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Research Article

Evaluation of Slope Retreat in Ikpoba River Benincity, Edo State, Nigeria

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Abstract

This empirical research study evaluates the slope recession in Ikpoba River Basin. The study adopted the experimental research design and direct field measurement primary data collection of rainfall events together with erosion variables at point location. The use of erosion rods to collect data involved monitoring erosion variables at the valley slope, to determine advance and retreat of eroded soil. However, the rainfall as well as the soil and slope characteristics event was monitored. This was carried out for a period of five (5) months (April to September excluding August) with the installation of thirty (30) erosion rods along a transect line down the slope. The rainfall amount was measured using autograph rain gauge at Benin Owena Meteorological station. Runoff amount was measured using an Ott-type-current meter with which the velocity was taken. The data collected were subjected to PPMCC Correlation and Regression Statistical Analyses. The hypotheses (H0) states that there is no significant relationship between rainfall amount and slope recession in Ikpoba River valley slope was tested. The result of the hypothesis showed that most rainfall events studied are unsatisfactory in predictors of slope recession but suggestion is made on that standardized diagnostic rainfall amount in slope recession, are of value only within clearly defined environment. The result of the findings also revealed the level of slope recession might be predicted with some degree of accuracy, based on rainfall. The study concluded that rainfall amount are significantly related to slope recession. The study recommended that since slope is very important, the understanding of the natural landscape to create awareness in soil erosion control, sedimentation and managing agricultural land areas along such slopes are required.

Keyword

Slope, Rainfall, Evaluation and Recession

Introduction

Slopes are very unique geomorphological landforms, which are virtually present in every landscape and prominent. Aside providing aesthetic scenery to many environments, they also play a vital role in rivers and stream management specifically river channel management and in planning and constructions of structures such as roads, buildings, bridges amongst others. The study of slopes is very important as they help in the understanding the natural landscape to create awareness in soil erosion control, sedimentation and managing agricultural land areas along such slopes. A slope can be defined, as any geometric element of the earth is surface and formed because of tectonic or depositional processes according to and may be of decreased recessed, retreated or increased with time. Those of tectonic origin include scarp slopes produced by faulting, and tilted surfaces resulting from earth movements. These result from erosive activity from such agents as rivers, glaciers and waves, such as valley, walls and cliff surfaces. The third category of slopes results from the deposition and accumulation of materials, such as alluvial farms and sand dunes[1-15]. Slope elements consist of the standard elements of a "hillside slope" such as convex slope, free face .scarp, constant slope (debris slopes and waving slope) and one of the remarkable landscape features of the land surface of the earth found in both the tropical and temperate region are slopes. Pal (2016) defined slopes are very steep surface between the valley floor and summits of adjacent uplands and described slopes as the angular inclination of the terrain between hill slope (crest) and valley bottom. And the most common type of slopes are valley slopes found on most pt on the land surface, it is possible to walk downwards, following the direction of the steepest slope, until a drainage channel is reached. Other type of slopes includes head slopes, escarpment and cliffs[16-37]. However, there are various geomorphic process that have ledto changes in the form of slopes and such changes are brought about by climatic factors from which precipitation and erosion are derived (Morgan, 2005) [38]. The most important geomorphic processes affecting the earth's surface today is soil erosion resulting from rainfall or raindrop impact and overland flow occurring in the humid tropical and temperate regions. These processes have led to degradation and degeneration of land surfaces render them unproductive and bad land (Morgan, 2005)[38].Accordingly, the accurate measurement of soil erosion has proven to be laborious, time consuming and expensive. Several techniques have been used to measure soil erosion of soluble yield at basin outlet due to hydrologic processes [39-43]. Various experiments have been directed at understanding slope degeneration including slope failures, flow phenomenon and rapid mass movement (Okuda, Okimura and Mizutani, 1976) [44]. Channel changes in the field as well as laboratory and theoretical studies, have been employed over time to understand slopes degeneration through erosional processes (Dietrich, 1982) [10]. However, within the context of this research study, calibrated ranging rods are utilized because it is one of the simplest and most effective methods used in monitoring changes, which occur in height, or the altitude due to attitude of ground surface that result from erosion and deposition. The basic idea behind the use of calibrated ranging rods to quantify surface change as very straightforward. A rod is firmly fixed on the ground and a note is made of the length of rod, which remains exposed. After some time, this exposed length is again measured. Increased rod exposure indicates erosion and decrease in exposure indicates accumulation. Boardman and Favis-Mortlock (2016) [7] stated that calibrated ranging rods are simple, robust and relatively cheap. The advantages of this method are very noticeable and better as compared to the expensive field/laboratory techniques such as $37^{C}s$ and 210Pb tracers, installation of flumes and laser scanning.

Statement of the problem

The Ikpoba river slopes used to support agricultural activities have been depleted of soil according to Aziegbe, (2000) [3] and invariably high nutrient content. Consequently, most of the agricultural activities within the slope have been reduced. Most slopes world over, generally support agriculture and other human activities. However, most of this river slopes have undergone episodes of degeneration due to high erosive activities up-slope downward and aftermath such that the soil resources are depleted.The depletion of the slopes materials arre carried out by two processes, which involve raindrop impact and surface flow. In the river valley, rain drop impact exert a considerable force detaching soilparticles and throwing themto distance of 10-15cm and those carried down slope travel farther before deposition according to Seby. When the rainfall intensity exceeds the rate at which the soil can absorb water along the slope, most of the soilare washed away as in the typical process of occurrence in Ikpoba river slope over the years.In the Ikpoba slopes, most of the soil and humus surface have been washed and carried by running water leaving dissected rills and gullies, thereby creating badland topography, which has affected the soil and led to un-cultivation at the surface. Not only has the slopes been rendered unproductive but most of the sediments generatedended up been deposited at the river channel as silt at the sides and at the lower section of the river in accordance with Odemerho (1992) [41] that high level of sediments production accompany high level run off from the upper slopes towards the lower part and end up in the stream channels which invariably makes stream channels to adjust their morphology to accommodate these new inputs of run off and sediments form the slopes.

Aim and objectives

The aim of the research study is to evaluate slope recession using calibrated ranging rods and rainfall as determining factors. In order to achieve this, the following objectives are stated as follow to:

a) Evaluate the level of slope recession in the Ikpoba river slope,

b) Determine the effect of rainfall amount on the evolution of the slopes and

c) Proffer solution to further recession of the slope.

The data generated from the study especially the evaluation, findings will provide empirical support for further slope studies. It will also support in the area of terrain management to geomorphologist and civil engineers in terms of road construction by properly looking at rainfall factors and slope degeneration over time. The study will also be useful to students who may wish to advance the study of slope development.

Hypotheses

The hypothesis generated for the research study is there is no significant relationship between rainfall amount and slope recession in Ikpoba River slopes.

Study area

Location and size

The study is carried out in Ikpoba River side slope, located in the Northern part of Benin City in Edo State. It lies between Latitudes 06° 011 and 06° 071 North and Longitudes 05° 041 and 06° 011 east as shown in (Figure 1&2). The Ikpoba River drains approximately area of about 730.20km2 according to Odemerho (1992) [41]. The river has a maximum stage discharge of 320cm and minimum of 191cm as stated by Owena River Basin Authority (1996) [45].

Relief and drainage

The topography of the basin is mainly on undulating plain with a relative relief of l2m (Odemerho, 1992) [41] slopes range between l.50 - 30.Relief in the basin resulted from fluvial processes that led to the dissection of the flat-lying sedimentary rocks. Generally,

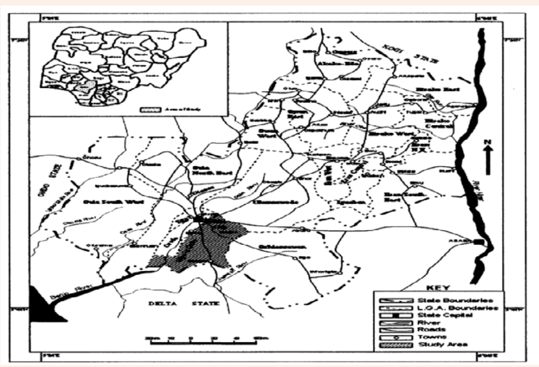

Figure 1: Map of Edo State Showing Study Area.

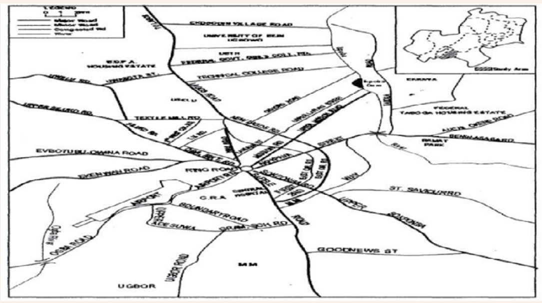

Figure 2: Benin City Showing Position of Ikpoba River.

the basin is a flat and monotonously plain without any marked topographical units except for the hill side slopes. The river takes its source from Esan plateau with Rivers Osiomo and Ohunwan constitute the major tributaries. The entire stream course is boarded by floodplains extending from approximately 15m to 18m on either bank, except as the head water reaches where the flood plains is observed only on one bank (Aziegbe 2000) [3]. The drainage conditions of the Ikpoba River can be observed as when the area is swollen by floodwater from the annual rains, the river overflows its banks, andthe river is swiftly flowing. However, in the dry, season the waters are confined to its shallow channels and slowly flow through various drainage features, structural units that include meanders, sand bars, channel fills, natural levees, back swamp deposits from generated sediment of slopes identifiable along the channel bed.

Geology and soil

The Ikpoba river basin is underlined by deeply weathered sedimentary rock referred to as the Benin Formation of Microene-pleoistocene age. The Formation consists of yellow and white sands with cross bedding. The sandstones are poorly exposed along the river bank and form gently sloping red sandy soils along the slopes and are coarse to fine grained, gravely, poorly sorted, sub- angular to well-rounded with lignite streaks and woody fragments.Another geologic formation discernible at the riverbanks is like the Imo shale group. The shales are dark, possible with increase thickness to the base. The alternate with beds of fine to grained iron-stained sandstones. A portion of the river channel along profile further consists of mudstone like the Nsukka formation, in age, lithology and environmental of deposition. The soils of the basin are classified as ferrallitic of highly leached with high proportion of kaolinite and free iron oxides, but generally, without a lateritic iron pans layer. The soil of the area is generally structure less, because they are devoid of cementing agents hence they are easily washed by process of erosion (Ogidiolu, 1996) [43].

Climate and vegetation

The studied area is located in the humid equatorial tropical climate under Koppen's classification. The annual rainfall exceeds 2000mm. Two distinct seasons of dry and wet season are experienced in the basin. The wet season begins in March and reaches its first maximum in July and the second in September. Two maxima are separated by the "August-Break". A brief spell.The dry season is relatively short and last from November to February. In any case, rainfall is experienced in all the moths of the year with January and December months being the driest. The rainfall amount and duration is one of the major climatic parameters that determine slope erosion by surface wash and eventually degeneration. Temperature is also uniform with the highest mean monthly temperature of 29.1°C recorded in the month of March, and lowest (24.04°C) in June. The tropical equatorial rainforest is the vegetation of the area. Most of the natural forest has been removed and destroyed by anthropogenic activities in most parts by farming, bush burning, grazing and lumbering. Today, most of the primary forest has been completely replaced by secondary forest except a galley of riparian vegetation along the fringe of the river channels sacred sites and shrines, which is a true representation of the natural rainforest. Some of the predominant tree species are Black plum (Vitex doniana) Indian almond (Terminalia catappa), French badamier (Terminalia macroptera) and African mahogany (Afzelia Africana). Tall grasses and herbs and also found and the dominant species include Elephant grass (Pennisetum purpureum), Boat grass (Monocybiumceresforme) and Devil weed (Chromolaena odoratum).

Population

The Ikpoba river basin has been experiencing an increased population growth since 1952. The cumulated figure for the area was 164,000 in 1952, and by 1963, it rose to 252,000. In 1991, the figure was put at 322,804. In addition, population increase is intimately tied to resource use; this has led to increased agricultural activities along the bank of the Ikpoba river slopes, and therefore high effects on the soil consequent upon accelerated erosion. Currently, by 2006 census, the population figure stands at 371,106. The projected population figure stands at 487,400 as presented by National Bureau of Statistics.

Conceptual Framework

The research study adopts the concepts of slope retreat and magnitude of erosivity and erodibility on hillside slopes. The two concepts are fundamental to understanding the study of slope and slope management.

Concept of parallel slope retreat

Parallel retreat of slope can be referred to as recession of slopes without changes in their topography, which is observed on slopes made up of multiple strata. However, the conditions needed for such parallel retreat have not yet be sufficiently classified. According to, parallel slope retreat evolves when rock strength remains constant and basal debris, like talus screes is continuously removed. These conditions are often met in areas where hard horizontal rock layers of basalt or hard sedimentary rock overlie softer rock one of the early geomorphologists laid the foundation of the concept of uniformitarianism. The school believed that slow processes such as erosive power initiated gradually by rivers in a landscape and if allowed to continue for a long time, could bring about enormous changes in such landscape. In the theory, he made it clear within the concept of uniformitarianism that hillslopes are regarded as modified under denotational agencies operating now as they have operated in the geological past as they will undoubtedly continue to operate came out with the view that two agencies were responsible for landscape evolution all over the world namely erosion by rivers and climatic factors explained this concept that most geomorphic processes observed today are basically the various forms of shear, or failure of materials responded to stress that are mostly gravitational but may also be due to climatic factors. Hence, he demonstrated that the manner of hillslope evolution is essentially uniformitarian in all climatic realms. The starting point according to Wood (1942) that distinguished the four elements which appear in a fully developed slope as the waxing slope, the free face, the debris or talus slope and the pediment. Woods (1942) contribution is sufficiently important to rank with the fundamental discoveries of Hutton and Penck that is basically uniformitarian in character and this applies to hill-slopes all over the world, at all stages of development and indeed of all geological ages.

Theory of erosivity and erodibility

Erosivity refers to the energy possessed by raindrops to lease erosion. It involves energy expenditure for breaking down soil cohesiveness, mobilizing soil particles and entraining them during overland flow. This energy is very important and enforced in the humid tropics where the rains are torrential in nature. To compute erosivity requires analysis of the drop size distribution of rain which generally increasing with rainfall intensity reported that this holds only for rainfall intensities up to 1.00mmh' at greater intensities, presumably because of greater turbulence to make lager chop sizes unstable. Another factor is rainfall kinetic energy (total energy available for detachment and transportation). According to Van Dijk soil splash rate is a combined function of rainfall intensity and kinetic energy. Erodibility as a concept refers to the susceptibility of the soil to erosion. It is a function of soil aggregate stability and is affected by different soil propertiesare of the opinion that erodibility is a direct function of the intensity of rain, the infiltration capacity of the surfaces, the chemical and physical, properties that control the disintegration of rocks and determine the cohesiveness of the soil which directly affect the degeneration and stability of slopes.

Literature review

Gradient or slope definition and measurement

The gradient of the ground is an important aspect of map interpretation that can be measured from topo sheets. It refers to the slope of the land stated that slope could be defined in degrees, as a gradient, as percentage and as many feet per mile or as metres per km. The following steps are used to determine the slope from a contour map. Find the difference in height being considered. The difference is called Vertical Interval (V.1.) and measure the distance between the two points using the scale of the map to ind the actual distance on the ground. This is called Horizontal Equivalent (H.E).

Gradient or slope = V.1/H.E…………1 and the first expression i.e. the V.1 is usually reduced to unit.

Presentation and expression of slope

Slope could be presented in three forms namely Degree (x°), Grade (1 in 1). Percentage (x%)

a) Slope as Degree (°): The tangent of a given angle (in degree) is equal to the rise divided by the run. Therefore, the inverse-tangent of the rise divided by the run will give the angle.

b) Grade (1 in 1): slope as grade for an elevation of 1 m over a distance.

c) Percentage (%) can be calculated as % rise in the same unit, then divide the rise and. multiply by 100 to have the percentage slope

Slope types

1. The convex slope (also known as the crest, or waxing slope), is the summit area of a hill or slope, the part of the initial upland that tends to become convex by being rounded off at, and towards its edge with the vertical face below it. Weathering and creep are the main processes responsible for this convexity. It is a soil-covered rock slope and is sometimes referred to as the upper wash slope.

2. The free face (scarp) is the bedrock outcrop on the steepest part of the slope. It represents the most actively eroded part of the hillside slope and is too steep to permit any accumulation of weathered material, such as scree. Black wearing of the slope is at its maximum here and is caused by wash and landslides.

3. The constant slope (debris slope) is that of the angel of rest of the scree debris, which collects at the foot of the free face. It is formed by detritus fallen from the scarp above. It is determined by the repose of the coarser material, as the accumulated material grows in height, the constant slope lengthens upwards at the expense of the lower part of the free face, which it covers. Weathering reduce the debris to finer particles, which are then removed by wash, flowing as rills or turbulent sheet- flow.

4. The wanting slope (pediment, foot slope or lower wash slope) is the broad concavity extending from the base of the other elements to the stream, valley floor or alluvial plain. It is frequently veneered with detritus, but could also be a rock-cut feature. It is produced by surface wash, and its profile may approximate to a hydraulic curve, more or less concave upwards.

Slope classification

Slopes can be classified under the mode of formation. The first type of slope is the pediment slope. A pediment slope is a very gently sloping (5°-7°) inclined bed surface Marshall. It typically slopes down from the base of a steeper retreating desert cliff, or escarpment, but may continue to exist after the mountain has eroded away. According to Marshall (2006), it is caused by erosion and develops when running water wash over it intense away. According to Marshall (2006), it is caused by erosion and develops when running water wash over it intense rainfall events. It may be thickly covered with fluvial gravel further washed over it from the foot of mountains produced by cliff retreat erosion. It is typically a concave surface gently sloping away from mountainous desert areas. Another form of slope classification is the depositional slope that consist of alluvial fans. Alluvial fan is a triangle-shaped deposited of gravel, sand, and even lower range sediment, such as silt, this sediment is called alluvium. Alluvial fans are usually created as flowing water interacts with mountains, hills or the steep wall of canyons. Stream carrying alluvium can be trickles of rainwater, a fast-moving creek, a powerful river, or even runoff from agriculture or industry. As a stream flows down a hill, it picks up sand and other particles alluvium. The flowing water carries alluvium to a flat plain, where the stream leaves its channel to spread out. Alluvium is deposited as stream fans out, creating the familiar triangle-shaped feature. The narrow point of the alluvial fan is called apex, while the wide triangle of the fan's apron. Alluvial fan can be tiny, with an apron of just a centimetre spreading out from the trickle of a drainpipe. They can also be enormous. A debris cone type of alluvial fan with a steep slope, closer to the shape of a half-cone than a flat fan. Debris cones can be created by the slow accumulation of alluvium over many centuries. They can also form boulders and other large materials gathered during landslide, floods, or other instances of mass wasting (Gerrard, 1992) [20].Slope tectonic is adapted to the deformation that is induced or fully controlled by slope morphology and that generates features that can be compared to tectonic features; the steep field in a slope is the result of gravity, topography and the geological setting created by an ensemble of geo-dynamic processes. Active tectonic (also called neotectonics) generates a stress field that can control slope processes, a strong feedback existing between geological history, tectonics, lithology, geo-morphological evolution and topography[46-49].

As a result, a list of factors and their relative influence are presented below.

a) Fabric induced by a local fault (stress field) within a slope e.g. subsidence due to weak or soluble materiasl causing complex sliding-topping phenomena.

b) Reactivation of pre-existing fault, discontinuities, joints, foliations or rock anisotropies; surfaces characterized by residual or lower than peak strength.

c) Regional tectonic movements inducing new slope morphologies, i.e, uplift, major fault movement, pull-apart zones and folding.

Erosion as a factor of slope development

Selby (1993)[50] classified soil erosion as a geomorphological process, which occurs on hilislopes, carried out by flowing water and splash processes Selby (1993) [50]. Term this erosion on hilislopes by raindrops and overland flow water, which is responsible for removing and transporting sediment as wash, a term adopted by many scholars. Accordingly Van Daele (2010) stated that sediment transported by running water usually have a large impact on hillside slopes especially as materials removed or carried away by run off lay bare agricultural fields Evrad (2010), reported that European countries and in Africa water flow from agricultural fields, carry large quantities of suspended sediment. These geomorphological processes cause floods in settlements, downstream and generally triggered on silty and loamy soils, which are prone to surface sealing (Boardman, et al., 2006) [4].Soil erosion is a natural phenomenon (that is, it varies naturally with climate, soils and topography) therefore, all landscapes which have slopes greater than 30 may experience some form of erosion and hence impact on hillslopes. According to Debrodt (2010) opined this pattern can be seen or reflected by slope deposits after such erosional processes on the slopes. Ashman and Pun, (2002) observed that some areas of soil erosion and consequent deposition is fundamental for natural soil fertility maintenance, such as the Nile Delta and the Niger Delta which receives sediment from the upper section of the river.In the tropics, where rainstorms may be very intense, the signs of erosion are obvious, which the river become full of sediments causing siltation, especially in the Ikpoba River (Aziegbe, 2000) [3]. It is however noted that in the temperate regions, where heavy precipitation events are not usually as intense and concentrated as in the tropics, soil loss usually occurs at lower intensity, but also causes damage to agro-pastoral land. A study carried out by Monsierus (2015) in a temperate climate of the United State of America on the impact of rainfall on land degradation, observed that mort hills lopes have been degenerated (lowered) by the effect of raindrop and splash erosion in reducing such hilislopes over the years. According to Boardman and Favis-Mort (2013) [4] are of the opinion that apart from sediment generated by erosion where sediments are deposited there is also the removal and reduction of materials along the hill slopes as a result of the duration and intensity of rainfall. Borgatti and Soldati (2010) [8] stated that climate change with most intense and extreme rainfall and population growth could drastically increase landslides and soil erosion, especially in developing countries, where both population and agricultural pressure on land resources often lead to exploitation of unstable slopes. From the above, it is evident that erosion can be highly regarded as a factor that is responsible for most slope recession both in the temperate and tropical regions of the world.

Rainfall intensity and slope recession

Rainfall is recognized as the major cause of slope degeneration and retreat the world over. A large number of rainfall-induced landslides in slope happened in recent times. For examples, on December 2014, landslides occurred in Indonesia caused by continuous rainstorms, which resulted in fiftysix death, and fifty-two persons missing; landslide in northwesternColombia occurred in May 2015 resulting in 83 deaths, dozens injured and more than 700 homeless people. The collapse of slope was mainly triggered by high intensity rainfall. The mechanism of slope failure induced by rainfall can vary depending on the slope angle. However, the analysis of wetting from the rainfall erosion of soil slopes with different slope angles was achieved using a self-designed Slope Rainfall Failure Test Device (SRFTD). A study carried out by Khan (2016), on the effect of rainfall intensity and erosion of soil in South-Western Province of China their findings shows that rainfall intensities plays a significant role in influencing erosion process. The mobilization f soil particles during rain- splash erosion depends on rainfall intensity. Thus, a major influence of rainfall on slope recession appears to be exerted through impact on runoff velocity and sediment transport capacity of run off which has been reported to increase with increasing flow velocity. According to Khan (2016) rain impacted flows, detachment and transport processes are highly dependent on the description of raindrop kinetic energy, and more of the raindrop energy is dissipated in water layer as flow depth increases, leading to a decline in sediment concentration on gentle slopes.

Geng, et al., (2010) in his contribution of rainfall intensities in slope recession came up with an equation below;

Total increment in losses with increase in slope steepness = E_i-e_o.

a) Rainfall intensity increment: $e_i = e_o$

b) Slope increment: E_i-e_i

c) Rainfall contribution in losses: (RC)% = (e_i-e_o)/(E_i-e_o) (3)

d) Slope contribution in losses: (SC)% = (E_i-e_i)/(E_i-e_o) (4)

Where

e_i= runoff or sediment losses under different rainfall intensities

E_i = runoff or sediment losses at a higher slope under different rainfall intensity of 33mmh' at 5° and 15° slopes.

Evidently, it is quite glaring that rainfall intensity is a pivot on which slope recession is achieved. Aziegbe (2000) [3] made an assessment on the role of climate in slope development land opined came out with the findings that rainfall erodibility/erosivity played one of the most significant part in achieving slope formation and degeneration (retreat) of river Asan in Auchi. Hence, the emphasis of this research is to evaluate hill slopes erosion using calibrated ranging poles (pins) to determine the level of slope retreat with rainfall as the major determining factors.

Research Design

The empirical study adopts the experimental design that involve direct measurement of rainfall amount, slope retreat and surface runoff along the valley slope.

Type of data

The data used for this research study are obtained from primary and secondary sources. Slope recession and rainfall records are generated with measuring instruments such as erosion rods (calibrated ranging poles) and rain gauge. The calibrated ranging rods are used to determine the level of reduction in slope, the rain gauge for measuring the amount of rainfall and the horizontal meter to measure the time taken for velocity of run off.

Method of data collection

The erosion rods (calibrated ranging poles) are thirty (30) in numbers pinned along downslope line previously identified during reconnaissance survey as shown in (Figure 3).

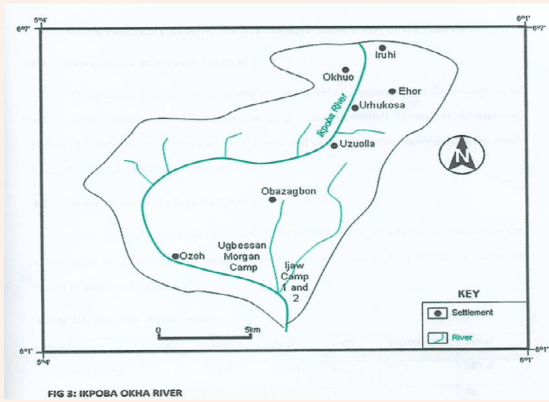

Figure 3: Ikpoba Okha River.

The rods are installed at a distance of 96 meters apart from the next one, in line with the techniques adopted by Morthdland (2015). Rainfall events, surface runoff and slope recession recording were taken directly and the mean values of the readings were observed. A reduction in erosion rods exposed showed an increased ground retreat and ground advance. Other characteristics of the river basin related to this study are measured that include; soil shear straight, penetration resistance, aspect, slope length and slope angle. Penetration resistance was carried out by the use of pocket penetrometer. Aspect was recorded, as azimuth in degrees, length of slope was determined from crest to base across the surface (Southere and Toy, 1986). Angle of slope was measured through field survey using Abney level equipment Rainfall events (rainfall amount) were measured using an auto graphic rain gauge and. runoff amount was generated within 60 seconds (See Appendix 1). Thirty rainfall events were monitored for a period of five months (5) - April, May, June, July and September in 2020and the autograph rain gauge readings were recorded from the Metrological Station of the Owena River Basin Development Authority [45], Benin City.

Statistical technique used for the study

Data on rainfall events and erosion variables were presented using descriptive statistics such as percentages, mean, range, and median. In addition, data were analysed using Pearson Product Moment Correlation (PPMCC) Coefficient Analytical method to determine the relationship between erosion rates and rainfall events. The hypotheses formulated were tested using regression analysis.

Data Presentation

This data obtained from field measurement for the evaluation of valley slope recession, used calibrated ranging rods and rainfall amount recorded as determining factors. These are presented and discussed below.

Rainfall events in ikpoba river

Data obtained from field measurement of rainfall events to determine recession of the valley slope in the area include amount of rainfall and surface runoff, are presented below in tables and graph.

Months	April	May	June	July	September	Total
Amounts (mm)	11.1	18.3	125.4	62.5	70.1	287.4
Event (No)	10	5	3	8	3	30

Figure 4: Rainfall events (mm).

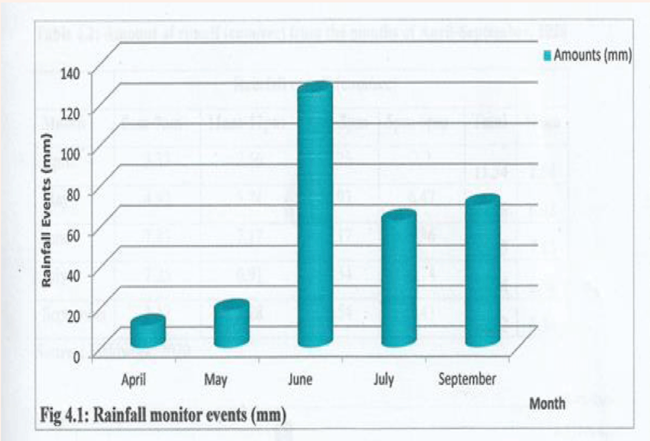

Figure 5: Rainfall monitor events (mm).

Table 4.2: Amount of runoff (cum/sec) from the months of April-September, 2020

	Rainfall runoff (cum/sec)					
Month	8am-9am	11am-12pm	2pm-3pm	5pm-6pm	Total	Mean
April	3.33	2.56	3.25	2.2	11.34	2.84
May	4.92	5.74	6.93	6.47	24.06	6.02
June	7.83	7.17	7.17	6.36	28.53	7.13
July	7.25	6.91	5.34	6.74	26.24	6.56
September	3.17	3.28	3.54	3.43	13.42	3.34

Figure 6: Amount of runoff (cum/sec (from the months of April-September, 2020.

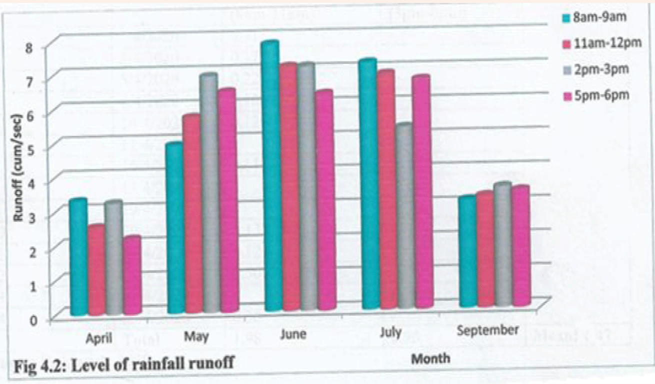

Figure 7: Level of rainfall runoff.

(Table 4 &5)showed the -rainfall data ofmonitored eventsdepicts the rainfall - runoff amount generated within 60 seconds, while the antecedent precipitation index was also computed and thirty (30) rainfall events were monitored for a period of five months (5) from April, May, June, July and September 2020 using the autograph rain gauge readings recorded from the metrological station of the Owena river basin development authority [45],Benin City. It could be deduced that the month of June had the highest rainfall amount of 125.40mm while April had the lowest indicating that rainfall events occurred most in June than other months. However, it was observed that most of the rainfall events especially in the month of June, had a total event number of three (3) and the total amount of 30 events for 287.40mm recorded rainfall indicating that the amount of rainfall determines the level of slope degeneration in the area.

(Figure 6 & 7)showed that April recorded a total rainfall runoff of 11.34cum/sec with a mean value of 2.84, May recorded 24.06eumlsee with a mean of 6.02, June recorded 28.53cumlsec with a mean of 7.13, July recorded 26.24cum/sec with a mean of 6.56, and September recorded13.42cum/sec with a mean of 3.34. From this analysis, runoff was highest in June compared to other months. The amount of runoff leds to the recession of valley slope that is because of rainfall factors.

Amount of slope recession from the month of april-september, 2020

The measurement of slope recession from the month of April to September 2020 are presented and analysed below.

(Figure 8)shows the total amount of morning and evening record of slope recession that are 1.98cm and 0.95cm respectively and mean value of 1.47cm for the month of April 2020 as shown in Figure 9. The observed slope recession is higher in the morning than in the evening. 'Ibis is an indication that the level of slope recession varies respectively according to the amount of rainfall.

(Figure 10 & 11)shows the total amount of morning and evening record of slope recession, which are 1.58cm and 1.29cm respectively and mean value of 1.44cm for the

Selected stations	Date	Morning reading between (8am-11am)	Evening reading between (3pm-6pm)	
1	2/4/2020	0.21	-	
2	3/4/2020	0.17	-	
3	5/4/2020	0.22	-	
4	8/4/2020	0.10	-	
5	10/4/2020	0.12	-	
6	11/4/2020	-	0.41	
7	16/4/2020	0.11	-	
8	18/4/2020	-	0.30	
9	19/4/2020	-	0.14	
10	20/4/2020	0.13	-	
11	22/4/2020	0.12	-	
12	24/4/2020	0.50	-	
13	07/4/2020	-	0.10	
14	30/4/2020	0.30	-	
	Total	1.98	0.95	Mean: 1.47

Figure 8: Summary of slope recession for the month of April 2020.

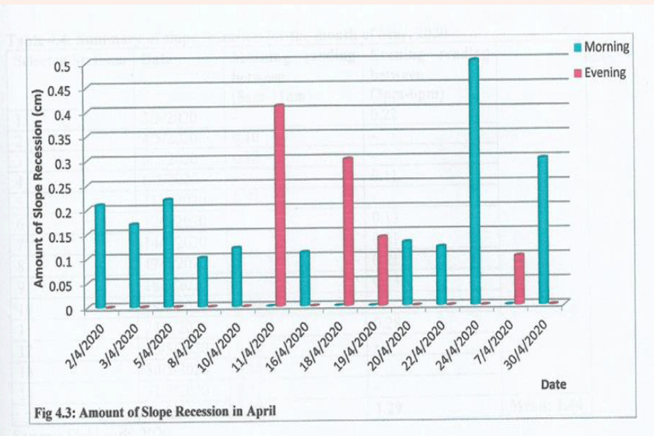

Figure 9: Amount of slope recession in April.

Selected Stations	Date	Morning reading between (8am-11am)	Evening reading between (3pm-6pm)	
1	3/5/2020	-	0.22	
2	4/5/2020	0.10	-	
3	5/5/2020	0.12	-	
4	6/5/2020	-	0.11	
5	11/5/2020	0.51	-	
6	12/5/2020	-	0.13	
7	14/5/2020	-	0.21	
8	17/5/2020	-	0.21	
9	18/5/2020	-	0.13	
10	19/5/2020	0.30	-	
11	24/5/2020	-	0.28	
12	26/5/2020	0.25	-	
13	30/5/2020	0.18	-	
14	31/5/2020	0.12	-	
	Total	1.58	1.29	Mean: 1.44

Source: Fieldwork, 2020

Figure 10: Summary of slope recession for the month of May 2020.

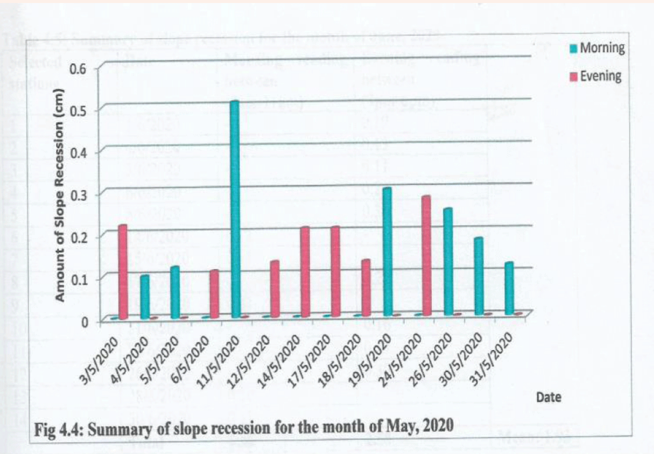

Figure 11: Summary of slope recession for the month of May 2020.

month of May 2020. Slope recession was not noticed in the morning in most cases, while it was observed in the evening and vice versa due to no rainfall.

Figure 12shows the total amount of morning and evening record of slope recession, which are 1.30cm and 2.55cm respectively and mean value of 1.93cm for the month of June 2020. There was no slope recession in few cases in the evening, while it was noticed in the morning and vice versa due to no rainfall. The observed slope recession is higher in

Selected stations	Date	Morning reading between (8am-11am)	Evening reading between (3pm-6pm)	
1	1/6/2020	-	0.19	
2	4/6/2020	-	0.13	
3	5/6/2020	-	0.11	
4	6/6/2020	-	0.23	
5	8/6/2020	-	0.36	
6	14/6/2020	0.17	-	
7	15/6/2020	0.11	-	
8	17/6/2020	-	0.22	
9	19/6/2020	0.81	-	
10	21/6/2020	-	0.16	
11	24/6/2020	-	0.27	
12	26/6/2020	-	0.30	
13	28/6/2020	0.10	-	
14	30/6/2020	0.11	-	
	Total	1.30	2.55	Mean: 1.93

Figure 12: Amount of morning and evening records of slope recession.

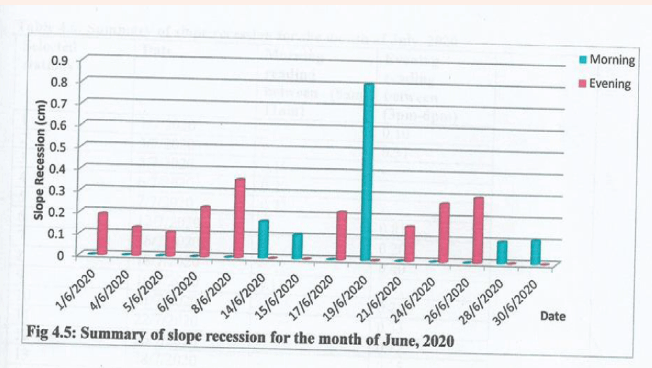

Figure 13: Summary of slope recession for the month the of June, 2020.

Selected stations	Date	Morning reading between (8am-11am)	Evening reading between (3pm-6pm)	
1	1/7/2020	-	0.10	
2	3/7/2020	-	0.31	
3	5/7/2020	0.19	-	
4	6/7/2020	0.20	-	
5	7/7/2020	0.22	-	
6	12/7/2020	-	0.81	
7	16/7/2020	-	0.20	
8	18/7/2020	-	0.40	
9	19/7/2020	0.15	-	
10	21/7/2020	-	0.24	
11	22/7/2020	-	0.33	
12	26/7/2020	-	0.12	
13	28/7/2020	-	0.25	
14	31/7/2020	0.35	-	
	Total	1.11	2.76	Mean: 1.94

Figure 14: Summary of slope recession for the month of July 2020.

the evening than in the morning. This is due to variation in the rainfall intensity and the level of slope degeneration as observed in Figure 13 below.

Figure 16 above shows the total amount of morning and evening record of slope recession, which are 0.61cm and 2.57cm respectively and mean value of 1.59cm for the month of September 2020. Figure 16 shows the total amount of morning and evening record of slope recession, which are 1.11cm and 2.76cm respectively and mean value of 1.94cm for the month of July 2020. There was no slope recession in few cases in the evening, while it was noticed in the morning and vice versa due to no rainfall. The observed slope recession is higher in the evening than in the morning as observed in Figure 17 below. **Hypotheses testing**

The hypotheses formulated are tested below using appropriate statistical tool.

Hypothesis: Ho: There is no significant relationship between rainfall amount and

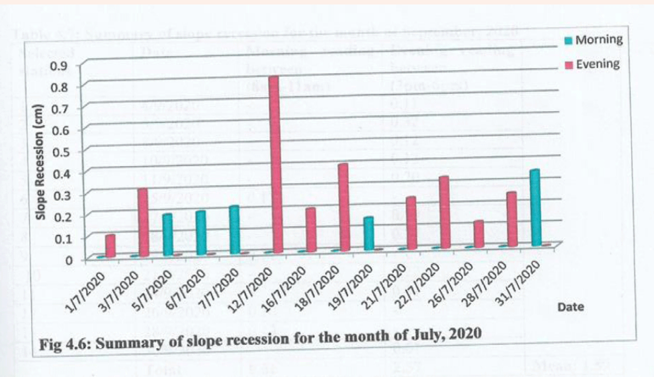

Figure 15: Summary of slope recession for the month of September 2020.

Selected stations	Date	Morning reading between (8am-11am)	Evening reading between (3pm-6pm)	
1	4/9/2020	-	0.11	
2	5/9/2020	-	0.32	
3	8/9/2020	-	0.12	
4	10/9/2020	-	0.13	
5	11/9/2020	-	0.20	
6	15/9/2020	0.17	-	
7	17/9/2020	-	0.19	
8	18/9/2020	-	0.37	
9	19/9/2020	0.11	-	
10	21/9/2020	-	0.22	
11	24/9/2020	-	0.31	
12	26/9/2020	0.20	-	
13	28/9/2020	0.13	-	
14	30/9/2020	-	0.61	
	Total	0.61	2.57	Mean: 1.59

Figure 16: Total amount of morning and evening records.

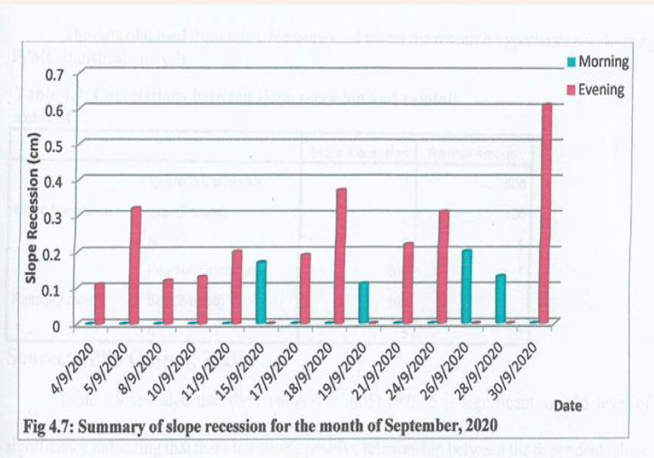

Figure 17: Summary of slope recession for the month of September 2020.

slope recession in ikpoba river valley slope. In testing this hypothesis, Figure 4 is used.

(Figure 18 &19) revealed that the r-value (r .805) P<0.05 is significant at 0.05 level of significance indicating that there is a strong positive relationship between the dependent (slope recession) and independent (rainfall amount) variables. The analysis showed that rainfall amount contributes 81% to slope recession in Ikpaba River Valley. Therefore, Ho is rejected while Hi is accepted.

(Figure 20) shows that the model (r = .805) is significant at 0.05 level of significance.

Month	Rainfall amount	Slope recession
April	11.1	1.47
May	18.3	1.44
June	125.4	1.93
July	62.5	1.94
September	70.1	1.59
Total	**287.4**	**8.37**
Mean	**57.5**	**1.67**

Figure 18: Mean record of Rainfall amount and slope recession. The data obtained from this table were used to test the research hypothesis below using PPMC statistical analysis.

		Slope Recession	Rainfall Amount
Slope Recession	Pearson Correlation	1	.805
	Sig. (2-tailed)		.100
	N	5	5
Rainfall Amount	Pearson Correlation	.805	1
	Sig. (2-tailed)	.100	
	N	5	5

Figure 19: Correlations between slope recession and rainfall amount.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.805[a]	.648	.530	.16780

Figure 20: Model Summary.

It could be deduced that rainfall amount has 65% contribution to slope recession in Ikpoba River Slopes. This implies that 65% of the relationship that exist between rainfall and slope recession can be explained while 35% cannot be explained. Therefore, the null hypothesis (Ho) which states that there is no significant relationship between rainfall amount and slope degeneration in Ikpoba River Slopes is rejected while the alternative hypothesis, which states that there is a significant relationship between rainfall amount and slope degeneration in Ikpoba river slopes, is accepted.

Discussion of findings

The following findings were derived from the analysis so far. The result of the analysis shows that rainfall amounts increased over the period of record (April-September) with June having the highest rainfall amount indicating that rainfall is heaviest in June and slope recession increased with varying surface runoff. The result of the findings indicates that a large proportion of the slope recession was observed mostly in the morning in some cases with little or no recession in the evening and vice versa. This indicates a tendency for amount to increase or decrease between the month of April and September 2020. In addition, high correlation values were observed for rainfall amount, surface runoff and slope recession with a varying mean value observed for all variables. A close examination reveals that rainfall amounts and events are good predictors of slope recession. The result of the analysis obtained from the hypothesis tested, show that there is a significant relationship between rainfall amount and slope recession in Ikpoba River Slope since the model (r .805) is significant at 0.05 level of significance.This finding is in line with Monsierus (2015) who observed that rainfall is recognized as the major cause of slope recession and retreat all over the world. A large number of rainfall-induced landslides in slope happened in recent times. This finding also corroborates with that of Borgatti and Soldati (2010) [8] that stated climate change with most intense and extreme rainfall and population growth can drastically increase landslides and soil erosion, especially in developing countries, wherepopulation and agricultural pressure on land resources often led to exploitation of unstable slopes.

Summary

This study is on the effect of rainfall amount as a determinant of slope recession in Ikpoba River Slope. The study adopts the experimental research design and direct field measurement of rainfall events and erosion variables at site. The data collected were subjected to PPMCC Correlation and Regression Statistical Analyses[51-53].

Findings

Itis discovered that rainfall amount is one of the major factors that predominates in slope retreat, recession and evolution followed by rainfall amount which researcher's facts corroborated by Lai, (1976) and Odemerho, (1982) [40]. In one of the studies carried out by Odemerho and 'Avwunudogba (1983) [42], an average rainfall of 1858.7mm for 7 months in three years, with an average of 132 rainy days was reported to have such effect. Rainfall in excess of 12.70mm has also been documented as threshold value for the humid tropics (Hudson, 1971) [30]. High sustained rainfall amount was observed in June compared to other months. Have been reported for the tropics (Jimoh, 1997) [32]. These identified processes above, can influence slope recession through detachment of soil aggregates, rapid runoff and high level of erosion. Besides, they can affect soil porosity and hence, soil hydraulic properties like saturated and unsaturated hydraulic conductivity, water retention characteristics which are major determinants to slope recession in Ikpoba River valley as observed by Imerson and Kwaad, (1990) [31].

Conclusion

The rainfall amount and duration will influence moisture content of the soil, which will in turn influence aggregate stability. The study shows the extent of slope recession prediction with some degree of accuracy on the basis parameters such as kinetic energy asd major revelations of the study. The range of values for these variables are limited since rainfall amount (R) and surface runoff (Ro) are significantly related to slope recession. A similar study carried by Odemerho (1992)[41] revealed that the area of study is an undulating plain with relative relief of twelve (12) meters and slope range between 1.50-30.Generally, the basin is flat and of monotonous aggradation plain without marked topographical features. Therefore, topography and relief plays an insignificant role of slope recession in the basin.

Recommendations

The rainfall amount plays a predominant role in slope erosion and the areas surrounding the basin should be planted with trees and grassesto reduce the impact of raindrop erosion andto reduce runoffto control erosion around the basin. Secondly, the surfaces and the basin should be covered with green lawns to reduce the rate of infiltration and surface overland flow. Thirdly, government and individuals should construct water channels to drain away fast flowing water especially during the rainy season.

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