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Assessment of environmental impacts and remedies for gully erosion in Ankpa Metropolis and environs, Kogi State, Nigeria

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ABSTRACT

The study area (Ankpa) falls within the Nigeria meteorological zone characterized by warm temperature days and moderately cool nights. Two distinct climatic divisions are demarcated. These are the dry and rainy seasons representing two broad periods of significant but contrasting variations of weather parameters, and hence geopedologic stability. Geologically, Ankpa falls within the Anambra Basin whose genesis has been linked with the development of the Niger Delta Miogeosyncline and the opening of the Benue Trough. Underlying the Benue Trough are the rocks of Anambra Sedimentary Basin consisting of Ajali Formation and Mamu Formation. Atterberg limit tests were carried out on soil samples from gully sites. Further particle size and compaction tests were made to assess the geopedologic and hydrologic causes of the gully erosion in the area and suggestions made for a lasting remedy to the menace. The plasticity index revealed that the soils are non-cohesive and non-plastic because it ranged from 1.2% to 5.2%. Sieve analysis indicate that the soil from the gully sites are within the medium to coarse grain range with low percentages of silt/clay, therefore the soil is non-plastic. The compaction test also shows that the optimum moisture content ranges from 13.50% to 15.20% while the maximum dry density ranges from 1.75mg/m^3 to 1.98mg/m^3. The maximum dry density values are generally low which indicates that the soil is not compact but loose. Enlightenment and awareness of erosion control should include land use habits of the people in their agricultural practices and care of vegetation. Concrete terracing of gully affected areas is recommended to reduce the impact or the force of rain-drop. This will restrict the widening of incipient gullies. A holistic rehabilitation development program of monitoring the pedosphere to reclaim devastated land as well as to ensure a safe environment.

Key words: Ankpa, Gully Erosion, Impact, Assessment, logical, Non-plastic soil, concrete terracing, remedies Geopedologic.

INTRODUCTION

Gully Erosion is an obvious and clear form of soil degradation consisting of an open incised and unstable channel generally more than 30 centimeters deep. It occurs where surface water flow has become trapped in a small concentrated stream, and begins to erode channels in the ground surface, making it wider and deeper. Uncontrolled progress of gullies results in 'bad land' topography and destroys the ecology and economy of the affected areas, Cavey (2006).

The Ankpa metropolis and the environs include vast area of Nigeria underlain by thick, extensive sand and sandstone deposits which enhance the groundwater resources potential of the area. However, their good hydrologic properties often produce negative environmental impacts in the area. This has led to specific in-site effects of gully erosion in Ankpa metropolis and environs which has also given rise to different hazards to lives and properties of the communities. Among these are:

- Reduced access to land and on properties
- A reduction in the area of arable and other agricultural land, which become divided into smaller parcels and leads to increased farming cost.
- Major changes to the patterns of overland flow causing sedimentation in watercourses and leading to bank erosion problems.
- Increased rates of erosion where more subsoil material is exposed.
- Further economic losses from soil erosion are incurred by landholders and the wider community from off-site effects such as:
- Sedimentation and increased flooding affecting fences, farms and public roadways, railways, culverts and bridges.
- Sedimentation of water ways and water supplies.
- Increased pollution from agricultural and chemicals and animal effluent in incised water ways.

Notable among these has been an increase in erodibility potential, accounting for the widespread development of a history of poor ground cover due to clearing high stocking rates, repeated cultivations or decimation by fire or rabbits. Seasonal and cyclic drought, concentrated runoff from steep lands flowing into cleared drainage depressions, unstable soils in drainage lines, intense rainfall, excavated runoff caused by factors such as low levels of free cover and poor soil infiltration around Ankpa and environs (Figure 1). All these have contributed to environmental impacts and there by produced badland topography and created fears among the dwellers in the area.

Gully erosion is generally most highly developed where the contributing effects of land use, climate and slope interact. The western slopes of NSW feature many hot spots of erosion on susceptible soils. High rainfall also contributes to the development of many serious gullies on the eastern slopes.

Okogbue (2005) in his detailed study and the factors which govern the development of gully erosion and landslides in southeastern Nigeria, suggested that gully erosion is controlled by physiography, geology, hydrogeology, and engineering properties of the soil materials.

Ankpa falls within the Nigeria meteorological zone that is characterized by warm temperature days and moderately cool nights. Two distinct climatic divisions are demarcated as the dry and rainy seasons representing two broad periods of significant but contrasting variations of weather parameters, as well as geopedologic stability. The rainfall regime is very high resulting in significant reduction of average intergranular contact. Particles disaggregation rate of the soil zone thus increase, especially in the sandy formation.

Figure 1: An erosion gully site in Ankpa

The Ankpa metropolis and environs is one of the areas of southeastern Nigeria that have been ravaged by severe gully erosion. In this study the environmental impacts of the gully erosion were investigated and remedies are being suggested to arrest and/or minimize the menace.

While the study mainly observed the environmental impacts and causes of gully erosion in the area, remedies suggested include agroforestry/maintenance of good ground cover, legislation/laws for afforestation and against deforestation, etc.

Other suggestions are enlightenment and awareness campaign on erosion control, proper land use habits of the people and their agricultural practice as well as care of the vegetation.

MATERIALS AND METHODS

Traverse method of survey was employed to gain access to sample locations. Soil samples were obtained from incipient gullies at depths of 0.5m and 3.0m, wrapped in polythene bags and taken to the laboratory for Atterberg limits determination. In addition, particle size analysis for the soil samples was carried out using the American type of standard sieve (Half-phi ASTM Stand) and a digital weighing balance. Furthermore, compaction test was done with the aid of a BS1377 mould and a 2.5 hammer.

Geology of the study area

Ankpa falls within the Anambra Basin whose genesis has been linked with the development of the Niger Delta Miogeosyncline and the opening of the Benue Trough, Murat (1972). The stratigraphy comprises of cyclic sedimentary sequence that started in the early Cretaceous time, Reyment (1965), Marine and fluviatile sediments comprising friable to poorly cemented sands, shales, clays and limestone were deposited, with occasional coal, peat and thin discontinuous seams of lignite, du Preez (1945). The sediments have been affected by the major Santonian folding, and a minor Cenomanian folding and uplift, Murat (1972). The study area is typical of Ajali Formation or the false bedded sandstone and the Mamu Formation. The Ajali consists of thick friable poorly sorted sandstone, typically white in colour but sometimes iron-stained. Ajali sand is often overlain by a considerable thickness of red earthly sands, formed by the weathering and feruginization of the Formation.

The Manu consists mainly of sandstone, carbonaceous shales, sandy shales and some coalseams (figure 2).

Figure 2: Geological map of Ankpa and Environs

Causes of gully erosion in Ankpa and environs:

Some of the most likely causes of gully erosion in Ankpa and the surroundings are:

- A history of poor ground cover due to clearing, high stocking rates, repeated cultivations, or decimation by fire or rabbits.
- Seasonal and cyclic drought
- Concentrated runoff, from steep lands, flowing into cleared drainage depressions.
- Unstable soil in drainage lines
- Intense rainfall
- Elevated runoff caused by factors such as low levels of free cover and poor soil infiltration.

Specific characteristics of gully erosion in Ankpa and environs:-

Gully erosion is generally most highly developed where the contributing effects of land use, climate and slope interact. Gully development and spread also involve disaggregation and removal of earth materials along a defined path down slope, in a course of running flood. Under satisfactory soil condition, flow velocity and volume constitute the major hydrologic factors controlling the potential for gully development.

The hydrologic components of eroding force (Fh) thus depends on the flow velocity (L/T) and the rate of increase of flow volume (V/T), given as:

$Fh=VL/T^2$………………………………………………….(1)

where: L is distance parameter (M), V is average flow volume (m^3) and T is time parameter(s).

Thus, $Fh = KVL/T^2$……………………(2)

where: K represents a constant factor corresponding to an index property of the running flood specifically the density (D) substituting PV=M (mass of flowing water).

$Fh = ML/T$
$= (M/T.L/T)$……………………………………(3)

For flood force during erosion, M/T depends on the amount and intensity of rainfall, while L/T is slope-controlled. The effectiveness of the force further depends on the strength properties, particulate nature (lithology) and density of the bedrock or soil.

RESULTS

Eight soil samples from gully sites in the study area at depths of 0.5m and 3.0m were analysed using Atterberg limits, sieve and compaction methods.

Table 1: Summary of Atterberg limits of soil samples from Gully sites in Ankpa metropolis

LOCATION	DEPTH (m)	LIQUID LIMIT	PLASTIC LIMIT	PLASTIC INDEX %
Ankpa 1	0.5 3.0	28.60 26.90	24.80 23.50	3.80 3.40
Ankpa 2	0.5 3.0	29.50 28.00	24.30 25.00	5.00 3.00
Ankpa 3	0.5 3.0	28.90 27.00	24.50 23.00	4.40 4.00
Ankpa 4	0.5 3.0	30.80 28.20	26.80 27.00	4.00 1.20

Table 2: Standard Range of Plastic Limits of Soil (Clayton and Juckes, 1978)

PLASTIC LIMIT OF SOIL (%)	PLASTICITY
Below 35%	Low plasticity
Between 35 – 50%	Intermediate plasticity
Above 50%	High plasticity

Table3: Plasticity indices and corresponding states of plasticity (Burmister, 1997)

S/N	PLASTICITY INDEX %	STATE OF PLASTICITY
1	0	Non plastic
2	1-5	Slight
3	5-10	Low
4	10-20	Medium
5	20-40	High
6	>40	Very High

Table 4: Graphic mean data interpretation for the study locations

Location	Depth (m)	Calculated mean	Soil Description
Ankpa 1	0.5	1.33	Medium sand
	3.0	0.96	Coarse sand
Ankpa 2	0.5	2.00	Medium sand
	3.0	1.00	Coarse sand
Ankpa 3	0.5	1.33	Medium sand
	3.0	0.70	Coarse sand
Ankpa 4	0.5	1.32	Medium sand
	3.0	0.73	Coarse sand

Table 5: Standard table for mean grain size distribution (Wentworth, 1922)

Phi (Ø) range	Descriptive terms
1.00 – 0.00	Very coarse sand
0.00 – 1.00	Coarse sand
1.00 – 2.00	Medium sand
2.00 – 3.00	Fine sand
3.00 – 4.00	Very fine sand
4.00 – 5.00	Silt

Table 6: Summary of Compaction Test on soils in the study area

LOCATION	DEPTH (M)	OPTIMUM MOISTURE CONTENT	MAXIMUM DRY DENSITY (MMD) mg/m^3
Ankpa 1	3.0	13.50	1.98
Ankpa 2	3.0	15.20	1.78
Ankpa 3	3.0	13.50	1.98
Ankpa 4	3.0	14.80	1.75

Compaction test data for the study area Akpa 1

Compaction Test No	1	2	3	4	5
WT of mould + Wet soil (g)	3690	3807	3898	3860	3805
WT of mould (g)	1821	1821	1821	1821	1821
WT of Wet soil (g)	1869	1986	2077	2039	1984
Density of wet soil (mg/m^3)	1.87	1.99	2.07	2.04	1.98

Moisture Content

Tin No	21b	32b	40b	33b	37b	20b	28b	44b	12b	8b
WT of Wet soil + Tin(g)	20.4	22.3	23.1	19.4	17.8	19.9	24.6	24.6	28.6	25.4
WT of Dry soil +Tin (g)	19.5	21.2	21.7	17.9	16.3	18.5	22.3	22.3	25.3	22.6
WT of Tin (g)	9.7	10.0	10.1	10.0	6.6	9.6	9.8	9.8	9.9	10.2
WT of Dry soil (g)	9.8	11.2	11.2	7.9	9.7	8.9	12.5	12.5	15.4	12.4
WT of water (g)	0.9	1.1	1.4	1.5	1.5	1.4	2.3	2.3	3.3	2.8
Moisture content %	9.2	9.8	9.8	12.1	15.5	15.7	18.4	18.4	21.4	22.6

Mean moisture content (%)	9.5	15.5	15.6	18.4	22.0
Dry density (mg/m^3)	1.71	1.76	1.8	1.72	1.63

Ankpa 2

Compaction test No	1	2	3	4	5
WT of mould + Wet soil(g)	3689	3834	3893	3859	3804
WT of mould (g)	1821	1821	1821	1821	1821
WT of wet soil (g)	1868	2013	2072	2038	1983
Density of wet soil (mg/m^3)	1.87	2.01	2.07	2.04	1.98

MOISTURE CONTENT

Tin No	21b	32b	40b	33b	37b	20b	28b	44b	12b	8b
WT of wet soil + Tin(g)	20.2	22.1	23.0	19.4	19.8	24.5	30.0	28.6	2.54	27.0
WT of dry soil+Tin (g)	19.3	21.0	21.6	17.8	18.4	22.2	26.8	25.3	22.6	24.9
WT of Tin (g)	9.5	9.8	10.0	10.2	9.5	9.7	10.0	9.9	10.2	9.2
WT of dry soil (g)	9.8	11.2	11.6	7.6	8.9	12.5	16.8	15.4	12.4	15.7
WT of Water (g)	0.9	1.1	1.4	1.6	1.4	2.3	3.2	3.3	2.8	2.1
Moisture content %	9.2	9.8	12.1	21.1	15.7	18.4	19.0		22.6	13.4

Mean moisture content %	9.5	16.6	17.1	20.2	18.0
Dry density (mg/m^3)	1.70	1.72	1.76	1.6	1.60

Ankpa 3

Compaction test No	1	2	3	4	5
WT of mould + Wet Soil (g)	3432	3779	4073	4010	3880
WT of mould (g)	1821	1821	1821	1821	1821
WT of wet soil (g)	1611	1958	2252	2189	2059
Density of wet soil (mg/m^3)	1.61	1.96	2.25	2.19	2.06

MOISTURE CONTENT

Tin No	44b	51b	22b	31b	47b	20b	12b	34b	27b	41b
WT of wet soil + Tin(g)	33.0	32.5	29.5	35.4	36.6	39.5	48.2	49.7	54.0	49.4
WT of dry soil+Tin (g)	32.1	31.5	28.0	33.5	33.7	36.2	42.3	44.4	47.9	42.9
WT of Tin (g)	10.4	10.2	10.1	10.3	10.0	10.4	10.0	9.9	16.5	9.8
WT of dry soil (g)	21.7	21.3	17.9	23.2	23.7	25.8	32.3	34.5	31.4	33.1
WT of Water (g)	0.9	1.1	1.5	1.9	2.9	3.3	5.9	5.3	6.1	6.5
Moisture content (%)	4.15	4.69	8.38	8.19	8.19	12.79	18.27	15.36	19.43	19.64

Mean moisture content (%)	4.42	8.30	12.52	16.82	19.54
Dry Density (mg/m^3)	1.53	1.81	2.0	1.88	1.72

Ankpa 4

Compaction Test No	1	2	3	4	5
WT of mould + wet soil (g)	3424	3779	4073	4073	4010
WT of mould (g)	1821	1821	1821	1821	1821
WT of wet soil (g)	1603	1958	2252	2252	2189
Density of wet soil (mg/m^3)	1.60	1.96	2.25	2.24	2.19

MOISTURE CONTENT

Tin No	44b	51b	22b	31b	47b	20b	12b	34b	27b	41b
WT of wet soil + Tin(g)	33.0	32.5	29.5	35.4	36.6	39.5	48.2	49.7	54.0	49.4
WT of dry soil+Tin (g)	32.1	31.5	28.0	33.5	33.7	36.2	42.3	44.4	47.9	42.9
WT of Tin (g)	10.4	10.2	10.1	10.3	10.0	10.4	10.0	9.9	16.4	9.8
WT of dry soil (g)	21.7	21.3	17.9	23.2	23.7	25.8	32.3	34.5	31.4	33.1
WT of Water (g)	0.9	1.1	1.5	1.9	2.9	3.3	5.9	5.3	6.1	6.5
Moisture content (%)	4.15	4.69	8.38	8.19	12.24	12.79	18.27	15.36	19.43	19.64

Mean moisture content (%)	4.42	8.30	12.52	16.82	19.54
Dry Density (mg/m^3)	1.53	1.81	2.0	1.88	1.72

DISCUSSION

The liquid and plastic limits were used to obtain the plasticity index which is a measure of the plasticity of the soils Onwemesi (1990). A plasticity chart was plotted. From the plasticity chart (table 1), all the soil samples from the various gully sites have their plots clustered within the low plastic range (Figure 3), hence they are cohensionless. The values of the plastic index obtained ranged from 1.2% to 5.2% which is very low. Therefore the noncohesive or the friable nature of the soils in the area account for the gully erosion problems because water flows through the soil with ease and move the soil particles down slope with increase in velocity of motion of the water.

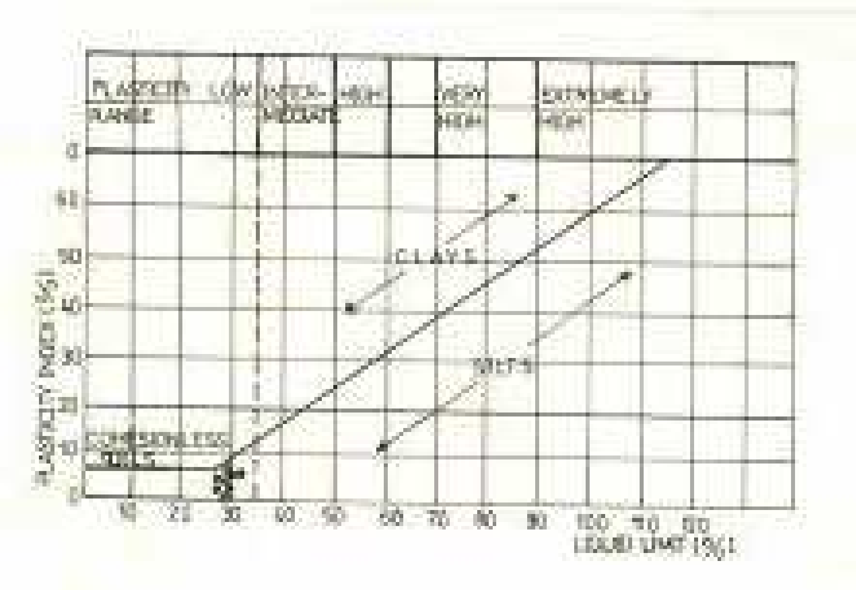

Figure 3: Plot of Atterberg limits of soil samples on the plasticity chart.

Sieve or particle size analysis involves the division of rock samples by sieving into sized fractions. The result can be used to distinguish between sediments of different environments and to classify soils.

Cumulative curves of the various soils from gully sites were plotted. From the curves the graphic mean was calculated using the relation:

$$\text{Mean} = \frac{\emptyset 16 + \emptyset 50 + \emptyset 84}{3}$$

The graphic mean is used to calculate the average diameter of the grain interpreted using Wentworth scale (1922) for sand. The values of the parameters in the relation above were traced from the curves as summarized in table 4 above. A typical curve is shown in Figure 4.

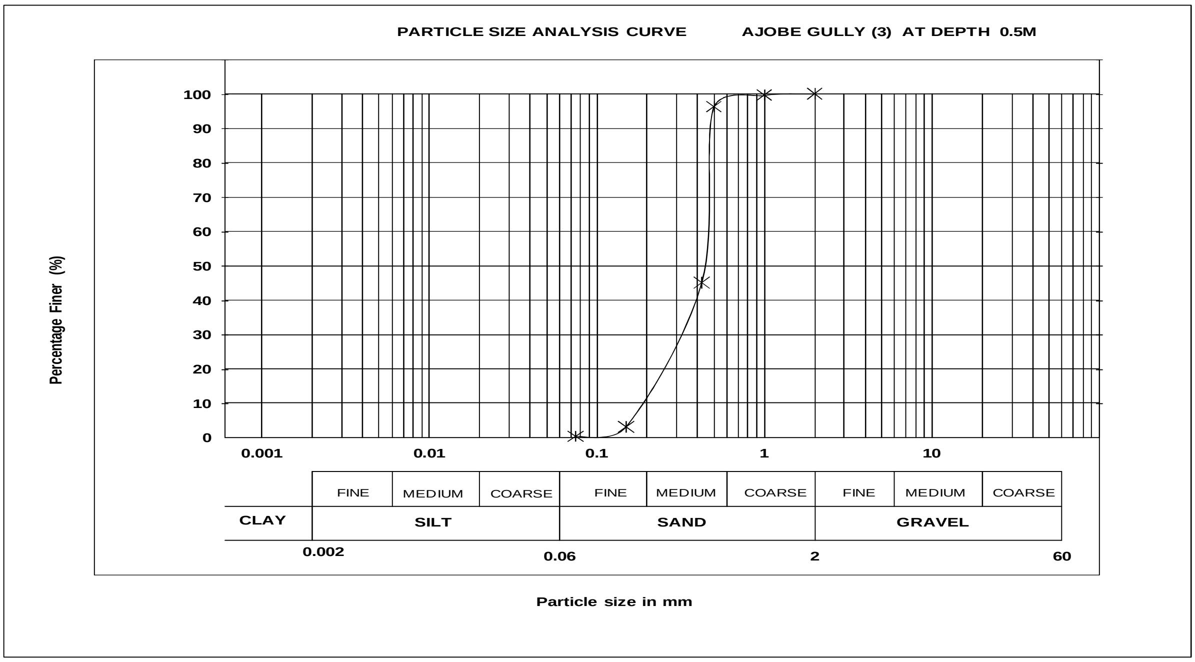

Figure 4: A typical sieve analysis curve for Ankpa

The result of the sieve analysis shows a grain size distribution ranging from medium to coarse with strongly unimodal curves. The absence of “fines” or silt/clay content indicates that the soils are non-plastic. These areas correspond with outcropping locations of the aquiferous Ajali sandstone characterized by good transmissivity (T) and conductivity (K) values. Such severe gully erosion menace also occurs in Nanka sands and the sandy members of the Ameki formation in Anambra State where the soil units with similar hydrogeotechnical properties exist, Egboka (1993).

COMPACTION TEST:

Compaction test shows the maximum dry density (MMD) and the optimum moisture content (OMC) of the soil. Due to seasonal changes, it is difficult to assign a standard value for the maximum dry density and the optimum moisture content for a particular soil. This value in the dry season differs from that in the rainy season. One of the major reasons for carrying out compaction test on soil is to increase the soil strength and to prevent seepage of water through the soil. Hence both soil water content and the bulk density (dry density) affect soil strength, which will increase when the soil is compacted to a higher density and when the soil looses water, dries and hardens.

Though compaction test indicates the maximum dry density to which the soil may be compacted by a given force and it indicates when the soil is either drier or wetter than its optimum moisture content while compaction will be more difficult. Brady and Weil, (1999) The porosity and water content of a rock also governs its comprehensive strength which decreases with an increase in porosity, since the water present in the rock will reduce the magnitude of internal friction of the rock, consequently decreasing its strength; the moisture content reduces the soil strength, Garg (2003).

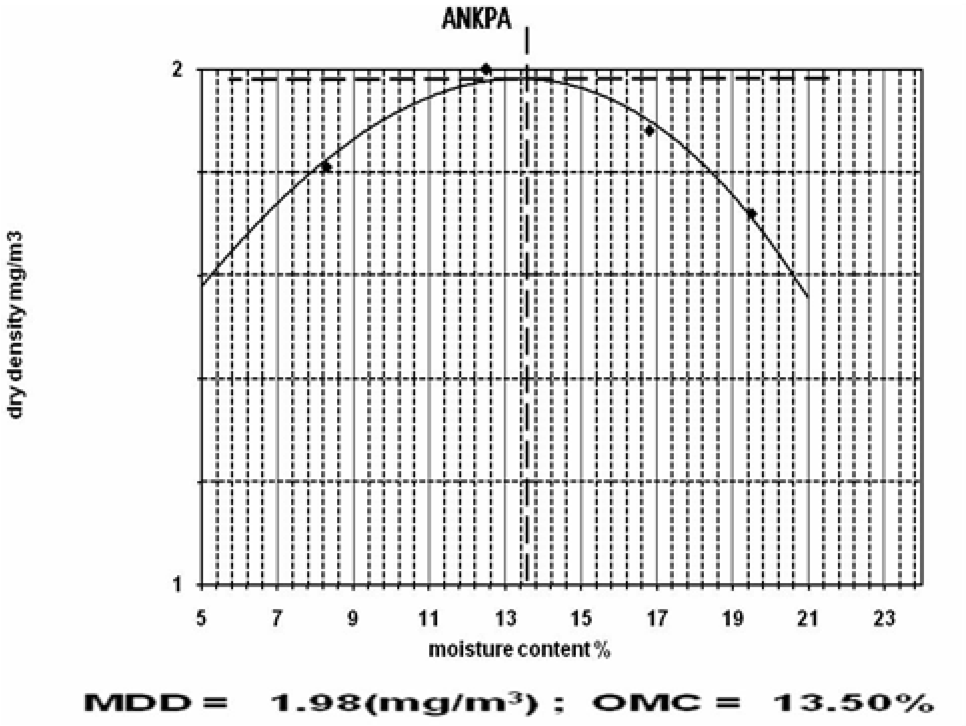

Figure 5: Dry density versus moisture content curve

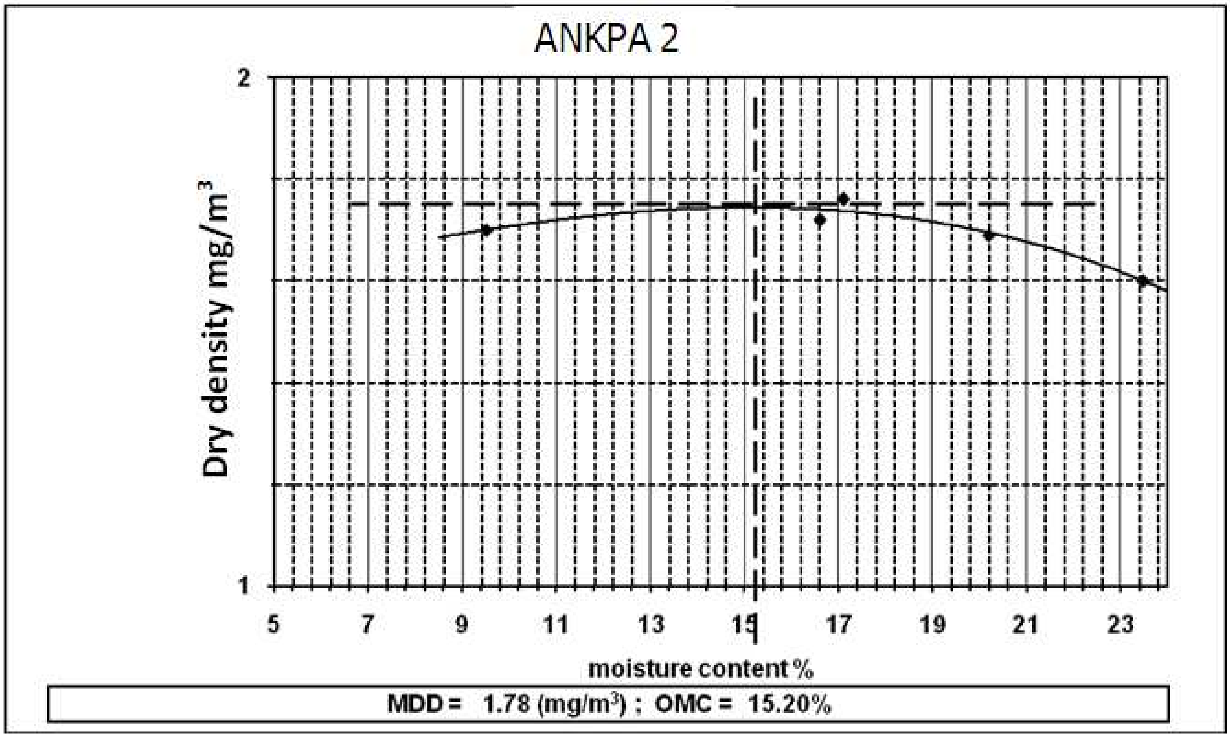

Figure 6: Dry density versus Moisture curve

The compaction test in table 6 shows that the optimum moisture content ranges from 12.5% to 17.7% while the maximum dry density values are generally low signifying that the soil is not compacted but loose(Figures 5 & 6).

ENVIRONMENTAL IMPACT ASSESSMENT FOR GULLY EROSION IN ANKPA METROPOLIS AND ENVIRONS:

Part of the purpose of an environmental impact assessment is to minimize the adverse effects of man upon the environment. However, it is very difficult for the non-specialist to know whether a particular phenomenon is part of the natural system or whether it has been generated by human activity. Only a proper scientific investigation can reveal the integrated relationships that exist between the various components of an environmental system. Once the natural system has been defined in this way, the interface with man's activities can be established.

To some extent, environmental impact assessment also incorporates the notion of risk assessment: for instance what is the risk of [A] happening if we allow the construction of project [B]? The whole subject of risk is a difficult one, although a risk may be measured, it is not necessarily the case that an avoidance of action will follow. People appear to be more prepared to cope with having to mop up after the damage is done than to take steps to avoid or lessen the risk. There appears to be a psychological gap between being aware of a hazard and doing something about it. Few people, apparently, are prepared to move their homes away from a location threatened by a natural hazard.

Impact assessment also provides estimate of expected changes in demographics, housing public services, and even the aesthetic quality of the community that will result from the development. The assessment also provides an opportunity for diverse community values to be integrated into the decision-making process. Together; these components of the assessment provide a foundation on which decisions about whether to alter or change a proposed development can be made.

The observations and the results of the compaction, plasticity, sieve analysis and grain size distribution tests reported here on Ankpa metropolis and environs indicate an area devastated by severe gully erosion. In order to reduce/minimize the menace of this erosion, urgent remedies are necessary.

REMEDIES

The menace of gully erosion in Ankpa metropolis and environs has called for urgent remedies in order to arrest further loss of arable land, buildings and other properties, transportation and communication links.

The use of chemical stabilizers such as lignosulfornate is a very effective technique to improve the erosion resistance of the soil. According to Indraratna (2008) lignosulfonate is known to increase the critical shear strength which decreases the coefficient of soil erosion as a power function of the critical shear strength. An application of the right quantity of chemical stabilizers at 95% compaction will reduce the coefficient of soil erosion and critically increase the shear strength. The use of chemical stabilizers can also take care of erosion through internal crack leading to piping. The long term weapon in controlling gully erosion is vegetation but structures may be required to stabilize a gully head or to promote siltation and vegetative growth in the gully floor. A good reason for this is that while structures may be subjected to decay and become less effective over time, vegetation can multiply and thrive and improve over the years.

For a long term success of gully stabilization, a good vegetative cover has to be established on the gully floor. This will prevent further gullying and allows the gully floor to gradually silt up reducing the fall over the gully head. Using wire netting, logs or concrete a series of small weirs can be constructed to trap sediment as well as encourage vegetative growth.

Alternatively, vegetative weirs can be established by planting species with erect growth forms such as vetiver grass and lomandra, Cavey (2006).

CONCLUSION

The results obtained in this investigation so far; (Atterberg, sieve and compaction test) show that the soils in the study area are cohensionless, not compact, and non-plastic, hence the menace of gully erosion has a geopedologic and hydrologic impacts. A highly exaggerated emphasis and predominance on engineering control measures involving construction of check-dams, bulldozing of earth materials, backfilling with soils and compacting, or construction of drainage or cut-off flood channels do not seem to be successful in checking gully incipient and extension or expansion. Rather the use of an integrated agronomic and engineering practices that will protect the soil and reduce run-off is required. This will involve afforestation and tillage practices that lead to the use of agroforestry practices which are based upon the development of the interface between the agricultural and forestry use of land.

In agroforestry, one is concerned with the place of trees in the landscape. This includes:

a) Alley cropping system
b) Use of multi-purpose and ornamental trees and shrubs;
c) The use of vetiver and bahamas grasses and lomandra.

All these are necessary to reduce the impact or the force of heavy raindrop.

Erodibility potential maps need to be prepared, using geological and geotechnical properties of the soil zones. Areas with high potentials for gully erosion hazards should be delineated for closer monitoring on regular basis.

RECOMMENDATIONS

a) Since this gully-control work is aimed at assessing and impacting development progress of systems and technologies that are both suited to local conditions and adaptable at the grassroot level, it is therefore suggested that maintaining good groundcover and planting of agroforestry nurseries containing more of erosion control species in the various locality areas of Ankpa metropolis and environs be developed. The nursery should contain not less than 50,000 – 100,000 seedlings or cuttings of each erosion control species for distribution to rural areas for planting.

b) Data indicate that anything under 70% of groundcover affects runoff and soil loss.
The percentage of groundcover affects the frequency and amount of soil loss, and major rain fall accounts for most of the runoff. These factors underline the necessity to keep groundcover in place at critical times of the year if possible.

A suitable cover of 30% is required on cultivated areas to have erosion rates which can be compared to the erosion rates from 10% stubble cover obtained after burning.

c) Tree planting campaigns should be intensified and there should be legislation/laws for aforestation and against deforestation. Enlightenment and consciousness in erosion control should include land use habits of the people in their agricultural practices and care vegetation.

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