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Assessing the Influence of the Nature of Slope on Sediment Yield in River Mada Drainage Basin, Akwanga, Nasarawa State, Nigeria

Funmilayo Alfa Yusufu
Department of Geography, College of Education Akwanga, Nasarawa State
E-mail: funmialfa@gmail.com

ABSTRACT

This study assessed the influence of the nature of slope on sediment yield in the River Mada drainage basin of Akwanga, Nasarawa State, to determine the rate of surface detachment and delivery downstream. *Field measurement using stratified sampling techniques was used to divide the drainage basin into three sub-basins (upper, middle and lower courses), using channel characteristics that are peculiar to any course of a river. Data on slope was collected using field measurements and observations with tools like rope, ranging poles, plumb, and tape. In each sub-basin, six (6) sampled points were measured manually, three (3) on each side of the river, making a total of eighteen (18) sampled points for the slope. A GIS Map of erosion depositional zones of the River Mada drainage basin was produced to show how sediments are eroded. The percentage of slope was measured using the formula, percentage of slope; P = Rise/Run x 100. Where P is the percentage, Rise is the rate of elevation and Run is the distance covered, divided by 100. Regression analysis on the significant effect of slopes/gradient on the sediment yield in the upper, middle and lower courses of River Mada shows that sediment yield in River Mada is dependent on the nature of the slope. The study concludes that the nature of the slope in the Mada drainage basin encourages surface detachment and delivery downstream, which renders surfaces bare and accelerates erosion in the area. The study recommends that there should be tree plantation farming on slopes to reduce surface runoff and the excavation of sediments on slopes downstream. There is a need for the government, through appropriate MDAs, to embark on data gathering on critical environmental variables through in-situ and field measurements using Remote Sensing and GIS, with the view to developing an integrated, comprehensive databank and information systems for environmental monitoring and natural resource management.*

Keywords: *Nature of slope, Sediment Yield, Drainage Basin, River Mada, Akwanga*

INTRODUCTION

Sediment yield has received worldwide attention among earth scientists because it is a measure of geomorphic activity and environmental problems associated with rivers on the Earth's surface. Sediment refers to a loose, unconsolidated accumulation of mineral or rock particles that have been transported by wind, water, or ice or shifted under the influence of gravity and re-deposited (Carla, 2003). Sediments are also referred to as particles suspended in a body of water that eventually settle out and accumulate on the bottom of a river. These particles originate from weathering and erosion of rocks into soil that accumulates in rivers, lakes, oceans, and other terrestrial or aquatic environments (Owens & Wailing, 2019).

The total sediment outflow from a drainage basin or catchment area measurable at a cross section or referenced in a specific period is referred to as sediment yield (Vanoni, 1975). Sediment yield annually exerts an enormous toll on the resources, both at the point of its removal, where it destroys agricultural potentials, and at the point of its deposition, where it reduces the capacity of rivers, canals and reservoirs. Sediment yield is strongly affected by surface materials, topography, rainfall seasonality, and vegetation cover and can be increased by soil disturbance, which often occurs because of land use (Griffiths, Richard and Webb 2006). According to Daula (2012) and Ade (2014), sediment yield affects the physical characteristics of river channels, typically changing the downstream shape of the channel and modifying the stream flow of rivers.

Every stream, small or large, has a drainage basin, which is the total area drained by a stream and its tributaries. A drainage basin is the entire area from which a river system derives water and rock waste (Chup 2004). The limits of the drainage basin or catchment area of a River are usually set by the topographic divides, which separate the basin from the slope that leads down the channels of other rivers (Chup 2004). These divides, therefore, functionally restrict the area from which a river system receives its water inputs. The cradle of settlement on Earth is traced to the availability of rivers or water sources due to their importance to man. Therefore, the importance of Rivers to both living and non-living organisms cannot be overemphasized. However, sediment accumulation has impacted or is impacting negatively on most rivers and landscapes, either due to natural or man-made causes.

In Nigeria, most Rivers are known for sediment load, for instance, Rivers Niger, Benue, Cross River, and Katsina Ala. Rivers Niger and Benue, known to be the major rivers in terms of length and width, are affected by sediment load, which hinders their navigability and transportation because of reduced depth (Ofomata 2009). According to Ocheri (2014), water volumes in rivers in Benue State have reduced due to sediment load in them. Kwarwarg (2012) asserts that pollution and flooding of Nigerian rivers are due to sediments, which have a negative effect on water quality. Sediment yield, therefore, poses a serious challenge to agricultural productivity and water resource sustainability (Olaniyan, 2023).

In the River Mada, it is observed that the water is muddy, there is persistent flooding during rainy seasons, morphological changes in the shape of the river, reduced depth and volume of water in certain pools, which are used to serve as habitats for bigger aquatic organisms, and accumulation of sand particles on farmlands, which were not common in the river. The problem of sediment yield in the river is suspected to be the topography and slope nature of the basin, rainfall intensity and amount, land use, channel erosion and poor structural characteristics and vegetation cover of the Mada Drainage Basin. In light of this background, this study, therefore, assesses the influence of the nature of slope on sediment yield in the River Mada Drainage Basin, Akwanga, Nasarawa State. The focus of this research is to assess and proffer a solution to the influence of slope and channel erodibility on sediment quality within the Drainage Basin. Basin. The study has both academic and developmental significance because it evaluates the influence of the nature of slope on sediment yield in River Mada Drainage Basin, as it exacts an enormous toll on resources at the point of removal through erosion and at the point of re-deposition, where it reduces the capacity of reservoirs, pools and forms certain landscapes. Therefore, this research will provide insight on the nature of slope as a driver of sediment yield, and the findings will contribute to formulating strategies for sustainable use of the River Mada drainage basin in Akwanga and environs.

MATERIALS AND METHOD

The Study Area

The River Mada drainage basin is located in Akwanga local government, one of the thirteen local government areas in Nasarawa State. River Mada takes its source from Jos Plateau, Plateau State. The river meanders through the Jema'a platform and enters Nasarawa State through the northern borders. Another drainage system is Ngesere, a tributary of River Mada and River Buku running north–south of the eastern part of Akwanga Local Government area. Nigeria (Lyam 1995). Located within latitude 8°5' and 9°0' North of the equator and between longitude 8°15' to 8°30' east of the meridian with a point location of 8°55', 8°25'E. The Local Government Area is bounded in the north by Sanga Local Government of Kaduna State, Nasarawa Eggon in the south, and Wamba in the East and lastly Kokona in the West (Lyam 1995).

The topography of Akwanga Local Government Area is part of the Precambrian basement complex rocks, which cover about 60% of the total superficial area of Nasarawa State. Found in the lower Benue trough with mostly landforms, e.g., Mada hills, Bayan Dutse, and Numa hills. The older Precambrian units of metamorphic and sedimentary rock types found in this area steeper gradient that occurs along stream cuts through rock outcrops. The rocks are found mostly in the northern part of Akwanga, e.g., Numa Hills, Bayan Dutse (Ninghaan). The area is composed of basement complex rocks, which formed some of the landforms, inselbergs and is made up of hilly areas. The major solid minerals in Akwanga are clay, mica, granite, columbite, and limestone (Lyam 1995).

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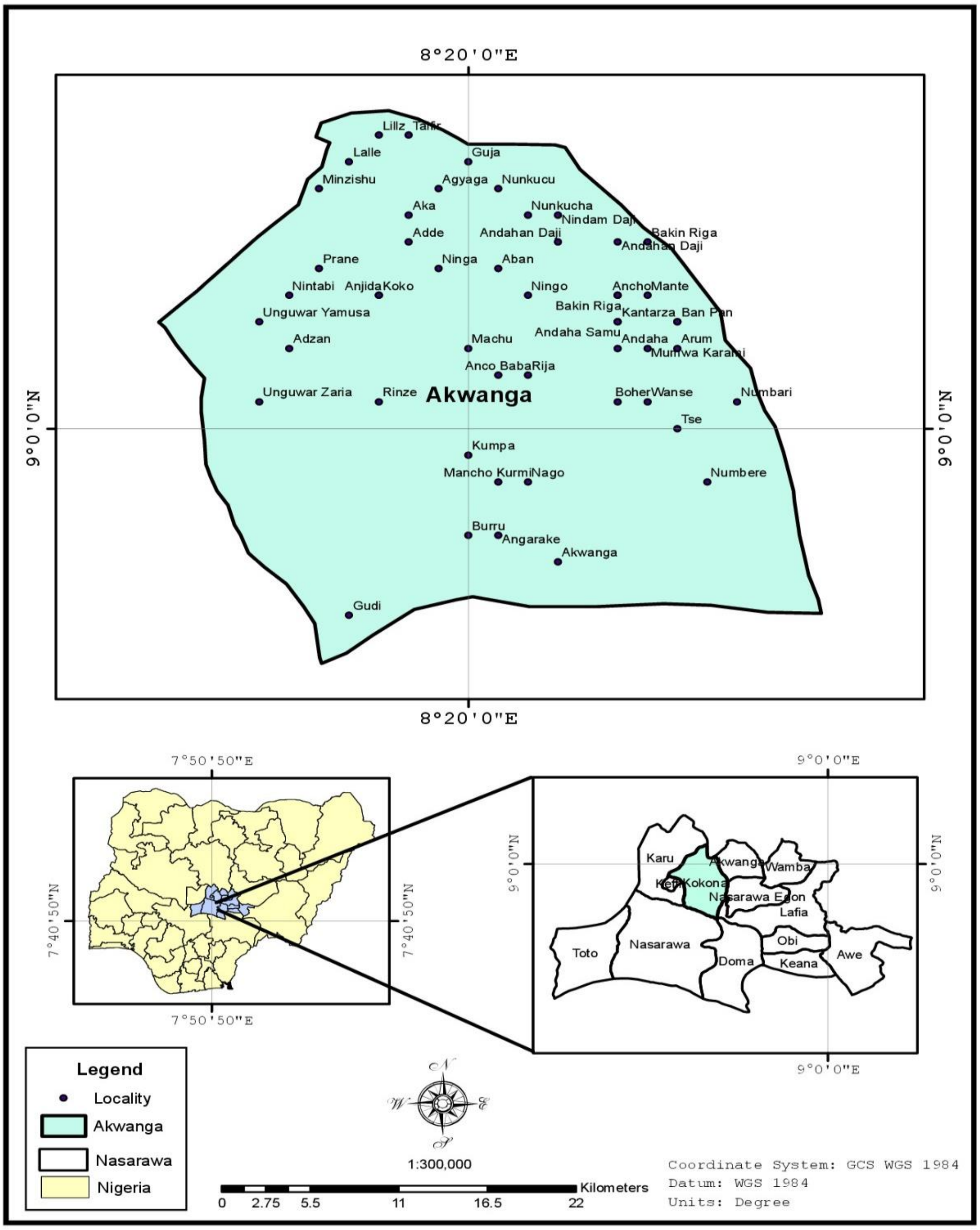

Figure 1: Map Showing Akwanga Local Government Area and its Localities
Source: United States Geological Survey 2025

The climate of Akwanga is like that of the State except for micro variation caused by terrain morphology. Akwanga is within the sub-humid tropical zone area. The Zone is characterized by two seasons that roughly coincide with summer and winter season of the temperate zone. It has mint max: between 17^0C - 37^0C. The dry season starts from November to March, and the temperature increases from January to March. The temperature is moderate in January because of harmattan influence. The hottest months being February to April with temperatures 30^0C - 36^0C maximum. The wet season begins from April to October, with the wettest months being July and August. The rain comes with thunderstorms of high intensity particularly at the beginning and end of wet season. The annual rainfall is 1526mm. Humidity is generally high during the rainy season, about 90%. The figure dropped to about 40% during dry season (https://nimet.gov.ng).

METHOD

Field Experiment

Field observation and measurement were adopted for this study. A stratified sampling technique was adapted where the drainage basin was divided into three sub-basins (upper, middle and lower courses), using channel characteristics that are peculiar to any course of the river. Direct measurement of slope gradient and sediment yield was made with measuring tools, like tape, plumb, line, ranging poles, and marker to determine the slope nature of the area. Data was collected from July 2025 to October 2025 because the Nigerian Meteorological Agency (NIMET), early in the year (2025), informed that there would be a late onset of rainfall (https://nimet.gov.ng). In line with the information, previous experience, particularly in the study area, reveals that, early months of rainfall, it normally infiltrates into the ground rather than the available as runoff.

Slopes in the Mada basin were measured using feet as the unit of measurement from the river channel up to a distance of 1,640 feet (500 meters or 1km) to the land surface. Eighteen (18) measurements were taken at different points and served as sample points. In each of the sub-basins, one kilometer (1.600miles) on either side of the river from the channel bank towards the land was measured as width. While five kilometers (5km) long, the length of the river on either side of the channel was measured as the length in each course of the river. A GIS Map of erosion depositional zones of the River Mada drainage basin was produced to show how sediments are eroded.

Sampling Techniques

Data on the slope were collected using field measurements and observations. In each sub-basin, six (6) sampled points were measured manually, three (3) on each side of the river, making a total of eighteen (18) sampled points for slope. The reason for this choice of distance is that some of the tributaries are close to the Mada river channel (presence of sub-basins within the Mada basin). The percentage of slope was measured using tools such as a rope, ranging poles, a plumb, and a tape. Sediment yield data were obtained through field measurements, where sacks were used to trap sediment that flow into it while the water sieves out of the sacks that were removed and emptied. The collected sediments were dried and measured per month as sediment derived using a British automated weight gauge graduated in kilograms.

Method of Data Analysis

Regression analysis was used to analyse the slope nature of the basin and the relationship with sediment yields, as well as channel erosion in the area. Statistical package for social sciences (SPSS) software was used to analyze data and Google satellite images were used for depositional and elevation images. The result of the measurement of the slope in River Mada is shown in Table 1.

Table 1: Slope Measurement of Mada Drainage Basin

River course	Sampled points	Bank A (f)	Bank B (f)
Upper	Angwanduhu	49	47
	Lelle	63	64
	Madadi	58	45
Middle	Dubu	49	48
	Nintabi	44	36
	Bakinkogi	43	46
Lower	Mada water works	21	19
	Ungwankeme	17	15
	Ginda	11	09
Total		**354**	**329**

Source: Author's Field Analysis 2025

Table 1 shows the slope measurement of the Mada drainage basin. Out of the three river courses measured, 18 sampled points were considered, 6 on each course of the river and 9 on both banks of the river. The slope measurements were taken from the channel bank up to 500 meters (i.e., half a kilometre) in the upland. It was observed that at the upper course of the river, the slopes on the two flanks are steep, and appear steeper as the channel progresses downstream. This implies that sediment moved more downstream. Again, in the middle course, the steepness is maintained but subtle at the end of the course, while at the lower course of the river, the slope is very gentle and most of the sediments moved from the upper and middle courses are re-deposited in this course of the river as the steepness of the slope reduces. It was observed that the slope of the Mada basin is steeper at the A bank of the river than at the B bank. The measurements taken also showed that the sum of A bank has 354 feet while B has 329 feet.

Slopes are an important factor that affects the rate of sediment yield in a drainage basin. Slope is a measure of steepness, and the unit of measurement can be percentages, degrees, or ratios. This research uses percentages as the unit of measurement. To calculate the percentage of slope, P = Rise/Run x 100. Where P is the percentage, Rise is the rate of elevation and Run is the distance covered divided by 100.

A line, a pole, a tape and a ranging pole were used to run for all points, which is 500 meters (half kilometre), converting 500m into feet where 1meter = 3.2808, therefore 500 x 3.2808 = 1640.4 feet, the run becomes 1640 feet. Therefore, for Angwanduhu, P = 49÷1640x100 = 2.9, the same is used for all sampled points and the result is shown on Table 2.

Table 2: Riverbank Erosion

River course	Sampled Points	Bank A (f)	Percentage (%)	Bank B (f)	Percentage (%)
Upper	Angwanduhu	49	2.9	47	2.9
	Lelle	63	3.8	64	3.9
	Madadi	58	3.5	45	2.7
Middle	Dubu	49	2.9	48	2.9
	Nintabi	44	2.7	36	2.2
	Bakinkogi	43	2.6	46	2.8
Lower	Madawater	21	1.3	19	1.2
	works	17	1.0	15	0.9
	Ungwankeme	11	0.7	09	0.5
	Ginda		21.4		
Total		**354**		**329**	**20**

Source: Author's Field Analysis 2025

Table 2 shows the percentage slope of the basin within its courses, where the upper course has slope on the A bank as 2.9, 3.8, and 3.5, while on the B bank, 2.9, 3.9, and 2.7 as percentage of slope. On the other hand, the middle course on the B bank 2.9%, 2.7%, and 2.6% for A, while the B bank has 2.9, 2.2 and 2.8 percentages. The table also shows lower course details for A and B banks, respectively. By comparison, the upper course of the river basin has gentle slopes at both ends of the banks and the middle and lower courses of the river. The middle course has steeper slopes but subtler as compared to the upper course of the river. The steepness here also encourages runoff and transport of sediments downstream. The lower course of the river, on the other hand, has gentle or flat slopes. This implies that the zone cannot remove or transport the bulk of sediments but serves as a depositional zone of sediment delivered from the upper and middle courses. This is in conformity with He, Cai & Liu's (2012) model, that sediments are sourced by rivers majorly in the upper and middle course of the river, while the lower course is a depositional zone. The Google satellite map in Figure 2 and the Google Digital Elevation Map in Figure 3 clearly show the sloping nature of the basin area. In effect, gentle slope terrains at the upper and middle of the basin have enhanced gentle runoff due to the hilly or high elevations that descend the slope. Thus, the study collaborates with the opinions of He, Cai & Liu (2012), Griffith, Richard, and Webb (2006).

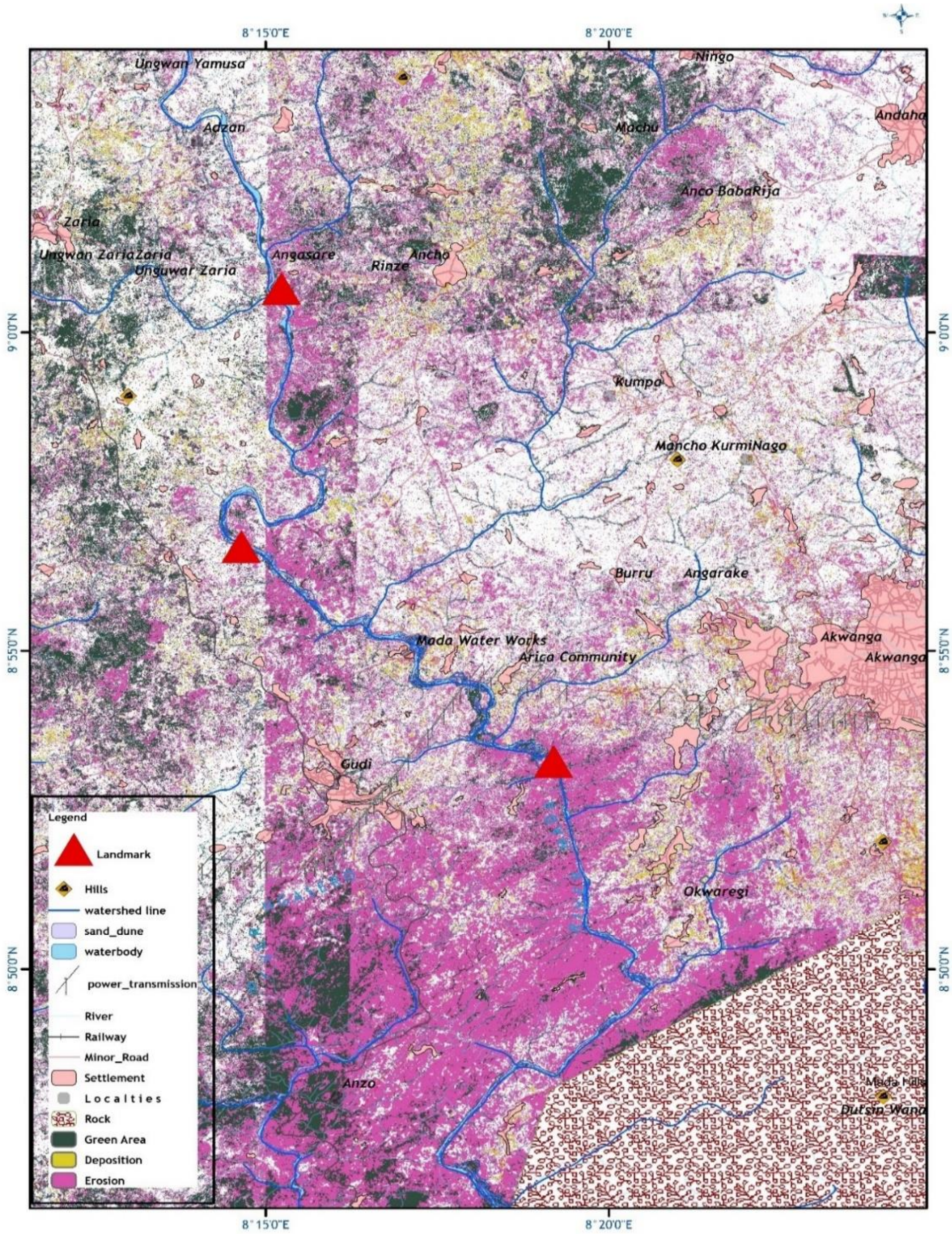

Figure 2: Map of Mada Basin showing Erosion and Depositional Zones
Source. Global Multi-Resolution Terrain Elevation, 2025

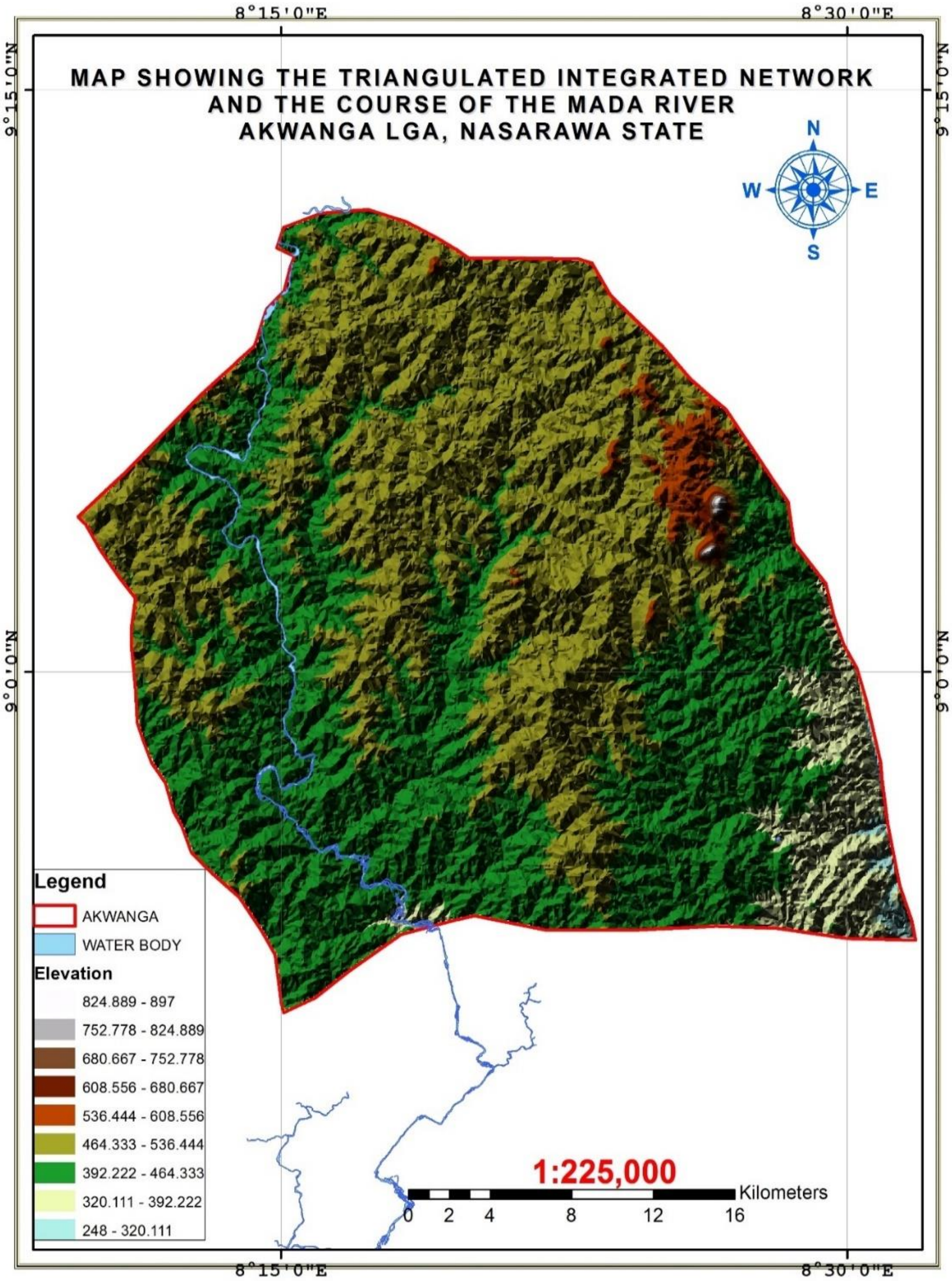

Figure 3: Map of River Mada Basin showing Digital Elevation Model
Source: Global Multi-Resolution Terrain Elevation, 2025

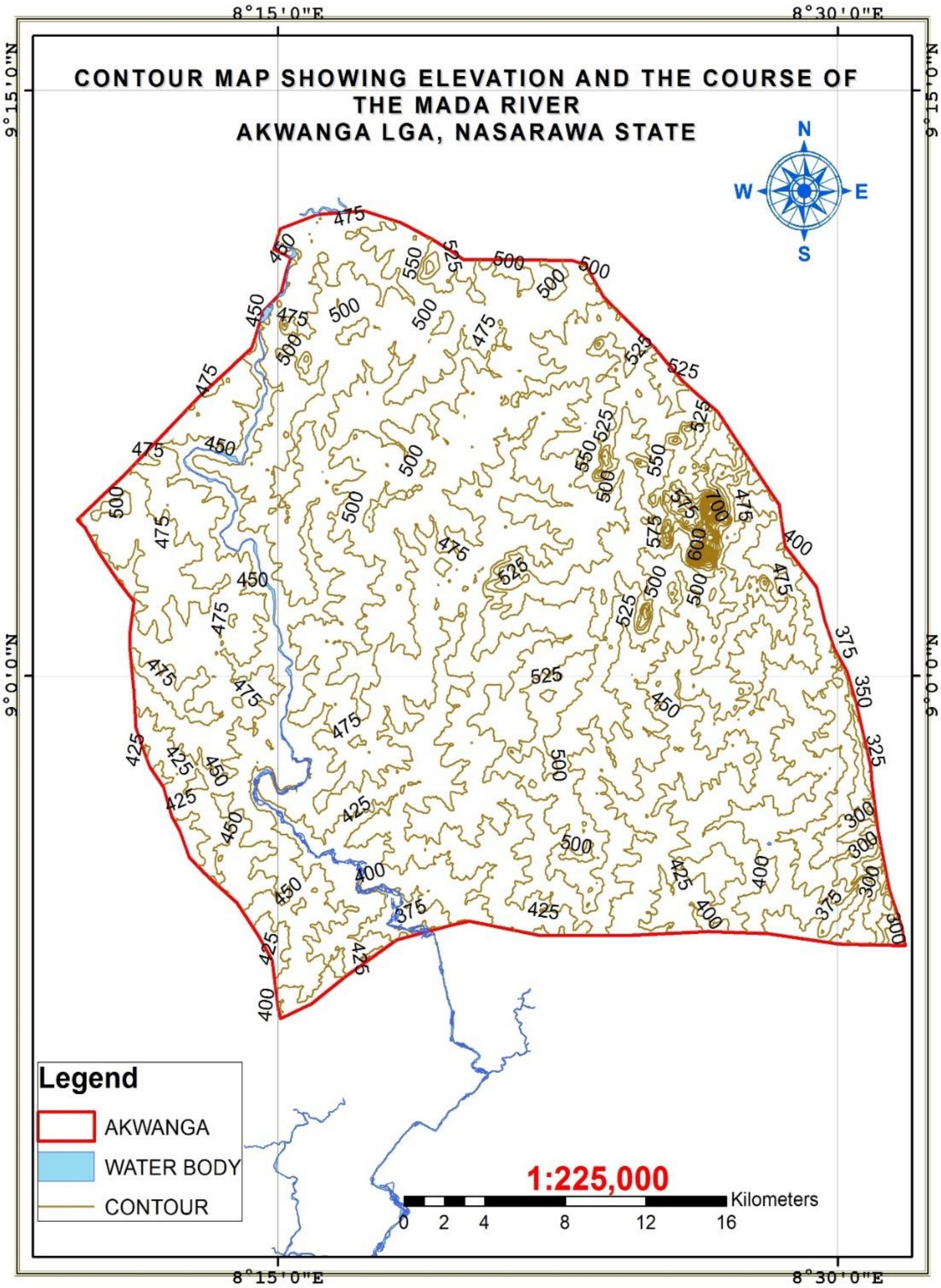

Figure 4: Map showing contour elevation on the course of river Mada.
Source: Global Multi-Resolution Terrain Elevation, 2025

Table 3: Regression analysis on the significant effect of slopes on the sediment yield in the upper course of River Mada.

Variables	R	R^2	Beta	T	Sig.	Remark
(constant)	.209	.044		.164	.000	Sig.
Angwanduhu			.156	.209	.048	Sig.
Lelle			.054	.079	.042	Sig.
MadadiI			.113	.181	.008	Sig.

Table 3 shows that the slope in the upper course of the river has a significant effect on sediments in River Mada. F (3,6) = 0.46, R.209. R^2.044, P<0.05. The result implies that sediments yield in River Mada is dependent on the slope nature of the Angwanduhu, Lelle and Madadi, respectively.

Table 4: Regression analysis of Slope on sediment yield in middle course of river Mada

Variables	R	R^2	Beta	T	Sig.	Remark
(constant)	.650	.423		.123	.010	Sig.
Dubu			.241	.239	.028	Sig.
Nintabi			.392	.886	.041	Sig.
Bakinkogi			-.445	-.994	.003	Sig.

Table 4 also shows that the slope in the middle course of the basin has a significant effect on sediment, F (3,6) = .733, R.650, R2423, P>0.05. This implies that sediment yield in middle course of the river is also dependent on slope of the course.

Table 5: Regression analysis of sediment yield on slope in lower course

Variables	R	R^2	Beta	T	Sig.	Remark
(constant)	.770	.593		2.448	.092	Sig.
New Bridge			-.556	-.941	.016	Sig.
Ungwankeme			.013	.018	.007	Sig.
Ginda			-.649	-1.099	.052	Sig.

Table 5 revealed that slope has significant effect on sediment yield, F (3,6) = .1.457, R.770, R^2.593, P>0.05, so sediment yield in lower course is also dependent on slope nature of the course. Based on result of the study it can be concluded that the nature of slope has a major influence on sediment yield in Mada Drainage Dasin.

CONCLUSION

The research concludes that the nature of slope in the Mada drainage basin encourages surface detachment and sediment delivery downstream, which render surfaces bare and accelerates erosion in the area. Based on the findings, the study recommends that there should be tree plantation farming on slopes to reduce surface runoff and excavation of sediments on slopes downstream. There should be dredging of the stream by the government to retain its depth to retain aquatic lives, water volume, and reduce persistent flooding. Also, there is need for the government through appropriate MDAs to embark on data gathering on critical environmental variables through in-situ and field measurements using Remote Sensing and GIS with the view to developing an integrated comprehensive databank and information systems for environmental monitoring and natural resource management.

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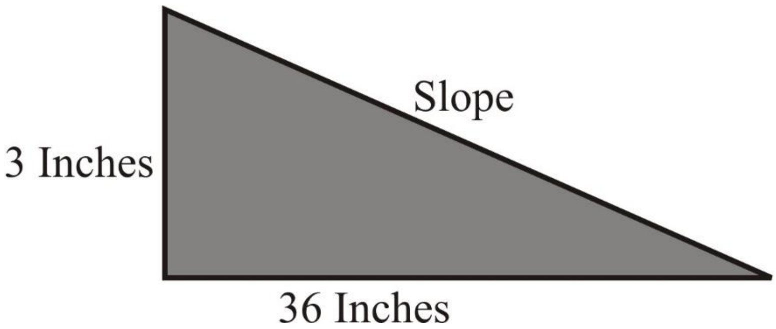
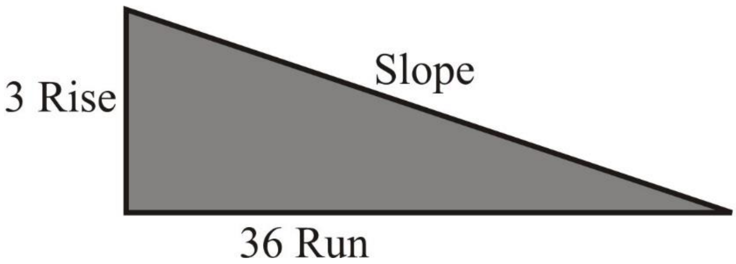
APPENDIX

RESULT OF REGRESSION ANALYSIS OF SLOPE

-Calculation of slope in gradient: slope gradient is written as Y:X, where Y is a single unit in rise and X is the run. Both numbers must use the same units. Example, if you travel 3 inches vertically and 3 feet (36 inches) horizontally, the slope would be 3:36 or 1:2 this reads as one in twelve slopes.



-Calculation of slope in percentage: This is calculated almost same as gradient, convert the rise and to same units. Multiply the number by 100 and you have the percentage slope. Example 3 rise divide by 36 run = 0.83% slopes.



-Calculation of slope in degrees: The most complicated way to calculate slope is in degrees, and it requires a bit of high school mathematics. The tangent of a given angle

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REGRESSION
/MISSING LISTWISE
/STATISTICS COEFF OUTS R ANOVA
/CRITERIA=PIN (0.5) POUT (.10)
/NOORIGIN
/DEPENDENT Sediments
/METHOD=ENTER Angwanduhu Slope MadadiI slope Madadi Slope
```

Regression

Variables Entered/Removed

Model	Variables entered	Variable removed	Method
1	Madadi, Lelle, Angwanduhu[b]		Enter

a. Dependent variable: sediments non-forested areas
b. All requested variables entered

Model Summary

Model	R	R. square	Adjusted R. Square	Std. error of the estimate
1	.209[a]	.044	-0.913	547.076

a. Predictors: (constant), Madadi, Lelle, Angwanduhu

RESULT OF ANOVA ON SLOPE

ANOVA

Model		Sum of squares	Df	Mean square	F	Sig.
	Regression	40868.431	3		.046	.985b
1	Residual	897876.983	3	13622.810		
	Total	938745.414	6	299292.328		

a. Dependent variable: sediments non-forested areas

b. Predictors: (Constant), Madadi, Lelle, Angwanduhu

Coefficients[a]

Model	**Unstandardized coefficient**		**Standardized Coefficient**	**t**	**Sig.**
	B	**Std. error**	**Beta**		
(constant)	343.329	2098.541		.164	.000

	Angwanduhu	126.071	602.849	.156	.209	.048
1	Lelle	40.157	506.494	.054	.079	.042
	Madadi	-91.457	506.494	.113	.181	.008

a. Dependent variable: sediments non-forested areas.