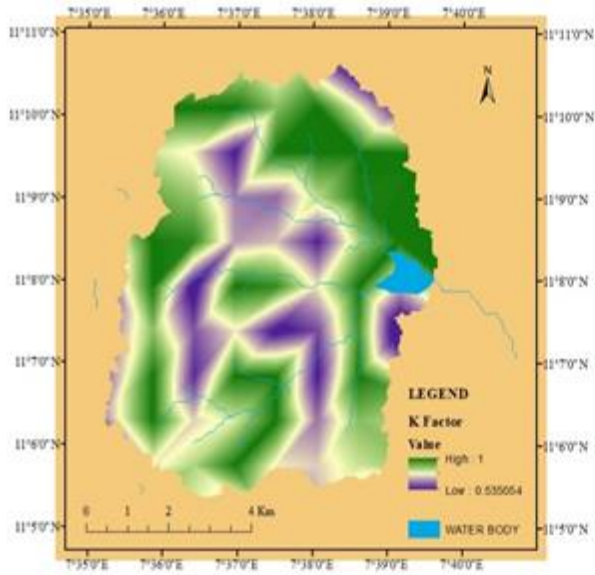


Figure 3: K Factor Map of Kubanni Basin

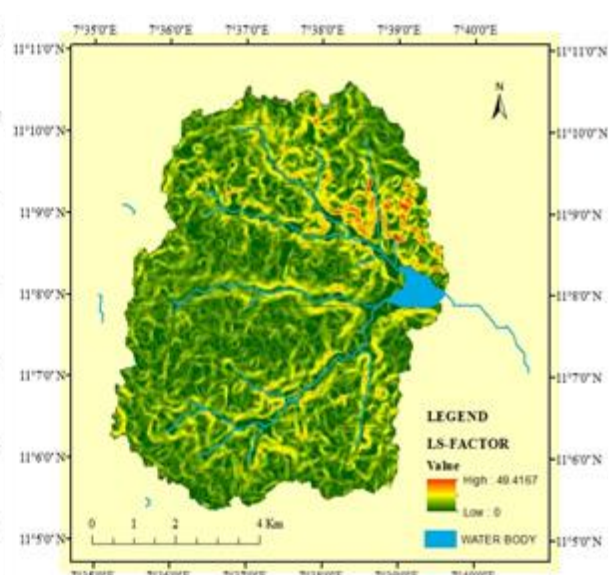


Figure 4: LS Factor Map of Kubanni Basin

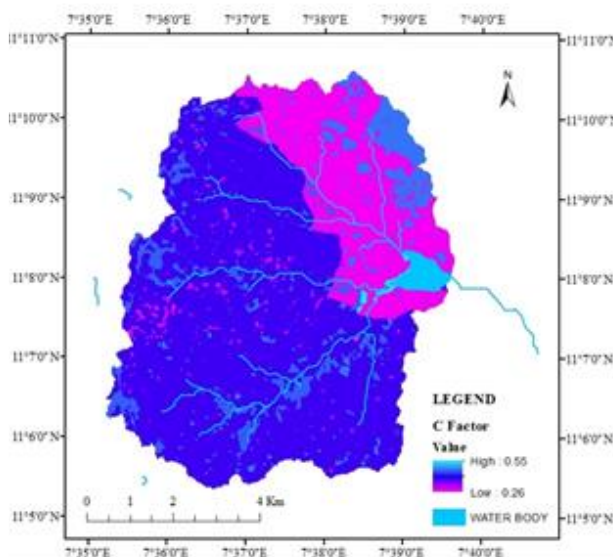


Figure 5: C Factor Map of Kubanni Basin

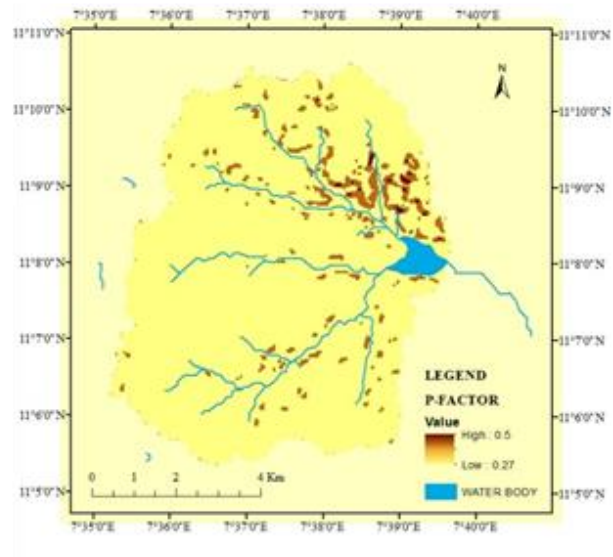


Figure 6: P-Factor Map of Kubanni Basin

basin reported sediment yield values which ranged from about 0.44 to 2.72 mt/ha/yr to about 1.71 to 12.79 mt/ha/yr in sub basins 1 and 2 respectively. While the result of this study is representative of the entire Kubanni basin, that of Iguisi, (1996) was representative of two sub basins which are but only a portion of the entire Kubanni drainage basin, and therefore could partly account for the contrast in the findings of the two sediment yield investigations. Furthermore, the differences in the methodological approaches in the two studies could also be accountable for the differences in the outcomes. While Iguisi, (1996) adopted the USLE model in his study, this study adopted the coupling of MUSLE model and GIS as a study technique. Further comparison of the findings

of this study with that of Yusuf (2013) shows a cautious similarity in terms of sediment yield amount, with a sediment delivery of 12880.55 tons/yr from Malmo stream into the Kubanni dam. The reasons for this closeness in similarity of findings could be linked to the similarity in the spatial sizes of the drainage basin and that of its sub basins. The findings of this study however contrasted with the findings of Olatunji et al., (2023) who despite the coupling of MUSLE model with RS and GIS techniques to investigate sediment yield in Asa Watershed in Kwara State, reported a sediment yield of 510.49 Tons/Km²/yr. The contrast between the findings of this study and that of Olatunji, et al., (2023) can be attributed to the differences in the orders of the two drainage basins which are

4 and 2 respectively. Overall, the GIS based estimation of sediment yield in the Kubanni drainage basin using MUSLE model returned a sediment yield of 13,206.692 tons ha⁻¹yr⁻¹ and a total annual sediment yield of 20,787.76 tons yr⁻¹ for the entire basin. From the result in Table 4, it is evident that the total annual sediment yield is expectedly higher than the amount of sediment yield on a local scale due to the cumulative effect of erosion from various locations within the Kubanni drainage basin. The higher values for total annual sediment yield are attributed to spatial variation of sediment generation which varies significantly across different areas within the drainage basin. Some parts of the Kubanni drainage basin experience higher erosion rates and soil loss than others (Ezenwa et al., 2022b). When summing up these sediment yield contributions from different parts of the basin, the total annual sediment yield reflects the combined impact of erosion from all the locations in the drainage basin.

4. CONCLUSION

The estimation of sediment yield using MUSLE model in Idrisi Selva 12 GIS environment returned an annual sediment yield amount of 13,206.692 tons ha⁻¹yr⁻¹ and a total sediment yield generated on an annual scale was found to be 20,787.76 tons yr⁻¹. The result of this study satisfies the curiosity as to whether or not soil loss estimation using USLE model in parts of the Kubanni drainage basin could approximate the soil loss profile of the entire Kubanni drainage basin. From the results of the sediment yield generation in the study area, it is safe to assert that the coupling of MUSLE model and GIS applications for sediment yield quantification was found credible for the drainage basin. The erosivity factor was derived based on case situation without in-situ rain gauges. The support practice factor was obtained from a prevalent strip cropping farming practice in the basin. The erodibility factor relied on the soil test results while cover management factor was obtained using NDVI rescaling approach. The running of the MUSLE model was carried out in Idrisi Selva 12 and the performance of the model and output were found credible. The application of MUSLE model in this studies embodied improvements which accommodated expanded information on soil erodibility. The utilization of recent data and modern geospatial tools in

this study renders its findings on sediment yield relevant to drainage basin managers and conservationists. Future studies of sediment yield estimation in this same study area should incorporate rainfall data obtained from in-situ rain gauges planted across the entire drainage basin.

REFERENCES

- Abdulrahman, S. A., Ajeez, S. A., Aruchamy, S., & Jegankumar, R. (2015). Prioritization of subwatershed based on morphometric characteristics using fuzzy analytical hierarchy process and geographical information system—A study of Kallar Watershed, Tamil Nadu. *Aquatic Procedia*, 4, 1322-1330.
- Ajibade, F. O., Nwogwu, N. A., Adelodun, B., Abdulkadir, T. S., Ajibade, T. F., Lasisi, K. H., ... & Olajire, O. O. (2020). Application of RUSLE integrated with GIS and remote sensing techniques to assess soil erosion in Anambra State, South-Eastern Nigeria. *Journal of water and Climate Change*, 11(S1), 407-422.
- Aminu, Z. & Jaiyeoba, I. A. (2015). An Assessment of Soil Degradation in Zaria Area, Kaduna State, Nigeria. *Ife Research Publications in Geography*, 13, pp 26 – 36.
- Anderson, J. M. & Ingram, J. S. I. (1993). *Tropical Soil Biology and fertility. A hand book of method* (2nd ed.) United Kindom, University of Oxford.
- Ayinla, A. I., & Jona, A. C. (2018). Prediction and Estimation of Sediments Discharge from Kangimi Dam Reservoir Catchment, Kaduna, Nigeria. *Universal Journal of Environmental Research & Technology*, 7(1).
- Balasubramani, K., Veena, M., Kumaraswamy, K., & Saravanabavan, V. (2015). Estimation of soil erosion in a semi-arid watershed of Tamil Nadu (India) using revised universal soil loss equation (RUSLE) model through GIS. *Modeling Earth Systems and Environment*, 1(3), 1-17.
- Bello, A. L. (1973). *The morphology of an erosional scarp, South of the Ahmadu Bello University, Zaria*. Unpublished B.A. Dissertation, Dept of Geography, Ahmadu Bello University, Zaria.
- Biswas, S. S. & Pani, P. (2015). Estimation of soil erosion using RUSLE and GIS techniques: A case study of Barakar River

- Ezenwa et al., (2023), *Sahel Journal of Geography, Environment & Development*, 4(2) 22-33. 2023
- Application of GIS-Based MUSLE Model Approach for Sediment Yield Estimation in the Kubanni Drainage Basin, Zaria, Nigeria
- basin, Jharkhand, India. Springer International Publishing Switzerland.
- Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soils Part 1. *Agronomy journal*, 54(5), 464-465.
- Chadli, K. (2016). Estimation of soil loss using RUSLE model for Sebou watershed (Morocco). *Modeling Earth Systems and Environment*, 2, 1-10.
- De Carvalho DF., Durigon, VL., Antunes, MAH., Almeida, WS. & Oliveira PTS. (2014). Predicting Soil Erosion Using RUSLE and NDVI Time Series from TM Landsat 5. *Pesq. Agropec. Bras., Brasilia* 49 (3), 215-224.
- Durigon, V. L., Carvalho, D. F., Antunes, M. A. H., Oliveira, P. T. S., & Fernandes, M. M. (2014). NDVI time series for monitoring RUSLE cover management factor in a tropical watershed. *International Journal of Remote Sensing*, 35(2), 441-453.
- El-Swaify, S.A. & Dangler, E.W. (1976). Erodibilities of selected tropical soils in relation to structural and hydrologic parameters. In: *Soil Erosion: Prediction and Control*, 105-114. Soil Conserv. Soc. Am, Ankeny, Iowa.
- Ezenwa, K. O., Iguisi, E. O., Yusuf, Y. O., & Ismail, M. (2022a). A SCS-CN Technique for Geospatial Estimation of Runoff Peak Discharge in the Kubanni Drainage Basin, Zaria, Nigeria. *Fudma Journal of Sciences*, 6(1), 314 – 322.
- Ezenwa, K. O., Iguisi, E. O., Yusuf, Y. O., & Isma'il, M. (2022b). Application of GIS-based SCS-CN method for Runoff Estimation in the Kubanni Drainage Basin, Zaria, Nigeria. *Journal of Geospatial Science and Technology*, 3(1), 1-12.
- Ganasri, B. P., & Ramesh, H. (2016). Assessment of soil erosion by RUSLE model using Remote Sensing and GIS-A case study of Nethravathi Basin. *Geoscience Frontiers*, 7(6), 953-961.
- Horton, R.E. (1932). Drainage basin characteristics, *Transactions of the American Geophysical Union* 13, 350–361.
- Iguisi, E.O (1996). *Variations of Soil Loss in Two Sub-Basins Near Zaria, Nigeria*. Unpublished Ph.D Thesis, Department of Geography, Ahmadu Bello University, Zaria.
- Iguisi, E. O. (1997). “An Assessment of Current Level of Sedimentation of the Kubanni Dam, Savanna, 18, 17-28.
- Jackson, G. (1970): Vegetation; Around the City and Nearby Villages of Zaria. In Mortimore, M.J. (eds) (1970). *Zaria and Its Region*. Occasional paper No. 4 Department of Geography Ahmadu Bello University, Zaria, Pp. 191.
- Jaiyeoba, I.A. (1995). Changes in Soil Properties in relation to Different Landuses in Parts of Nigerian Semi-Arid Savanna, *Soil Use and Management* 11: 84 - 89.
- Kamaludin, H., Lihan, T., Rahman, Z. A., Mustapha, M. A., Idris, W. M. R. & Rahim, S. A. (2013). Integration of remote sensing, RUSLE and GIS to model potential soil loss and sediment yield (SY). *Hydrology and Earth System Sciences Hydrol. Earth Syst. Sci. Discuss.*, 10, 4567–4596.
- Kumar. K. M., Annadurai, R. & Ravichandran, P. T. (2014). *Assessment of Soil Erosion Susceptibility in Kothagiri Taluk Using Revised Universal Soil Loss Equation (RUSLE) and Geo-Spatial Technology*. International Journal of Scientific and Research Publications, 4(10).
- Mbajiorgu, C., & Adegede, P. A. (2019). Event-based sediment yield modelling using MUSLE in north-central Nigeria. *Agricultural Engineering International: CIGR Journal*, 21(2), 7-17.
- McCool, D. K., Brown, L. C., Foster, G. R., Mutchler, C. K., & Meyer, L. D. (1987). Revised slope steepness factor for the Universal Soil Loss Equation. *Transactions of the ASAE*, 30(5), 1387-1396.
- Moges, M. M., Abay, D., & Engidayehu, H. (2018). Investigating reservoir sedimentation and its implications to watershed sediment yield: The case of two small dams in data-scarce upper Blue Nile Basin, Ethiopia. *Lakes & Reservoirs: Research & Management*, 23(3), 217-229.
- Morgan, R. P. C. (2005). *Soil Erosion and Conservation* (3rd ed.). UK: Blackwell Publishing Company.
- Mulvaney, T. J. (1851). On the use of self-registering rain and flood gauges in making observations of the relations of rainfall and flood discharges in a given

- catchment. *Proceedings of the institution of Civil Engineers of Ireland*, 4(2), 18-33.
- Olatunji Olaniyan, S., Azeez Idris, A., Adegbola Adedayo, A., & Adisa Oluwatoyin, A. (2023). Estimation of Sediment Yield from River Asa Catchment Using Modified Soil Loss Equation (Musle) and Geographic Information System (GIS). *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)*, 14(1), 13-19.
- Ololobou, Y. P. S. (1982). *Some Aspects of River Channel Morphology in the Zaria Area of Northern Nigeria*, Unpublished Ph.D Thesis, Dept. of Geography, Ahmadu Bello University, Zaria.
- Parveen, R., & Kumar, U. (2012). Integrated approach of universal soil loss equation (USLE) and geographical information system (GIS) for soil loss risk assessment in Upper South Koel Basin, Jharkhand
- Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K. & Yoder, D. C. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). *Agriculture Handbook, No. 703, USDA-ARS*.
- Risse, L. M., Nearing, M. A., Laflen, J. M., & Nicks, A. D. (1993). Error assessment in the Universal Soil Loss Equation. *Soil Science society of America journal*, 57(3), 825-833.
- Shehu, J., Yusuf, Y. O. and Isa, B. K. (2016). Dissolved Sediment Delivery by the Samaru Stream into Kubanni Reservoir of Ahmadu Bello University Zaria, Nigeria *Journal of Natural Sciences Research* (Online) 6(8).
- Shin, G. J. (1999). The analysis of soil erosion analysis in watershed using GIS. *Department of Civil Engineering, Gangwon National University, Gangwon-do, South Korea, Ph. D. dissertation*.
- Sundara Kumar, P., Venkata Praveen, T., Anjanaya Prasad, M., & Santha Rao, P (2018). Identification of critical erosion prone areas and computation of sediment yield using remote sensing and GIS: a case study on Sarada river basin. *Journal of The Institution of Engineers (India): Series A*, 99, 719-728.
- Verma, S. K., Prasad, A. D., & Verma, M. K (2022). An assessment of ongoing developments in water resources management incorporating SWAT model: Overview and perspectives. *Nature Environment and Pollution Technology*, 21(4), 1963-1970.
- Wischmeier, W.H. & Smith, D.D (1978). *Predicting rainfall erosion losses. A Guide to conservation planning*. USDA-ARS Handbook No. 537. United States Government, Washington, DC.
- Wright, S.B. and Mc Curry, P (1970). Geology. In: Moretimore, M.J. (Ed). *Zaria and its Region*. Department of Geography, Ahmadu Bello University, Zaria.
- Yildirim, Ü. & Erkal, T. (2013). Assessment of soil erosion in the Ihsaniye watershed area, Afyonkarahisar, Turkey. *Scientific Research and Essays, Academic Journals*. 8(10), pp. 388-397.
- Yusuf, Y.O. (2006) *An Analysis of the Magnitude of Suspended Sediment Production by the Northern Most Tributary of the Kubanni River, Zaria, Kaduna State*. Unpublished M.Sc. Thesis. Department of Geography, Ahmadu Bello University, Zaria.
- Yusuf, Y.O. (2009). A Comparative Analysis of the Suspended and Dissolved Sediment Yield of a tributary of the Kubanni River and their Implication on the ABU Dam. *Journal of Applied Scientific Research*, 5(11). pp. 1853-1859.
- Yusuf, Y. O. (2013). *Sediment Delivery into the Kubanni Reservoir, Ahmadu Bello University, Zaria*. Unpublished Ph.D Thesis, Department of Geography, Ahmadu Bello University, Zaria.