Applied Ecology and Environmental Sciences, 2015, Vol. 3, No. 2, 60-65
Available online at http://pubs.sciepub.com/aees/3/2/5

DOI:10.12691/aees-3-2-5

The Mechanics of Civil –Works Induced Gully Erosion: Applications to Development of Preventive Measures in South Eastern Nigeria

Godwin I. Nwankwor[3], Ubong P. Udoka[1,*], Boniface C. Egboka[2], Alex I. Opara[3]

[1]Alo-Terra Development Initiavtive, 19 Stadium Lane, Owerri, Imo State
[2]Department of Geological Science, Nnamdi Azikiwe University, Awka, Nigeria
[3]Department of Geology, Federal University of Technology, PMB 1526 Owerri, Imo State, Nigeria
*Corresponding author: ubongp.udoka@gmail.com

Received March 03, 2015; Revised April 12, 2015; Accepted April 24, 2015

Abstract Evidence from a comparative analysis of shear strength of surficial sediments and shear stress of runoff for various flow depths and natural slopes in parts of South- Eastern Nigeria indicate that these sediments are really not as highly erodible as it is presently believed. The shear strength of top soils range from 5 to 60kN/m^2, and are higher than shear stress of runoff which ranges from 0.07 kN/m^2 to 14 kN/m^2 for flow depths of up to 5cm and slope angles of about 20^0 both of which rarely occur in nature. Soil erosion should not constitute a major problem in this region. The problem of soil erosion in our environment is primarily due to the reckless removal of top soil and activities that tend to concentrate runoff. It is thus necessarily due to high erodibleness of soils, but rather as a result of our unwillingness to help these soils sustain our development. It is shown that implementation of simple and cost effective designs in our roads layout, and other related civil engineering works can considerably reduce soil erosion problems in the area. The efficacy of the technique to curb the incidence of erosion is examined within the context of hydrological and runoff- water routing functions of the design components. Implementation of these techniques will not only minimize environmental hazards and keep erosion in near total check, but will also add an aesthetic component to our environment.

Keywords: *mapping, erosion control, risk, flood, gully erosion control, Imo state, road construction, land use land cover mapping*

Cite This Article: Godwin I. Nwankwor, Ubong P. Udoka, Boniface C. Egboka, and Alex I. Opara, "The Mechanics of Civil –Works Induced Gully Erosion: Applications to Development of Preventive Measures in South Eastern Nigeria." *Applied Ecology and Environmental Sciences*, vol. 3, no. 2 (2015): 60-65. doi: 10.12691/aees-3-2-5.

1. Introduction

Gully Erosion is a notable occurring environmental hazard in the eastern part of Nigeria. It is the most obvious evidences of crustal instability in the country particularly in the sedimentary formations of the interior basins. Some of these gullies (e.g. Amucha, Okwudor, Umuagor, Urualla, Isu Njaba etc) have depths varying from 22m to 150m, widths between 0.4m and 5.6km and lengths between 0.7 and 2.5km most of them lie along a linear zone of weakness and have become tourist attraction (Onu and Opara, 2012). The very great depths of these gullies and the failure of almost all control measures strongly suggest that they may result from interplay of exogenic and endogenic forces. In Imo State alone, there are at least 401 identified erosion locations in more 27 local government areas of the state. This distribution includes communities such as Umushievula Avuvu, Ikeduru local council area to parts of Ngor Okpala, Ehime Mbano, Ihitte Uboma, Mbaitoli, Njaba, Aboh Mbaise, Owerri North, Owerri West, Owerri Municipal, Onuimo, Isiala Mbano, Ideato North and South local council areas (Nkwopara, 2012). This occurs under diverse geologic, climatic and soil conditions from one part of the country to another depending on the initiating factors and development conditions. (Onwueme and Asiabaka, 1992; Idah *et al.*,2008; Onu, 2011). According to Igwe (1999), a lot of environmental factors such as geomorphology, geology, vegetation, rainfall which occur in an aggressive pattern have been proven by some researchers to account for the erosion problems in the eastern part of Nigeria. This has resulted to a loss of arable land which are assets for agriculture. Much more, issues arising from erosion expand to loss of lifes, habitation, separation of communities from developmental activities, etc.

Over the years, a considerable amount of research work has been done to address the soil erosion problems in the South- Eastern sub region of Nigeria. Kinnel, (2013) described the erosion processes and factors such as erodibleness and rainfall erosivity which are strong causative force to erosion. He also accounted for the effect of runoff on erosivity with soil particles travelling at varying velocities. He also provided a relationship between these variation and soil erodibility values. Egboka and Nwankwor, (1985) invoked the concept of groundwater hydraulic gradient to explain the gullying process in Amucha/ Okwudor and some related areas.

A comprehensive summary of the geotechnical properties of soil, rainfall characteristics as well as erosion phenomenon has been documented by Niger Techno Limited (1975). In almost all cases, the results of these studies have described the surficial sediments and soils as highly erodible. On this premise, the problem of soil erosion in the sub region has virtually been accepted as an inevitable phenomenon.

It has to be recalled that the issue of accelerated soil and gully erosion in the South Eastern Nigeria became very severe from the 1970's in the wake of widespread uncontrolled civil engineering works and urbanization that followed the oil boom period. In the process, the natural soil cover and vegetation were stripped off recklessly; runoff was concentrated and improperly channeled. It is thus considered that a relationship exists between this sudden change in land use and the phenomenal increase in incidence of soil erosion, aware that these soils have sustained the traditional land use practices of our several past generations. We do not have any reasons to believe that soils and rainfall characteristics in South Eastern Nigeria have dramatically changed over the years or that they are drastically different from those of other tropical regions.

If our soils, surficial sediments and rainfall characteristics are drastically different from those of other tropical regions, then their strength, textural properties and erosive power must be unique; and their strength (a measure of resistance to the erosive power of the runoff), in particular, should be expected to be much less than or at best comparable with the shear stress (the erosive power) of runoff generated by the "unique" rainfall. This investigation considers the strength of soils and surficial sediments of parts of South Eastern Nigeria in the context of their textural and shear strength properties as well as the shear stress of runoff. It is shown that the incidence of severe gully erosion lies in our willingness to help these soils sustain our development rather than in an inherent fragileness and ease of erodibleness. Simple and cost effective technique of land use practices particularly in our road construction works are presented as a means of considerably reducing soil erosion problems. The hydrologic and runoff- water routing functions of these techniques are discussed.

2. Methodology

Apart from the documented data of the textural and shear strength properties of surficial sediments and soils from Niger Techno Limited (1975), Igbokwe et al (2003), and Egboka (2004. The This study in particular was carried out across most soils and gully erosion sites in South- Eastern Nigeria, as presented in Figure 1. The samples were collected from each of the three soils horizons at each location. These horizons consists of Top Soil (TS), Red Earth (RE), and the Unweathered Parent Geological Materials (FS) as illustrated for typical gully profile (Figure 2.) The shear strength of the top soil (root zone) ranges from 5Kn/m^2 to 60 Kn/m^2 ; the silty clay (fines) percentage varies from 0.90% to 70%. The shear strength of the red earth, horizon (RE), ranges from 6 Kn/m^2 to 27 Kn/m^{2,} with the fines varying from 0.60% to 5.0%. The bottom parent materials(FS) have a shear strength values ranging from 2.0 Kn/m^2 to 3.5 Kn/m^2 while the percentage fines vary from 0.1% to 0.3%.

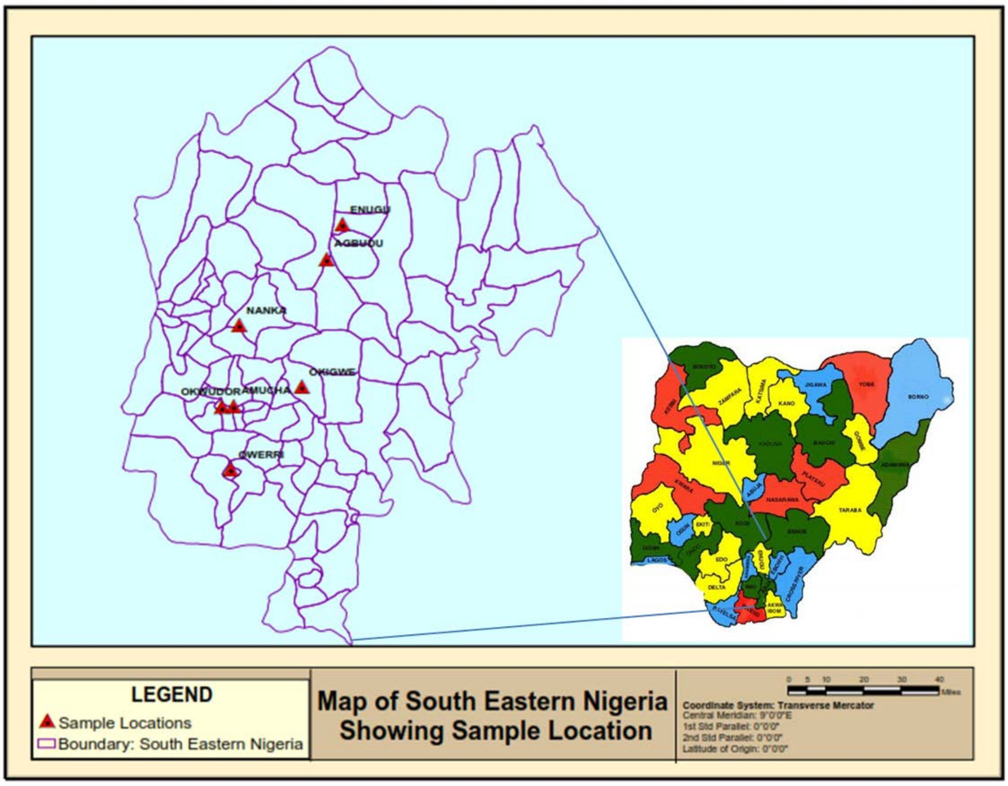

Figure 1. Map of South Eastern Nigeria Showing Sampling Location

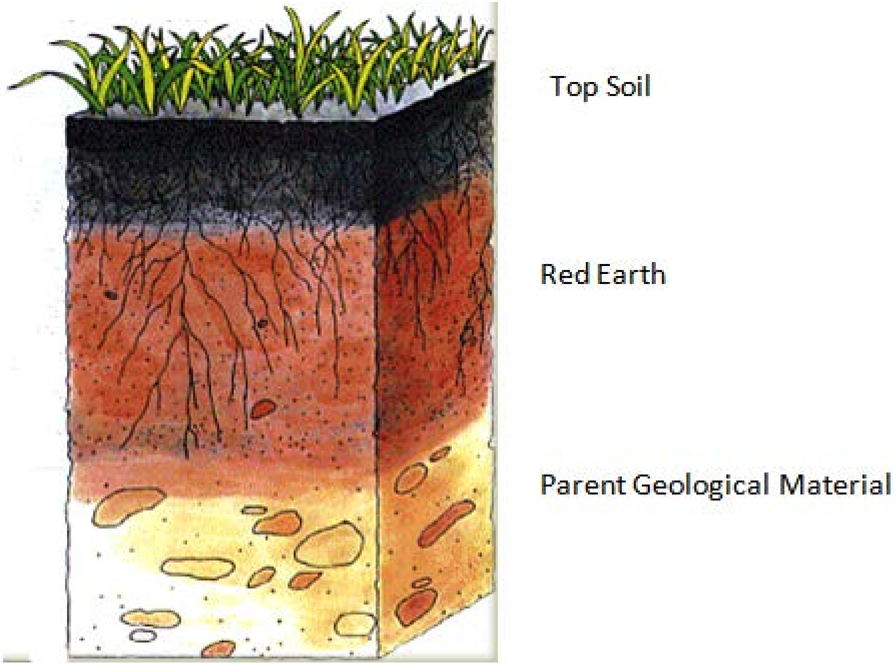

Figure 2. A generalized Profile of Gully Face Showing the Three Major Horizons- Top Soil, Red Earth and Unweathered Parent Geological Material

2.1. Shear Stress of Runoff

The shear stress of runoff (F) was estimated analytically from the relationship (Ritter, 1978),

$$F = \lg \frac{d}{12} \sin \phi \qquad (1)$$

Where *d* is the runoff depth, Θ is the slope of ground surface, l is the water density and g is the gravitational acceleration.

Figure 3 shows how runoff shear stress varies with flow depth for selected ground slope angles. It shows that shear stress increases tremendously for a moderate increase in slope angle.

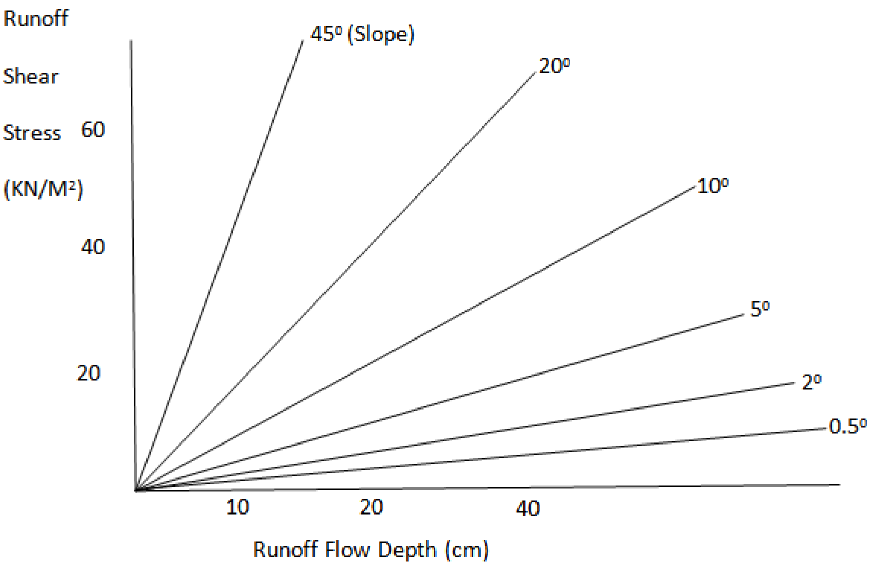

Figure 3. Plot of Runoff Shear Stress Flow Depth for Various Slope Angles of Ground Surface

2.2. Shear Strength/Stress

Soil and Gully erosion would be expected to occur when the shear stress of runoff exceeds the soil shear strength. A study of Table 1 and Figure 3 shows that the shear strength of top soils is higher than the shear stress of runoff for normal ground surface slope angles of less than 5^0, and few depth that occurs naturally(much less than 10cm). The red earth (RE) and, in particular, the bottom parent material (FS) have a shear strength values that are less than or marginally comparable to runoff shear stress, more so when flow is not concentrated.

It is thus clear that once the top soil is removed and/ or runoff is concentrated (i.e increase in flow depth), erosion is inevitable. One obvious way by which the top soil is removed and run off is concentrated is through recklessly executed road construction and civil engineering works, and to a very much less degree by traditional or even sophisticated farming practices, suggesting that civil works rather than farming practices are responsible for out our erosion problems. This is consistent with results of survey conducted by the Erosion Research Center at Federal University of Technology, Owerri on causative factors of the accelerated soil erosion problems. The survey showed that about 75% of gullies in the sub region is initiated and/or linked to road construction works.

Table 1. Some Textural Properties of Soil and Surficial Sediments From Parts of South-Eastern Nigeria (TS= Top Soil, RE= Red Earth, FS= Unaltered Parent Geologic Material). (Source: Techno Nigeria Limited Report)

Location	No. of Samples	Horizon	% Fines (Clay + Silt)	Shear Strength (KN//M^2)
Okwudor	3	TS	0.9 - 1.4	15 - 16.2
		RE	0.9 – 1.6	10.1 – 9.8
		FS	0.2 – 0.3	3.0 – 3.5
Amucha	4	TS	1.0 – 1.2	23.0 – 24.5
		RE	0.6 – 1.0	18.5 – 20.2
		FS	0.1 – 0.2	2.1 – 3.0
Owerri	3	TS	0.9 – 1.3	5.0 – 6.0
		RE	1.2 – 1.5	6.0 – 6.5
		FS	1.1 – 1.0	6.2 – 6.3
Okigwe	3	TS	4.7 – 5.0	26.0 – 25.2
		RE	1.8 – 1.9	24.0 – 26.5
		FS	0.1 – 0.2	2.0 – 3.1
Agulu/Nanka	6	TS	1.9 – 2.0	24.6 – 25.2
		RE	0.6 – 0.8	18.1 – 19.5
		FS	0.2 – 0.3	2.30 – 3.3
Enugu	1	TS	70	60.0
		FS	60.2	54.0

Having identified what we and other workers strongly believe to be the maor cause of the accelerated soil/gully erosion, there is need therefore to examine this factor in greater detail. The examination offers a means of assessing the status of our road construction methods.

3. Results

A cursory survey of our roads layout easily reveals myriads of patterns, designs and constructional habits. These patterns and habits have one common denominator- they are “nurseries” for gully erosion problems.

Figure 4 shows I cross sections, the existing roads layout habits. The sections are specific for rural roads, highways and do not include urban (intra-city) roads and streets. The roads can be grouped into two: The conventional tarred highways, and the rural earth roads popularized by the Directorate for Roads and Rural Infrastructure (DFRRI). Figure 4(a) is a tarred road, appropriately cambered (I,e. slightly convex upwards) and provided with side drains. However, the shoulder is covered sparsely with stones chippings or gravel. In Figure 4(c), the road shoulder is “painted” with tar (very light tarring). As runoff concentrates over the tarred portions, it flows over the unprotected or minimally protected shoulder. Under increased shear stress of runoff, the stone chippings tumble over and become gradually rolled down towards the drain, rills develop and the shoulder fails giving rise to mini gullies which then coalesce and eat their way into the road proper under the ever increasing runoff concentration and exposure of weaker horizons (see Table 1). In some cases, the drain may become silted creating even more serious problems.

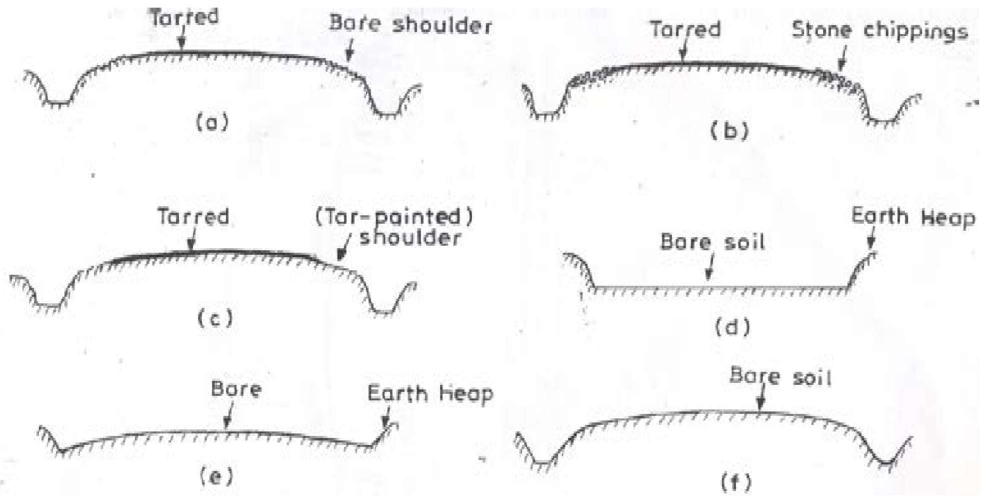

Figure 4. Vertical Cross Sections of Some Existing Roads; (a) – (c) : Tarred Roads (Highways); (d) – (f) Earth (Rural) Roads – Schematic

Figure 4(d) to Figure 4(f) are typical rural DFRRI earth roads. Figure 4(d) is simply a “drain”, it is a stream flowing over and through a losse sandy channel. Like a stream that it is, it easily erodes the ‘bottom and bank” valley (roads) which invariably is the red earth, a low shear resistance material. Rills and potholes develop coalesce and propagate across the road into the nearby grounds generating gullies in its wake under the pounding action of high runoff concentrations. Figure 4 (e) is cambered but really has no drains. It is usually not compacted. Rills develop very quickly on such roads as runoff flows over the bare soil(not natural top soil) an uncompacted red earth hauled from a nearby borrow pit. In all the above cases, the concentrated runoff exerts shear stress magnitude that exceeds the shear resistance of the (usually) weak red earth road materials. Gully erosion thus becomes an inevitable consequence.

3.1. Runoff Channelling and Diversion

Most gullies in the South Eastern Nigeria can be traced back to poor termination and unplanned diversions of road runoff concentration. Runoff concentration over the tarred portions of a road or over the entire road, if bare, is propagated into the drains resulting in even greater runoff (water) depth. The prevalent unplanned diversion and termination of drains often into abandoned borrow pit only ensures that the high erosive force of concentrated runoff initiative gullies further downslope of the road. It would be strange and unnatural if that does not happen. Even where the drains are abruptly terminated on natural top soils (of a shear strength indicated in Table 1), or in stabilized stream valleys, the high runoff shear stress and turbulence effect would be combine to cause gully devastation.

In addition to improper channeling of runoff and other errors apparent from Figure 4, some other very common flaws in our roads construction habits include poor shoulder protection and lack of poor drainage facility, use of poor quality soil material, clear lack of transparency in the execution and lack of commitment and dedication. Others are wrong timing of road project implementation (with regard to the seasons), lack of consideration for topography and most important lack of maintenance.

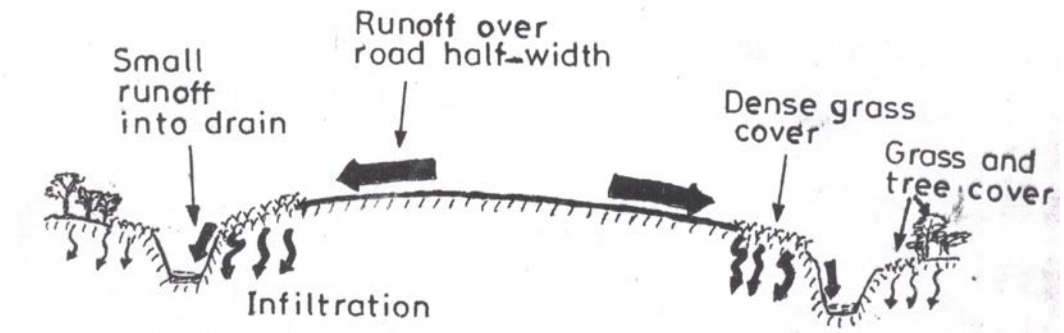

Figure 5. A Schematic Vertical Cross-Section of Model Roads; Reduction of Runoff Concentration Through Infiltration Over a Densely Grassed Shoulder is Illustrated

3.2. Conceptual Model Road: Design Aspects

Roads have of necessity to be built. A functional design for such roads is not only necessary but imperative. Such designs must be fulfill the criteria that runoff concentration and bare surfaces be minimized.

A conceptual model road which is applicable to both tarred and earth roads, the shoulders are densely grassed. This reduces the amount of runoff reaching the drains through interception, temporary detention and induced infiltration of runoff. The reduced runoff into the drains makes the net runoff volume less destructive and easier to manage during the eventual flood water termination and diversion stage. The diversion scheme is to plan and sequentialised along the road length. The dense grass cover protects the bare soil, creating a natural top soil condition whose shear strength can withstand the runoff shear stress. A grass cover would be expected to perform better than stone chippings since the latter is not toppled over down into the drains. A well maintained grass belt on both sides of our roads would provide an invaluable aesthetics component to the environment. The design is cheaper and more cost effective than wholesome engineering works often associated with the handling of larger volume of runoff.

The model also emphasizes the fact that roads should be cambered, and at a slightly higher elevation than the drains and immediate surroundings. The drains could be made of concrete or preferable some porous but stable material. Furthermore, the ground beyond the drains should be grassed and vegetated in such a manner that it merges into the more distant areas hitherto undisturbed during the road construction.

In order to perform the function of runoff volume reduction, the grassed shoulder width should relate in some way to the half width of the road itself. Too narrow a grass belt will be obviously not be effective, while it is uneconomical to have an unnecessarily too wide a grassed shoulder- width ratio that is appropriate for the local conditions of rainfall, topography and soil infiltration characteristic is needed in order to achieve optimum performance.

This envisaged road construction layout is simply to achieve a basic objective- restoration of the environment to pre- construction condition. This is very pertinent for erosion control. A survey of our road network shows that rills and gullies are virtually non-existent along and in the vicinity of road segment whose shoulder are, by the accident of nature, properly grass covered. This lesson we out to learn.

4. Conclusion

The soils and surficial sediments of Southern Eastern Nigeria are not easily erodible as is hitherto believed. Gullies are initiated primarily on road shoulders and surrounding area due to runoff concentration and improper diversion/termination of drains.

To minimize runoff concentration, roads shoulder and ground near the drains should be densely grassed. Fast growing grass species must be identified and planted timely to ensure stabilization before the middle of rainy season.

Roads should be raised above the general ground level. Earth roads, in particular must be campered, compacted and should be at least 30cm higher than the normal ground level.

At specific interval, determined by topography, water detention pits should be dug. If the shoulders are properly grassed, siltation and runoff inflow rates into the sump will be appreciably reduce. The pits can then be operationally effective for a much longer time.

Maintenance of roads and drains must be placed on giant engineering structures for soil erosion control. Where they must be erected, adequate steps should be taken to ensure that they are on a continuing basis, protected and maintained. Since these structures invariably concentrate runoff water, their failure always result in more serious damage than if there had been no such mechanical structures at all.

Wherever the environment is disturbed as though road construction, and other engineering works, the area must be rehabilitated and returned to the pre construction condition by planting grass and trees. This ensures a restoration of the more resilient top soil condition, and thus prevents development of rills and gullies. The model presented earlier aims at achieving this fundamental objective.

References

[1] Asiabaka, C.C. and Nwankwor, 1993: An Assessment of the Status of Wetlands in Humid Tropical Rainfall Belt of South-Eastern Nigeria: Socio- Economic Impact Analysis Technical Report.

[2] Egboka, B.C. and G.I. Nwankwor, 1985: The Hydro geological and Geotechnical Parameters as Agents for Gully Erosion in the Rainforest Belt of Nigeria. J. African Earth Science. Vol. 3(4), Pp. 417-425

[3] Floyd, B. 1965: Soil Erosion and Deterioration in Eastern Nigeria. Geography Journal. Vol. 117, Pp. 291-306

[4] Ibe, K.K. 1993: Siltation of Springs in Abia State. Abstract. Proceedings Nigeria Mining and Geosciences Society Conference. Jos

[5] Idah, P.A., Mustapha, H.I., Musa, J.J., Dike, J (2008). Determination of Erodibility Indices of Soils in Owerri West Local Government Area of Imo State, Nigeria. AU. J.T 12 (2) 130 – 133

[6] Igbokwe et al (2003, Egboka (2004). Distribution of Gully Sites in Southeastern Nigeria. Igbokwe J. (2004). “Gully Erosion Mapping /Monitoring in parts of South

[7] Igwe, C. A. (1999). Land use and soil conservation strategies for potentially highly erodible soils of central-eastern Nigeria. Land Degradation Development [10], 425-434.

[8] Niger Techno Limited. 1975: Prefeasibility Study of Soil Erosion in East Central State of Nigeria. Technical Report. Federal Ministry of Agriculture and Field. Vol.XIV. No. 3. Pp 64-74

[9] Nkwopara,C., 2012; Threatened By Erosion: The Traumatic Experience of Imo Communities, Pp. 35, Vanguard Newspaper, Vanguard Media Limited

[10] Nwajide, C.S. and M.Hogue, 1979: Gullying Processes in South Eastern Nigeria. Nigerian Geography Journal. Vol.8, Pp.45 -59

[11] Ogbakagu, I.N. 1965: Soil Erosion in Northern Parts of Awka – Orly Uplands, Nigeria. Nigerian Journal of Mining and Geosciences. Vol. 13, Pp. 6-9.

[12] Onwueme, I.C and Asiabaka, C.C (1992) Erosion as an Interactive Force in the Human Environment. Erosion Research Centre, FUTO

[13] Onu, N. N and Opara, A. I.,2012. Analysis and Characterization of Njaba River Gully Erosion, Southeastern Nigeria: Deductions from Surface Geophysical Data;Australian Journal of Basic & Applied Sciences, Vol. 6 Issue 4, p122

[14] Ritter, D.F., 1978: Process Geomorphology. W.M.C. Brown Coy. Publisher, Lowa.