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EFFECTIVE WATERSHED MANAGEMENT FOR ENVIRONMENTAL HAZARD CONTROL/ MITIGATION IN NIGERIA

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Gully Erosion: Causes, Effects and Remediation in Nigeria

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Abstract

Gully erosion in Nigeria has been a major environmental degradation affecting people, their lands and infrastructure. The National Geohazards Monitoring Centre has carried out detailed and systematic studies of the incidence of gullying in several states of the country. The purpose of the studies is to enumerate the gullies in each studied state and systematically document the basic parameters of each investigated gully with aim to assembling all the data relevant to formulating combat strategy. The landmass of Nigeria is underlain by both crystalline basement rocks and Cretaceous-Tertiary sediments within the seven Nigerian sedimentary basins. Some of these basin-fills consist of unconsolidated formations that are highly erodible. Most of the gullies in Nigeria are concentrated in the Southeast. This is attributable to the fact that most of southeast is underlain by friable lithofacies of Ajali, Nsukka, Ameki, Nanka, Ogwashi/Asaba and Benin Formations and is transversed in some parts by cuestiform topography (Idah-Enugu-Okigwe-Arochukwu and Awka-Uyo). The erodibility of any underlying geologic unit depends so much on the competence of the rock materials.

Combat strategies should involve detailed enlightenment programs on proper land use practices, engineering designs and construction of civil works with due attention to environment.

Control and combat measures should involve the formulation and delivery of public enlightenment for all stakeholders on proper land use practices, these should include proper engineering designs and construction of civil works with adequate consideration to highly venerable environment.

1.0 Introduction

Gully erosion is a widespread geohazard in Nigeria and virtually no region, even areas underlain by crystalline basement rocks, is unscarred. In the south-eastern part of the country, soil and land loss is so intense that the area has been tagged the 'type place of gullying in western Africa'. The area is therefore a logical starting point for a systematic study of gullying and its impact.

Earlier studies of gully erosion by the Geological Survey of Nigeria and many other workers, especially pedologists and geomorphologists, documented it as a major geohazard in Nigeria especially south-eastern part, where it has devastated farmlands, uprooted homes, destroyed infrastructure, and silted up water sources. The consequences have been largely in terms of tremendous material losses and psychological trauma incidental on loss of ancestral homes and conversion of the victims to refugee status. The proneness of the soils of an area to gullying is attributed to their derivation from very poorly consolidated bedrocks which include the geological units comprising the lithic fills for instance, of the southern Benue Trough, the Anambra Basin, and the Niger Delta Basin. There has been an assumption that gullying has been restricted to the sedimentary terrains of the country but this been approved wrong by the occurrence of gullies in recently studied crystalline basement terrains ofKastina, Gombe, Kogi and Cross River States. Gullies may be less frequent in basement areas, perhaps due to the greater resistance of unweathered crystalline rocks to erosion. The underlying attribute is the erodibility of the substratum, in conjunction with such other factors as climate, topography, the effectiveness of the vegetal cover and the anthropic factor. It is obvious that battering rain storms usually generate very heavy and highly erosive floods which, on soils with scanty vegetal cover and even moderate slopes, initiate rills that progressively transform into gullies. Combat measures should include proper enlightenment programme on proper use of land practices, engineering designs and construction and civil works with due attention to environment of the erosion prone areas.

Fig. 1 Map of Nigeria showing States already mapped by NGMC Gully locations

Experiences from many field observation and analysis by the National Geohazards Monitoring Centre, Nigerian geological Survey Agency have applied updated methods to leverage on the effort of various workers on gullying during the last century. It is now more fully realised that gully is an upper part of river system or drainage that conduct water during and immediately after the rain. It is basin-based event triggered when environmental stability, specifically the substratal configuration, has been upset naturally or anthropomorphically, aided by torrential precipitation generating voluminous and highly erosive floods. This is the background for formulating a geomorphic model summing up gullying as mass movement-induced headward and flankwise recessions related to the base level.

1.1 Previous Studies

Stamp (1938) may be regarded as the earliest published discussion of soil erosion in Nigeria and, as indicated by Skyes (1940), combat action on gullying in southeastern Nigeria had been on since the 1930s. Complete studies were carried out by Grove (1951a) in the area of the present Enugu, Anambra and Imo States and published as Geological Survey of Nigeria Bulletin (No. 21). He recognized two main types of gully on the scarp slopes of the Udi plateau (*i.e.* the Enugu Cuesta) and the Awka-Orlu uplands (*i.e.* the northern parts of the Awka – Uyo Cuesta). From a review of several studies, FAO (1990) concluded that most of the gully erosion in Nigeria is caused by badly designed roads and the clearance of vegetation from building sites. The studies mapped out gullies and proffered combat measures, the application of which slowed the scourge, saving large areas of territory. Other studies, some of them of small specific areas or individual gullies, include those by Okezie (1964), Floyd (1965), Nwajide and Hoque (1979), Egboka and Nwankwor (1986), Uma and Onuoha (1988), Okogbue and Ezechi (1988), Nwajide (1992), Albert *et al.* (2006), Chuka and Akpokodje (2007), Igbokwe*et al.* (2008), Osadebe and Akpokodje (2008), Akpokodje*et al.* (2010), Igwe (2012), and Abdulfataie*t al.* (2014). Deserving of special mention is the publication by Hudece*t al.* (2006) following a study of gullying processes in Abia, Anambra, Enugu and Imo States, funded by International Development Research Centre (IDRC), Ottawa, Canada, and carried out from 1992 to 2000. The project goal was to reduce gully erosion in southeastern Nigeria by explaining the widespread occurrence of gullies in the area, and to design a strategy for the prevention and control of gullying.

2.0 Definition/classification

Erosion, generally, is the wearing away of earth materials (soil and rock), commonly through the abrasive action of fluids. In the contest of the Nigerian environment where there erosive action of wind and glacier is negligible or absent, water is the sole erosive agent (Fig.1). With water as the focus of physiographic phenomena, the study of its effects provides a strong link between an understanding of physical and socio-cultural environments. The hydrologic cycle is one of the great systems of the Earth and a natural manifestation of great ubiquity which follows water in its myriad paths. Man attempts to alter the cycle by building dams, reservoirs, canals, and the use of water in farming, and power supplies.

The commonest classification of erosion is the one based on form – the type derived from the impingement of exogenic fluid agents, especially water and wind, on the soil surface. There is also the subsurface kind of erosion which occurs when flowing groundwater dissolves out leachable components of the rock and accumulates them on the underlying impermeable layer. This process results in tunnels which reduce the stability of the overburden. Collapse of tunnel roofs produces deep gullies, especially in karst areas. Several factors determine the class of erosion that prevails in a given terrain since overlaps are common and there are really no distinctive zone boundaries. Gullying, for instance, which commonly progresses by headward recession, can extend through the rill zone, across the sheet zone into the splash zone, and has been observed in the parts of Nigeria, especially southeast area, to develop within the sheet zone without passing the rill stage.

2.1 Classes of erosion

2.1.1 Rain splash: The simplest form of erosion occurs when raindrops hit the soil surface (Fig. 2). It has been demonstrated that a normal raindrop hits the ground with an impact up to 14 times its weight (Donahue, 1963) and this is why rain splash erosion can effect nearly 90% of the erosion on bare slopes (Ellison, 1948).

2.1.2 Sheet erosion: is the process of levelling off, or more or less uniformly removing, thin (mm – thick) layers of soil surface material from a flat to gently sloping ground surface by broad continuous sheets of runoff. It is essentially an overland flow phenomenon (Fig. 3a) and for it to commence during a rainstorm event, the infiltration capacity of the soil has to be exceeded, and soil moisture storage and any depressions have to be filled.

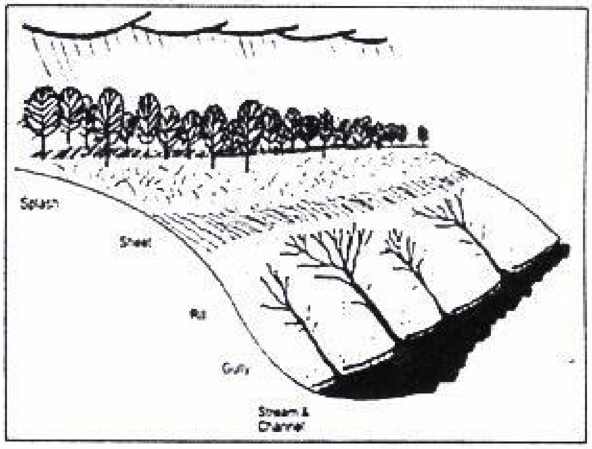

Fig. 2. A model idealizing the different classes of erosion

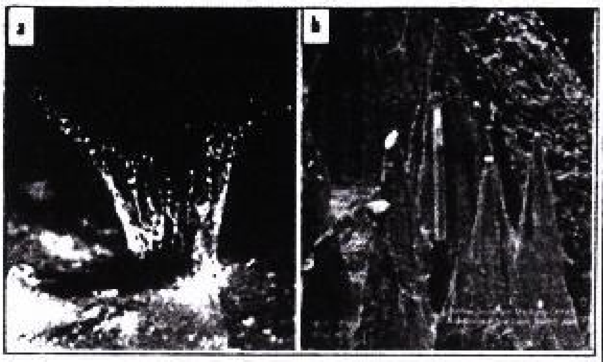

Fig.2. (a) Dispersal of soil particles by a single rain drop (b) Earth pillars resulting from raindrops reducing unprotected areas from the original level (here up to 12 cm)

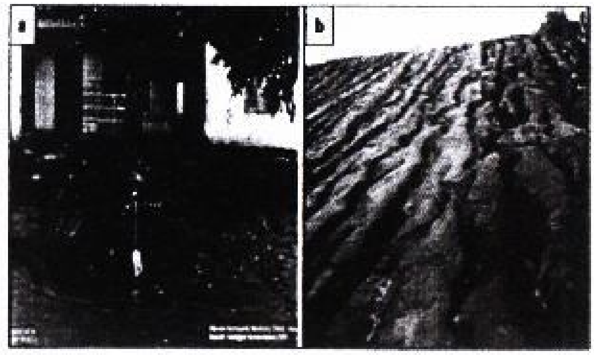

Fig. 3(a) Housing foundation and normally buried tree roots exposed by sheet erosion, (b)Rills formed by concentrated flow lines on a gentle slope.

2.1.3 Rill erosion: like sheet flow, is dependent on overland flow, and their hydraulic characteristics are similar. It is the scouring out of narrow, shallow (mm to cm) discontinuous channels due to the uneven removal of surface soil by running water concentrated in streamlets of sufficient discharge and velocity to imbue erosive force (e.g. Fig. 3b).

2.1.4 Gully Erosion: Gullying may be defined as the erosion of soil or soft rock material by running water that forms distinct, usually narrow channels wider and deeper than rills, and which usually carry water only during and immediately after heavy rains. Another way of looking at a gully is that it is any erosion channel so deep that it cannot be crossed by a wheeled vehicle or eliminated by ploughing (Fig 4). During rainless periods a gully remains as the dry upstream extension of fluvial channels, unless where deep enough to intersect the water table to form a spring. It is commonly believed that rills transform into gullies, but, as has been stated earlier, gully formation can be triggered on a hillslope if the conditions are complete, without passing through the rill stage. Indeed in some parts of the country especially the southeast Nigeria, gully formation commences from alocal base level, usually a river or flood channel. Concentrated overland flow, plunging down a steep slope or into a channel, scours the base, undermines the headwall collapse and causes headward retreat, producing a linear depression that gradually widens with mass movements.

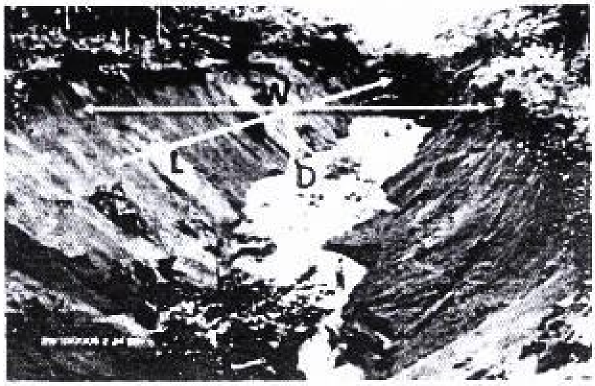

Fig.4. A section of a typical gully: L= length, W = width, D = depth

3.0 Classification of Gullies

An early classification of gullies of south-eastern Nigeria (Grove, 1951a) was into two - slope gullies and those due to groundwater emergence. Ezechi (1987) classified gullies in the same area into three – base level, scarp and incidental gullies. Overlaps are evident in these classifications. From field evidence, every gully in the project area has a head that is clearly a scarp and a mouth that opens up to a base level which is another, usually larger, gully or a drainage line that receives and conducts away the debris. Gully inception requires a trigger, natural or anthropic; in other words, a gully can be incidental on natural or artificial trigger.

Classification of gullies in subtropical areas, especially in northern Europe, is commonly into two - permanent and ephemeral (Poesen*et al*., 2011). The applicable definition of gullying there is that it is a process whereby runoff accumulates and often recurs in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths. Permanent gullies (also called classical gullies) would here be defined as those too deep to eliminate with farm tools and may be up to 30 metres deep. Ephemeral gullies are those carved by concentrated flow and are deeper than rills but less than permanent ones, and can be tilled over with farm tools, only to reform in the same location by subsequent runoff.

The National Geohazards Monitoring Centre (NGMC) while recognizing and respecting the criteria used by earlier studies, classifies gullies based additionally on activity, *i.e.* whether a given gully is still progressing (headward and laterally), or the gullying processes have ceased and the gulliable sides stabilised, whether permanently or metastably?

3.1 Gully Model

Several explanations and models by various authors allude gully erosion in the humid tropics is solely due to water hydraulics, *i.e.* concentrated runoff flow rate over and above a critical threshold force just sufficient to cause incision a concept proposed by Horton (1945, cited by Poesen*et al*., 2011) and the force is expressed in terms of boundary shear stress

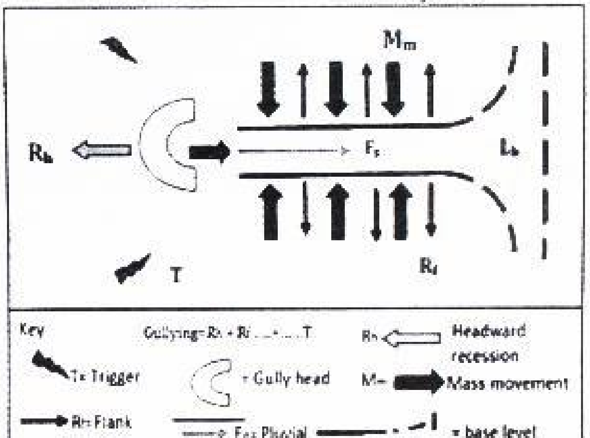

Fig. 5.A sketch modelling the gullying processes identified in southeastern Nigeria (after Nwajide, 2015, pers. com.)

3.2 Gully Erosion Facilitators (Triggers)

Some conditions or factors must be present for gully to occur. These factors are referred here as triggers, and they include: *Substratum* which includes bedrock, soil, topography and drainage. The other factors are *climate, vegetation* and *man's activities*. The common undesirable attributes of these factors precursor significant soil loss, have been summarized in Table.1. The present discussion recognises the separate contributions of the drainage characteristics as well as the reaction of the country rock (*i.e.* bedrock) whether outcropping or mantled by autochthonous soil when subjected to gullying forces.

In Nigerian southeast for instance, gullying is almost exclusive to four lithostratigraphic units – the Ajali, the Ameki-Nanka, the Ogwashi – Asaba and the Benin Formations. Their disposing characteristic is their overwhelmingly sandy composition coupled with their very low diagenetic state despite their ages that range in millions of years.

Table1. Gullying facilitating attributes of the study area

Factors		Gully-facilitating attributes	Effects
Substratum	Bedrock	Composed of largely friable sandstones	Markedly gulliable
	Soil	Lateritic zone with friability inherited from bedrock	Markedly gulliable
	Topography	Moderate to high-angle long, and generally convex-up slopes of cuestas	Encouraging voluminous erosive runoffs
	Drainage	Ephemeral and perennial	Incisive
Climate		Intense cloudbursts, disruptive raindrops, voluminous runoffs	Erosive
Vegetation		Roots disruptive of soil crumb structure	Weakens soil structure
Man		Reckless land use; unplanned civil construction	Man-induced land loss

Since every lithologic exposure is erodible, the susceptibility of a lithostratigraphic unit to yield to erosive forces resulting in removal of soil or bedrock to an extent that cannot be ploughed through even by farm machines should be referred to as ***gulliability***.

Another property though not to have featured prominently in the consideration of erodibility in general and gulliability in particular is texture, especially grain size of the bedrock. This property is commonly transmitted to, or inherited by, regolith, especially the lateritic soil horizon. Erodibility is generally enhanced by the granularity of the substratum. In effect, clay particles tend to cohere and resist erosion.

Gully processes could be said to obey two physical principles: (1) the second law of thermodynamics (Angrist and Hepler, 1967), which states that there is always a tendency in natural systems towards a spontaneous increase in the amount of entropy, and (2) Le Chatelier principle which holds that if a constraint is applied to a system in equilibrium, the system adjusts to a new equilibrium that tends to counteract the constraint. However, when applied to gullying phenomena, we realise that while entropy increase applies to gully heads (Fig.6a) equilibrium restoration operates at the mouth, *i.e.* around the base level where sidewall gradients have been substantially lowered, gully depth is minimum, and the slopes are levelling out(Fig.6b).

3.2.1 Topography: As erosion factor consists of slopes the relevant aspects of which are the angle, length and shape. In general, high-angle slopes generate more voluminous runoffs than gentler ones since the downslope aspect of the force acting on the water molecules increases with higher gradients. As shown by Holy (1980), erosion intensity is proportional to the square of the slope gradient. Longer slopes allow for more infiltration especially during low-intensity storms, thus achieving reduced soil loss. But, for higher-intensity storms, runoff increases progressively downslope and if flow is concentrated, gullying commences.

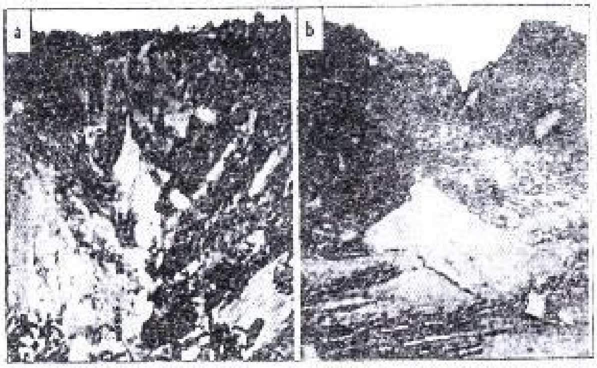

Fig. 6(a) Gully head – a setting for spontaneous breakdown, (b) A gully mouth illustrating a setting restoring equilibrium

3.2.2 Drainage: Has two functions – erosion and transport of materials. It is noteworthy that the headwaters of many drainage lines emerge from gullies. On the other hand, most gullies have perennial river channels as their base levels. To this extent therefore, most gullies are the dry extensions of drainage lines and conduct flood waters only during or immediately after rain storms. As an erosion agent, pluvial action effects corrasion, deepens the gully floor, undercuts the sidewalls and widens the gully by facilitating mass movements.

3.2.3 Climate: is the critical element that impinges directly on the substratum by way of precipitation to effect erosion as well as influence other factors. For instance, insolation is essential for the development and blooming of the vegetation, the formation of clouds, their movement, and eventual precipitation.

3.2.4 Vegetation: mainly protects the substratum from the direct impact of the elements, especially raindrop. The effect of concentrated flow is also attenuated by vegetation, especially by grass and other plant stands as well as leaf litter. It is often the main material for both prevention and cure for combating erosion in general. However, while fibrous roots function as binders and facilitators of soil crumb structure formation, the deeper penetrating roots of higher plants may actually be disruptive of the soil foundation – the bedrock (Fig.7).

3.2.5 Man: plays an ambivalent in role as erosion trigger. It is unavoidable to clear vegetation for farming, urbanization, road construction and other land uses. This puts the ecosystem to disequilibrium. Gullying is thus one of the reactions of the disrupted equilibrial components in the process of trying to recover. In reaction to his action on the ecosystem, man devices a host of combat measures to the scourge. It is often too little too late. Coupled with the tendency for gullying to be incurable, the result is the kind of disastrous soil and land loss well known in southeastern Nigeria.

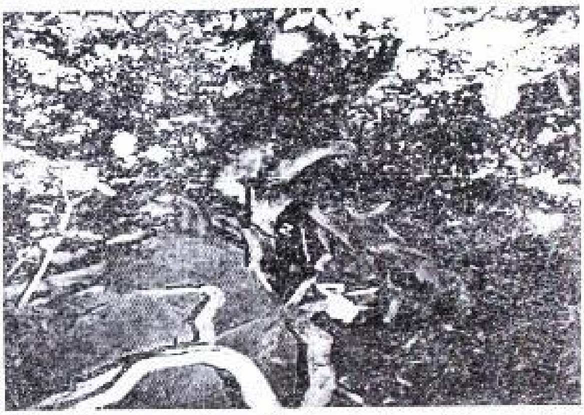

Fig.8. Tree roots disrupting bedrock and thus acting as a facilitator of erosion

In a review of gullies in five state of Nigeria across the various climatic zones of the country and traversing the two major rock classes – basement and sedimentary, Alichi et al (2014) found that the negative impact of human activities on the land accounts for the initiation of most of the gullies documented in the states. These include improper termination of storm drains and culvert outlets, indiscriminate sand quarrying, overgrazing, bush fire and improper farming practices. The most important across board anthropic trigger is improperly terminated or insufficient storm drain, for example Fig. 9. It was discovered that about 42% of the gullies in Gombe axis where anthropically triggered; about 71% in kogi; 62% in Enugu and about 51% in Abia State; all together constituting over 65%. Further break down indicates contribution from concentrated overland flow (s) as 40% in Kogi, 22% in Enugu and 44% in Abia. High slope gradient (h) (slope angle above 55%) constitute as follows: 4% in Kogi, 15% in Enugu, and 5% in Abia. Contribution from civil engineering (e) is 45% in Kogi, 46% in Enugu, 43% in Abia. Mining activities (m) in all cases constitutes <4%, whereas cultural practices (c) contributes evenly in all the states about 14% (Fig 10). The high percentage of anthropic triggers relative to natural triggers indicates that much of gullies in these areas could be avoided or minimised if proper impact assessment and environmental friendly ethics are carried out in out in planning and management of developmental projects and land use.

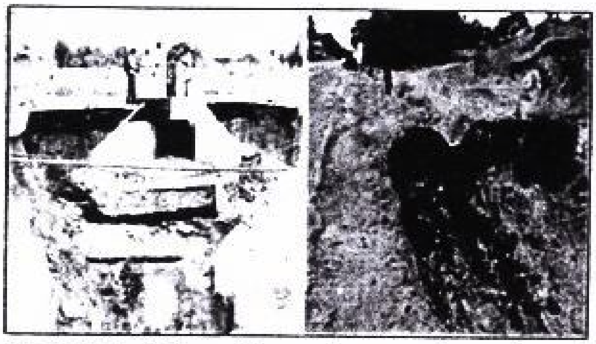

Fig 9. Gully triggered by an improperly terminated storm drain

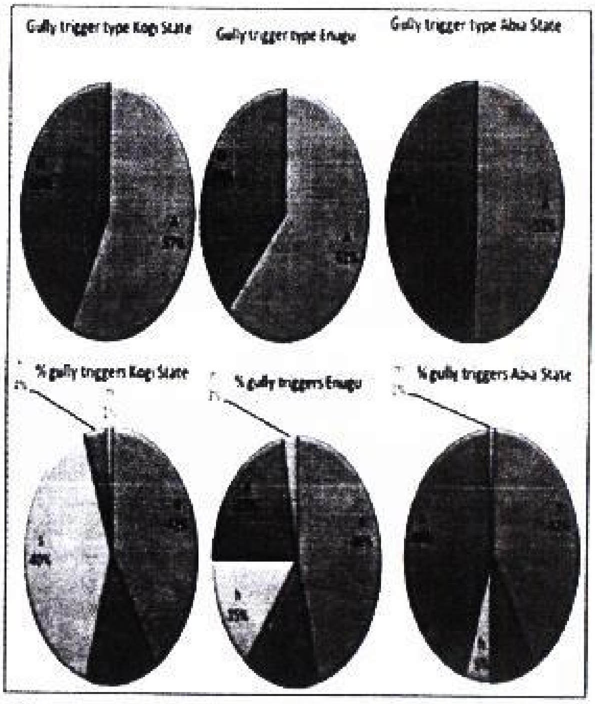

Fig 10. Comparative summary of the impact of anthropic and natural factors on gully development; N= Natural triggers, A= Anthropic triggers; e = civil engineering triggers, c = cultural triggers, h = high gradient, s = surface runoff, m= mining activity.

4.0 Gullying mechanisms and products

The processes involved in defining a gully may be classified into two: those lengthening a gully and defining its trajectory, and those expanding it. The former set of processes, designated as R_h (headward retreat),results in the incision of the ground surface, in some cases leveraging on the rilling stage of erosion or breaking the ground a new, or following an aid in concentrated flow, such as a depressed foot path or a natural topographic depression. Once initiated, progress is headward, *i.e.* upslope. It is also seasonal, since it follows the annual cycle of rains and dry season. A close examination of the headward retreat shows that pluvial action is the force that effects both the initial incision and the deepening. Pluvial action expresses in two erosive ways: shearing action and corrasion. Shearing action is due to the flow strength of the water proper, and is the product of the flood flow velocity, v, and the shear stress. This scouring action deepens the incision but achieves minimum widening.The other mechanism is corrasion which is generally defined as an erosional process in which the substratum is worn away by the abrasive action of the solid materials carried along by running water. This amounts to the wearing away of the floor and sides of the channel by the cutting, scraping, scratching and scouring effects of the bed load. Finally, headward retreat is often aided by the collapse of the headwall caused by the undercutting effect of the plunging flood waters (Fig.1 11a, 11b).

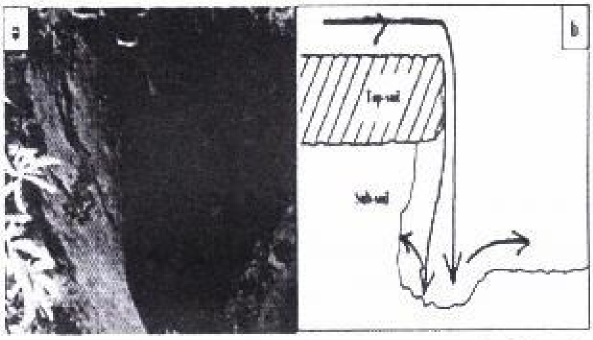

Fig. 11(a).Headward retreat at the gully head effected by the scouring and undercutting action of flood flow, (b)An illustration of the undercutting action of concentrated flow causing headward recession

Gullies studied in Nigeria by the NGMC are largely rectilinear in profile, *i.e.* mostly approximate to a straight line; a few others are somewhat curvilinear or broadly sinuous. The predominantly linear geometry implies that, from inception, the lengthening tendency by far exceeds the widening. The implication of this is that gullying is predominantly a headward retreat or recession process. However, if we consider soil and land loss, the widening process becomes very significant. The deepening process may be determined from onset by the base level as the datum deeper than which the gully cannot incise. The rather very imposing visual impact of gullies is due to the widening perhaps more than the lengthening. This widening is solely due to **mass movement (M_m).**

It would be useful to look at the general principles of the kind of subaerial mass movements involved in gullying. In some localities, the soil surface shows ***en echelon* cracks** parallel to the rim of the gully wall. These cracks actually demarcate the blocks that would move next (Fig.12a) Such cracks not only define the movable mass, but also facilitate the movement by serving as the crevice through which water seeps and lubricates the movement.

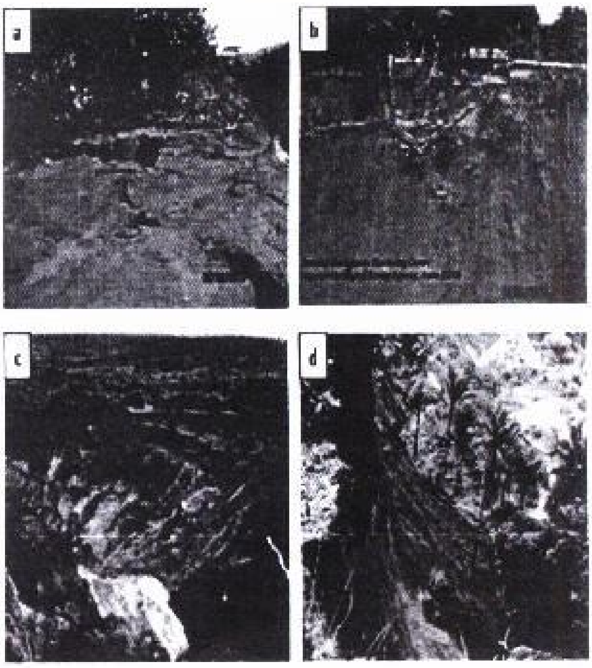

Fig. 12(a).Tension cracks on ground surface parallel to the rim of gully wall (b). Slumping on a gully flank wall; note the undisturbed form of the upper part of the slump mass (c) A succession of slumped masses forming terraces on a gully wall (d). Debris flow – a mass movement at the gully edge

Slumping is perhaps the most frequent kind of gully-widening mass movement observed in the study of gullies of Nigeria. It is commonly a kind of downward slide, accompanied by some degree of rotation, along a curved surface, with at least the upper surface of the moving block relatively undisturbed Fig 12 b & c). However, although initially intact, every slump mass is on its way down the gully wall to final disintegration and transportation by pluvial flow along the gully floor to the base level.

Rockfall occurs when a chunk of rock detache from the top of the gully wall and drops or roll down the steep slope to the gully floor. This happens even in dry weather and is often the least moist and fastest in movement. Depending on the shape of the gully wall, the pieces may accumulate into a talus heap (Fig.13) awaiting evacuation by the subsequent episodes of storm water discharge.

4.1 Impacts of gullies

Gully has been observed to be a major driver of the rock cycle, largely powered by the hydrologic cycle, making it a very important geological process. It exposes new layers of the bedrock as a basis for the formation of new soil. Erosion assists in concentrating heavy minerals from their disseminated mode of occurrence in their parent rocks. This way, placers like tin, gold and other precious minerals become economically recoverable. It has recently been realized that when soil is eroded it carries along some amount of carbon, a noted greenhouse element, and deposits it in nearby wetland areas. This is considered highly beneficial since wetlands impound carbon for long periods of time which is a nature's method for fighting global warming. Erosion has in many localities around the world created awe inspiring and spectacular sceneries, such as caves and badlands, some of which are revenue-earning geotouristic destinations. Also to be regarded as beneficial is the fact that gullying exposes soil horizons and, in some localities the bedrock, for close field study and sampling by pedologists and sedimentologists (Fig. 14)

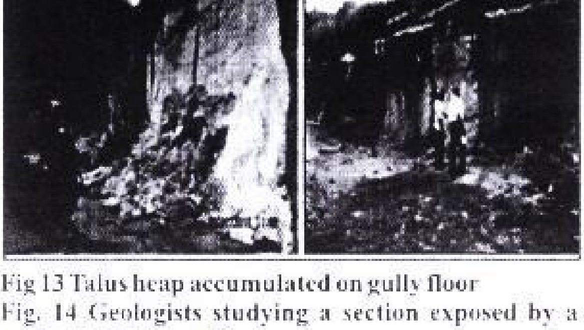

Fig 13 Talus heap accumulated on gully floor
Fig. 14 Geologists studying a section exposed by a gully at Udi, Enugu State

Nevertheless, they remain environmental and economic disasters so much so as to completely nullify whatever benefits as indicated above. Gullying represents the extreme form of erosion and, in most part of Nigeria especially southeast it goes far beyond the background level.

The World Bank (1990) recognized three main environmental problems facing Nigeria: soil degradation and loss, water contamination, and desertification associated with uncontrolled deforestation. In more specific terms, there are at least six main concerns: gully erosion, coastal erosion, fishery loss, wildlife and biodiversity losses, air pollution and the spread of the water hyacinth and nypa palm. Gullying contributes in one way or the other, directly or indirectly, to most of these problems and causes damage to the nation estimated in 1990 at $100 million per annum.

The adverse impacts of gully erosion in Nigeria could be grouped as: land loss and soil loss, landed property loss, infrastructure loss, and water siltation.

4.2 Soil and Land Loss

According to Brown (1984), soil loss over the Earth surface due to erosion amounts to about 25 billion tonnes per annum. In the study area a major impact of the various types of erosion is soil loss, especially from slopes with scanty vegetal cover. This results in loss of nutrients and impoverishment of the soils. Even more significant is the loss of land due to gullying. This is by far a more serious impact of erosion since it means a complete deprivation of access to the gullied areas. The most important kind of soil and land loss is the rendering of large tracts of territory completely inaccessible and unusable for agriculture, residential and indeed any other kind of land use (Fig. 15)

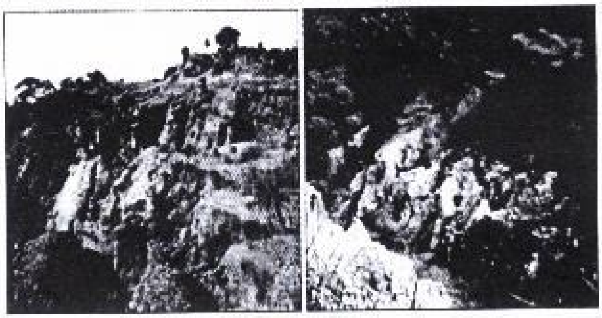

Fig. 15.*left*Badlands terrain in the area underlain by the sands of the NankaFormation in the Nanka area of Anambra State, *right;*Badlands topography in the area underlain by the Ajali Formation

4.3 Landed Property Loss

Effect of gullying becomes much more agonizing when landed property such as a domicile or an institution is destroyed fully or in part (Fig.16) In many cases the affected buildings might be a series ancestral homes built far in the past when no risk of the sort posed by gullying was in any way evident, but now lying within the area of influence of an aggressively advancing gully. Efforts at stemming the impending disaster are often too feeble too late.

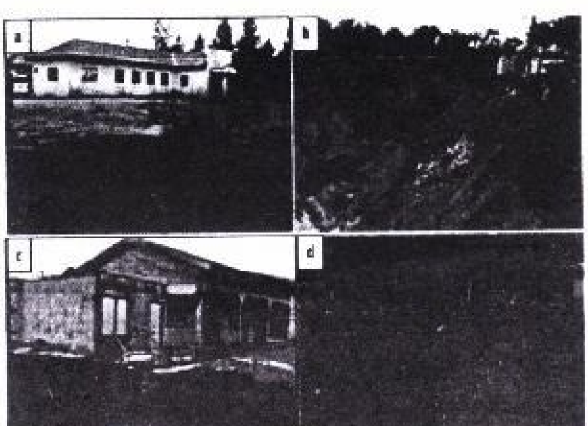

Fig. 16 a. Destruction of landed property at the flanks of a gully, Afikpo, Ebonyi State, b.Remnants of a destroyed mansion, Urualla, Imo State, c. Destruction of landed property along the path of the headwardprogress of a gully, NguzuEdda, Ebonyi State, d. An illustration of the defiant stance of some affected families - staying put in the face of very obvious danger, Ekwulobia, Anambra State.

4.4 Infrastructure Loss

This kind of gully-induced destruction is commonly visited on basic facilities and installations needed for the functioning of society and running of civilization. The best known and most susceptible objects are roads (Fig.17).

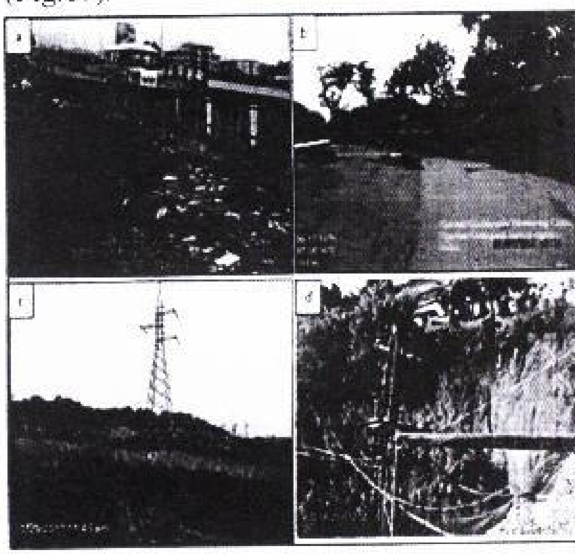

Fig. 17*a*. A gully of the Nkisi drainage system undercutting the Onitsha - Enugu expressway at Onitsha; note communication cables exposed, *b*. A water pipe exhumed by a shallow gully, Ezeagu, Enugu State, c. Power transmission line under threat, Ekwegbe, Nsukka, Enugu State, *d*. A felled power line, EdimOtop, Calabar, Cross River State

4.5 Water Source Siltation

A part from the already discussed impacts of gullying which are attendant to the mass movements initiating, lengthening, deepening and widening the gully, the main destructive process is the deposition of the evacuated material resulting in water source siltation and the smothering of farm crops. The real impact is the deprivation these consequences of mass movements visit on the people, especially the village folk who are already at the lowest scale of material well-being. An example of each case is shown in figure 18.

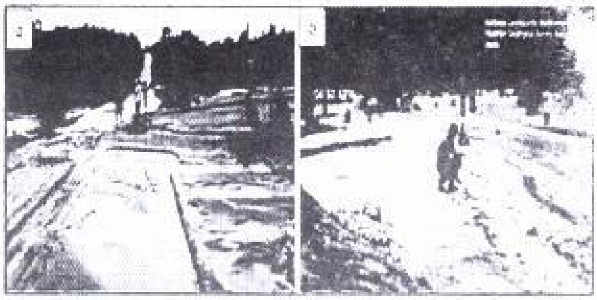

Fig. 18a. Water source silted up due to deposition of material derived from mass movements at IdimIkot-Effiom, Cross River State, b.Flow of bedload over the Alor – Abatete road; note erosion of the road on the left.

5.0 Combat Activities

Levels of erosion control activities scale up from the individual household through community or town, to the three tiers of government. Somewhat at its own level is foreign assistance from friendly first world countries, but most importantly from United Nations agencies notably the World Bank and Food and Agriculture Organisation. In a general way, the contribution of the indicated levels may correlate with the above stated hierarchy if viewed in terms of increasing sophistication and money. For the individual household situated in the rural area, whether there is a threat of gullying or not, the instinct is to minimise all forms of erosion by rain water. The illustrations below (Fig 19) depict various levels of existing activities at combating the menace of gully erosion in Nigeria.

Fig 19 various levels of existing gully combact measures: a. rain harvesting to impound water, b. slope stabilisation with sand bags, c. ineffective community effort at stabilising a gullying earth road, d. diversion of runoff water into catch pits.

5.1 Recommendations on Combat Strategy – Integrated Approach

Individual house holder should reduce impact of precipitation on premises, harvest water, contain excess water within premises to minimise the threat to housing foundation. On the community level, maintenance of rural roads and sumps for flood waters, enforce local rules on containing flood waters within households; apply ideas from enlightenment efforts of higher authorities and experts esp. on farming methods in order for early gully inception detection and elimination. NGOs should liaise with communities on appropriate combat strategies; stimulate combat activities; source funds, expertise/technology. Local Government authorities to oversee above activities, undertake simple reclamation works, emphasise soil conservation andgully prevention in enlightenment campaigns; ensure EIA is carried out for every serious activity impacting the environment. State Government should use diverse expert areas to study and understand the geohazard prior to design and execution of remedial works; assess degree of gullying holistically and determine suitable combat approach; ensure judicious application of ecological funds; source foreign/grass-roots funds, expertise and technology; draw up appropriate curriculum for self-enlightenment campaigns; conduct EIA for every major developmental project impacting the soil and the environment. Federal Government to Provide the directly concerned agencies (e.g. NGSA, Ministries of the Environment, Works, and Agriculture) with appropriate and adequate enablement to ensure proper studies, design and construction of control/devices; source foreign expertise, funds and technology for comprehensive combat; ensure judicious application of ecological funds.

The method of combat should ensure that appropriate type of control is applied from chip to expensive approach. Also, use of all possible areas of technical expertiseand technology, local and foreign: geoscience, agronomy, engineering should be approached to ensure success of control measures. Finally, judicious budgeting for combat activities; tight controlled and supervised use of ecological funds as well as funds from donor sources is recommended for better result on gully control effort and value for money.

Conclusion: The study of gullying which is intended to fully understand its antecedents, triggers, and mechanisms should involve pedology, agronomy and geology (especially geomorphology and geotechnics). This forms the basic multidisciplinary approach articulated herein for combating the scourge. The scheme is designed to facilitate the forging of the synergy required for stemming the ferocity of gully erosion and aid in the recovery and rehabilitation of large tracts of devastated territory. Cooperation among the disciplines will avert the common incidence of failure of control measures and civil structures designed and constructed solely on the basis of local considerations and incomplete data. This present work embodies empirical research data and provides a substantial part of the information required for urban and country planning, environmental management, and infrastructural development especially civil construction.

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