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Target Oriented Procedure for Erosion Control in the Nanka/Agulu Axis of Nigeria

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Abstract: *This work addresses the gully erosion problems of the Nanka/Agulu area of Anambra State, Nigeria. Field reconnaissance and observation visits were made to five major erosion sites in the study area to obtain a first-hand and on-the-spot assessment of the degree of erosion menace in these areas and to collect soil samples for laboratory analyses. The collected soil samples were subjected to visual inspection before classification tests. The investigation/field work was carried out and conducted in accordance with the guidelines given in the general specification (erosion control) vol.11 of the Federal Ministry of Works and Housing, and where necessary, the British Code of Practice for site investigation (C.P.2089). The representative soil samples were subjected to the Natural Moisture Content, Atterberg Limits, Mechanical Sieve Analysis, Compaction and Triaxial Compression tests to ascertain their nature, texture and erodibility. Data obtained from the sites and from these tests were inserted into mathematical formulations on the management of erosion problems. This enabled the quantification of the soils' erodibility estimation and the recommendations on the management of the erosion problems in the study area. With data obtained at the sites, computations and designs of Revetments along the sides of the Gullies, design of Run-off/Flood Drainage Channels, and, design of Run-off/Flood and Sediment Retarding Structure (Sedimentation Weir) were carried out. Results revealed that proper Soil Conservation Designs, Flow Velocity Control, Reduction of Soil Segregation(Rainfall Erosivity), Soil Conservation Measures, proper Management of Human Activities. Agro-forestry control. Ground Cover Establishment and construction of necessary Erosion Control Structures at the proper locations as this will adequately help in checking the erosion problems.*

Keywords: *Erosion, target-oriented, environmentally-oriented, erodibility, erosivity.*

1. INTRODUCTION

This paper addresses the gully erosion problems of the Nanka/Agulu area of Anambra State, Nigeria. Erosion is a major problem, and, poses serious environmental hazards in many parts of Anambra State, Nigeria. Nanka-Agulu axis is a major erosion-hit area in the state, where gullies have taken catastrophic dimensions, threatening farmlands, streams, and, even the entire human settlement, thereby affecting agricultural output. Addressing this problem requires a target-oriented and clearly structured procedure. Simultaneously, it will be necessary to meet relevant legal, engineering, and, environmental requirements, and, to produce designs that are environmentally–oriented.[1] It is aimed at studying factors responsible for land degradation, therefore, causing hazardous erosion in the area, and, through scientific analyses of the area's soil, proffer solutions towards curbing the menace. Earlier works on related projects were extensively reviewed to ascertain the degree of the problem, and, solutions and recommendations that had been proffered by earlier researchers. The erosion hazard management process proposed consists of three phases: erosion hazard identification, erosion hazard analysis/ assessment, and, erosion hazard handling, which, are based on each other.

There are a number of basic principles for controlling run-off erosion that have proved sound and are well known. These include:

1. Proper attention to soil, foundation and topography in site selections
2. Minimum exposure of bare areas by control of clearing and grading operations
3. Diversion of run-off water away from critical areas using drains and other erosion control structures

4. Flattening of and/or stabilization of slopes depending on soil type an its angle of repose
5. Reducing slope lengths of erosion control structures
6. Control of construction equipment access and travel ways
7. Use of temporary/permanent vegetative cover
8. Public enlightenment programmes
9. Ensuring proper implementation of the remedial measures
10. Utilizing soil stabilization measures
11. Use of terraces across steep slopes
12. Not ploughing along slopes.

Previous works on this problem reveal that the factors affecting the erodibility of soils in the research area are:

- Particle size of the soils
- Land scope
- Vegetation
- Presence of salt and colloidal matter in the soils
- Moisture content of the soils
- Soil compaction
- Soil properties
- Human activities
- Rainfall characteristics.[2]

This paper is aimed at revealing the factors responsible for land degradation, thereby, causing hazardous erosion in the Nanka/Agulu axis of Anambra State, Nigeria. In this paper, recommendations on the possible treatments that could be applied to the soils in the study area to curb their credibility, based on their nature and characteristics are made. The level of gully formation in the study area, based on which possible management measures are recommended is ascertained in this paper. It is aimed at identifying how gully erosion sites in the study area could be usefully utilised as hydropower systems, storage reservoirs for water supply, and/or, recreation and fish ponds.

2. Materials and Methods

2.1. Materials

Soil samples collected at selected gully sites in the study area, the materials used for this research work include: rain gauge, cellophane bags, hand augers of varying diameters, dry oven with thermometer, desiccators, air-tight container made of non-corrodible material; with lid, weighing balance with an accuracy of 0.01g, ground glass plate of about 200mm x 150mm, a flat glass plate of about 10mm thickness and 450mm^2 area, palette knives, a 6mm diameter rod of length 100mm, moisture content can, grooving tools of both British standard and ASTM, spatula, Cassagrande's liquid limit device, evaporating dish, wash bottle, a set of British standard (BS) sieves; with lids and receivers, sieve shaker with timer (mechanical shaker),mechanical stirrer, sample divider, a set of metal trays, a set of sieve brushes, a set of evaporating dishes, one set of mortar and rubber pestle, scoop**,** cylindrical metal moulds, colar, rammer, stopper, density bottle, gas jar, glass bottle fitted with a screwed conical cap (pycometer), stop watch, hydrometer, measuring cylinders, rubber (latex) membrane and triaxial compression test machine.

2.2. Methods

This research work was carried out following the following steps: (1) Field Survey and Data Collection (2) Laboratory Testing/Soil Sampling (3) Analysis and Presentation of results.

2.3. Field Survey and Data Collection

Soil samples were collected from five erosion sites within the study area. The researcher collected samples from two erosion sites at Nanka, and other samples from three erosion sites in Agulu towns. Soil samples were collected at the strata boundaries or still at intervals of not less than 15m. The collected samples were subjected to visual inspection before classification tests. The investigation/field work was carried out and conducted in accordance with the guidelines given in the general specification (erosion control) vol. II of the Federal Ministry of Works and Housing, and where necessary, the British Code of practice for site investigation (C.P. 2089).

The representative soil samples were subjected to the following tests:

- Moisture content determination
- Consistency/Atterberg limits determination (liquid limit, plastic limit and shrinkage limit)
- Particle size distribution using mechanical sieve analysis
- Sedimentation
- Compaction
- Specific gravity
- Triaxial compression

3. Result and Discussion

The tests and analyses were conducted to ascertain the most appropriate materials to be used for the gully erosion sites reclamation in the study area. The results were also used to compare the results of the laboratory analyses of soils obtained from borrow pits.

The results of the geotechnical investigations (sieve analysis) reveal that the soils from the various boreholes in the study area are quite good and well graded. The specific gravity tests gave an average gradation of 2.67 which indicates a well graded soil as it falls within the range of values of well graded soils (2.65 to 2.80).[3] The results of the compaction tests (standard proctor tests) carried out in accordance to IS: 2720, indicate that the soil is well compacted; having Optimum Moisture Content ranging from 9.5% to 13.3%, and, Maximum Dry Density ranging from 1.18g/cm^3 to 1.8g/cm^3.

The results of the geotechnical investigations are shown on Table 1 in the Appendix 1.

Based on the United Soil Classification System (USCS), the soil can be classified as silt- clay with medium Plasticity (MH soil). This indicates that the soil has a Liquid Limit of more than 50%. The soil has a fair Plasticity Index with an average of 33%. Based on shear strength, the soil can be classified as a cohesive frictional (c'-Ø) soil, an indication that the soil is a composite soil (triaxial test). The sedimentation analyses reveal that the soil contains about 28% clay (particles less than 2µ size).

The soil being a mixture of clay and sand (from the Atterberg limits and triaxial compression tests) has erodibility index of 0.53. Though the soil is well compacted, it is very difficult to retain its cohesiveness when exposed to rainfall with kinetic energy of about 302.63MJ (rain drop size of about 3mm to 6mm and rainfall intensity of about 1l0mm/hr) and with rainfall erosivity of 272MJ.m/ha.h.[4] Also, since the clay content of the soil is very low (from the sedimentation tests), it becomes very easy for the soil to be eroded under the influence of a very high drag force (320MJ kinetic energy of rainfall). The rainfall pattern in the study area during the period of studies increased gradually from 2002 to 2014, the highest being witnessed in the last three years. The aforementioned factor is the main cause of the speedy formation of the gullies which receive run-off from many illegal drainage channels channeled into them.

Other factors that contribute to the development of gullies in the study area are:

1. The land slope in the axis and the watershed rocks are tilted and faulted (gully-formation-enhancing topography or long and steep slopes). Intervention by man has caused disruptions in the topography of the axis' land slope such that the changes in some places are as much as 60%.[5]
2. Although the soil in the study axis contains some amount of clay, it lacks sufficient binding (cementing) component which makes it easily erodible.
3. High intensity of precipitation (intense rainfall) in the study axis.
4. Uncontrolled/unregulated farming practice in the area of study.
5. Bush burning is a recurring activity in the study area.
6. Grazing of the vegetation in the study axis by animals has virtually removed the little vegetation cover available (no vegetation cover to prevent the impact of rain drops on the soil).

4. CONCLUSION

Soil erosion is a hazardous recurring problem in the erosion-ravaged area of Nanka/ Agulu axis of Anambra State, Nigeria. Continued drifting of the soil in this area gradually causes a textural change in the soil, and, loss of fine sand, silt, clay and organic particles from the area's soil lowers the moisture holding capacity of the soil. This, in turn, increases the credibility of the soil, and, compounds the erosion problem. In view of the tremendous capacity for flowing water to dislodge and transport not only soil particles, but, also sand and boulders in the study area, it is imperative that control measures be devised that will first of all prevent the dislodgement of soil particles and, then reduce and maintain run-off velocities at or near levels that will prevent accelerated soil erosion in the area. The level of gully formation in the study area, based in which possible management measure are, in this paper recommended is such that gullies have taken catastrophic dimensions, threatening farmlands, streams, and, even the entire human settlement, thereby, affecting agricultural output.

The gully formations in the study area is also so large that the amount of sediment from the gully erosion fields as a result of such fields being divided by large gullies has been a serious problem. The formations in the study axis have been characterized by massive landscape loss and washing away of soil particles, with tributaries, which, worsen by undercutting, resulting in avalanches, landslides and other forms of subsidence. [6]

RECOMMENDATION

It is recommended that to control incisions at canyons, gorges and gully-beds, the following engineering remedies be applied to reduce erosion:

a. Intercepting drains

b. Curbs and gutters

c. Turf cover

d. Slope and channel lining

e. Stabilization of the gully faces

f. Construction of revetments on the gully faces

The following erosion control measures for checking erosion ravages in the study area are also recommended:

i. Soil conservation designs

ii. Flow velocity control

iii. Reduction of soil segregation

iv. Soil conservation measures

The following human activities are also recommended for the mitigation of erosion in the study area:

a. Afforestation and good cultivation practices

b. Proper construction patterns

c. Discouragement of quarrying and borrow pit mining

d. Proper termination of drains at drain out falls

e. Application of agro-forestry in erosion control

f. Ground cover establishment

g. Adoption of proper tree planting techniques.

The following erosion control structures are also recommended to be constructed at proper locations in the study area for effective control of erosion:

- Retarding structures (sedimentation weirs)
- Diversions
- Wooden groynes and wicker-work fences.

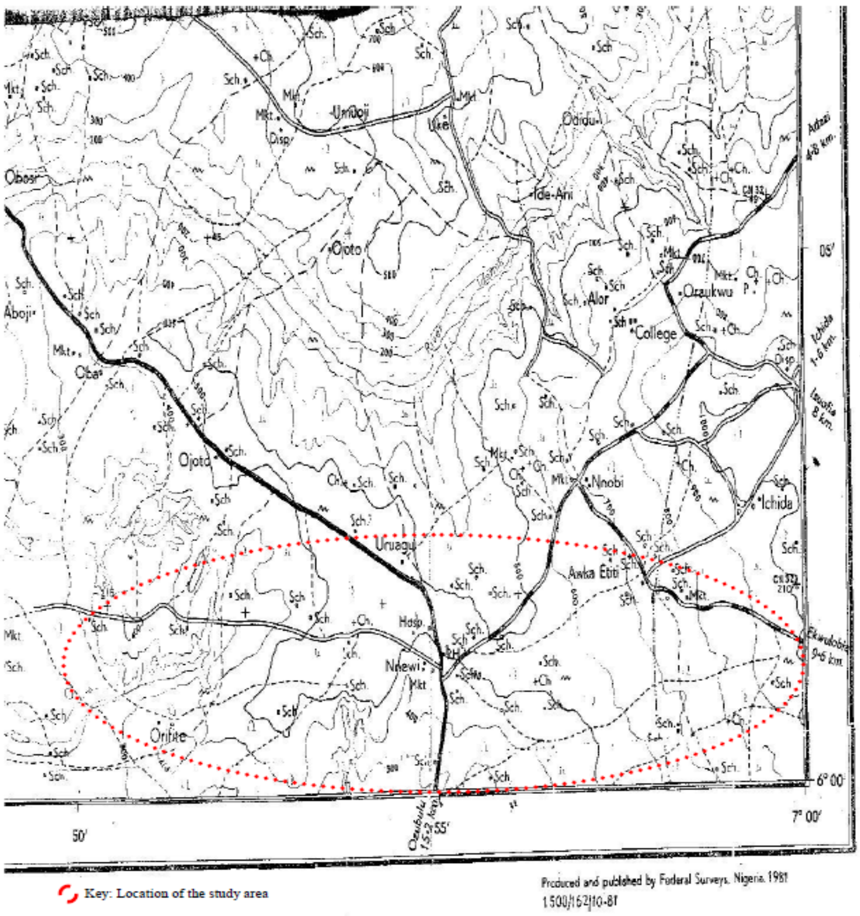
APPENDIX 1

Table1. *Result of Geotechnical Tests Conducted on Soil Samples from the Study Area*

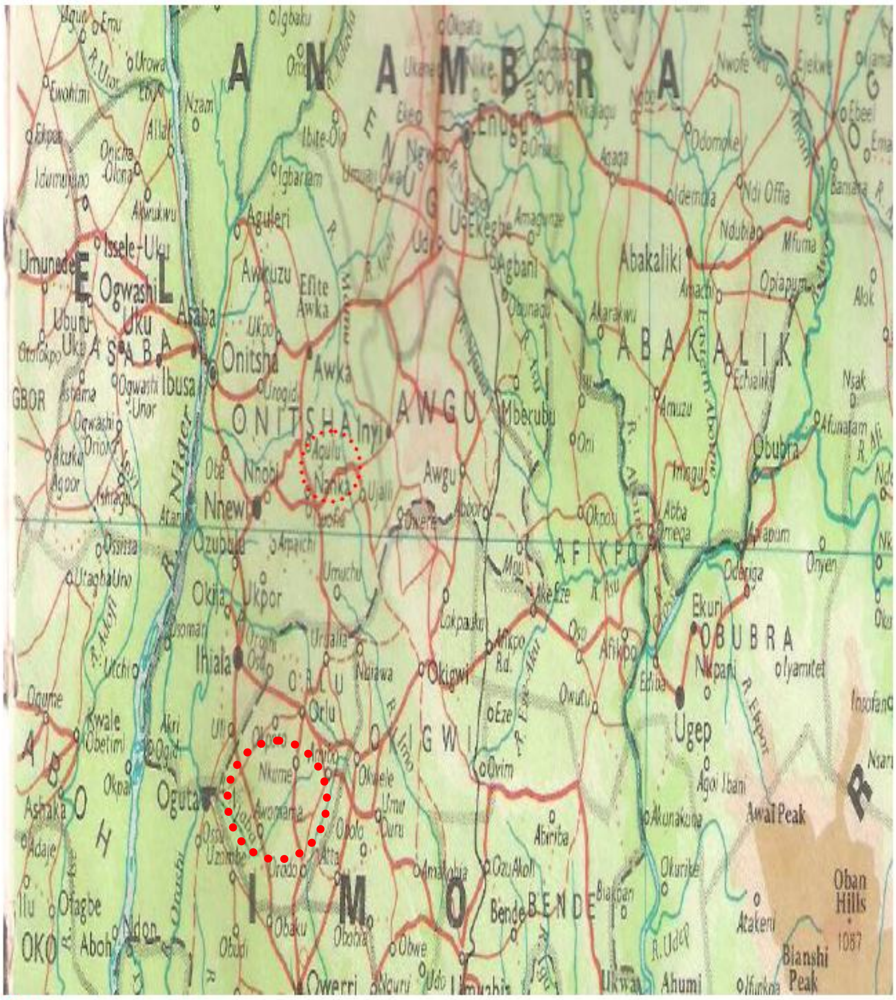
	DEPTH (m.)	SPECIFIC GRAVITY [G.S] (cm/s^2)	SIEVE ANALYSIS % PASSING THROUGH			COMPACTION		ATTERBERG LIMITS				TRIAXIAL	
			1.18	0.425	0.075	OMC (%)	MDD (g/cm^3)	LL	PL	PI	SL	C(KN/m^2)	∅(degrees)
1								-	-	-	-	-	-
	0.50	2.58	85.89	31.98	6.84	12.80	1.74	-	-	-	-	-	-
	1.20	2.60	82.70	36.87	7.93	10.00	1.75	-	-	-	-	-	-
	1.80	2.97	92.32	66.96	25.25	10.00	1.83	-	-	-	-	-	-
2	0.50	2.58	96.90	65.19	35.93	11.90	1.73	-	-	-	-	-	-
	0.80	2.93	80.51	36.06	5.62	12.10	1.70	-	-	-	-	-	-
	2.00	2.61	95.18	60.77	13.16	9.50	1.18	-	-	-	-	-	-
3	0.50	2.52	96.90	65.19	35.93	12.50	1.80	51.30	17.59	33.70	12.86	-	-
	1.00	2.60	96.42	66.84	38.92	13.30	1.75	55.30	19.20	36.12	12.86	-	-
	2.00	2.59	96.45	66.79	39.91	13.20	1.73	62.99	20.85	42.14	13.57	22.00	9.00
4	0.50	2.62	93.58	59.55	25.96	11.50	1.85	37.38	14.20	23.18	12.14	-	-
	1.00	2.50	92.57	58.22	25.01	11.30	1.83	40.64	14.69	25.95	13.57	-	-
	2.00	2.56	90.95	58.31	29.63	11.60	1.84	55.35	16.38	38.97	11.43	24.00	10.00
5	0.50	2.37	98.04	68.82	35.59	11.00	1.80	44.31	18.46	25.85	13.57	-	-
	1.00	2.58	97.92	69.45	38.16	12.50	1.67	58.05	18.79	39.26	12.86	28.00	1.00
	2.00	2.60	97.26	70.09	37.51	11.20	1.78	55.51	21.99	33.52	12.86	34.00	5.00
6	0.50	2.66	98.20	68.38	36.60	11.50	1.80	38.86	14.26	24.60	12.14	-	-
	1.00	2.89	97.75	69.19	37.27	12.20	1.79	53.15	19.13	34.20	12.86	38.00	26.00
	2.00	2.68	97.98	70.23	35.00	12.00	1.78	51.25	17.57	33.68	12.86	44.00	19.00

Summary of the results of the geotechnical investigations on the study axis' soil samples.

APPENDIX 2



APPENDIX 3



Key: Location of the research area.
Map of part of southern Nigeria depicting the research area.

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