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MAN AS FACTOR OF SOIL EROSION IN SOUTHEASTERN NIGERIA

by

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RESUME

L'érosion du sol est un élément très important dans le Sud-Est du Nigeria. L'action de l'homme sur cette érosion a toutefois été exagérée, tandis que l'importance du milieu physique n'a jamais reçu l'attention qu'elle méritait.

Les résultats de plusieurs études nous ont, en effet, amené à la conclusion que l'élément le plus important pour expliquer les phénomènes d'érosion, ici, n'est pas l'élément humain et que la contribution essentielle de l'homme est de compliquer une situation préexistante, ou mieux, de jouer le rôle d'un stimulant dans un environnement favorable à une érosion de type ravinant.

Une étude récente (G.E.K. OFOMATA, 1975) montre que 79 % de ce type d'érosion peuvent être expliqués en fonction de la densité de la population, contre 83 % pour le relief (configuration du terrain) et 90 % pour la pluie. La régression entre l'érosion du sol (x) et la densité de la population (y_1), le relief (y_2) et la pluie (y_3) sont représentées par les équations suivantes :

$y_1 = 0.4 x + 0.5$ .... (i)
$y_2 = -0.3 x + 0.2$ .... (ii)
$y_3 = -0.7 x + 4.0$ .... (iii)

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Soil erosion is one of the most striking features on the land surface of Southeastern Nigeria. Of a total surface area of 75,488 km^2, some 47 % of Southeastern Nigeria is affected by one form of soil erosion or another : 22 % is affected by what may be referred to as 'serious' soil erosion, while only a little less than 2 % is menaced by the highest degree of erosion – the gully type 1 See fig.1 and table 1).

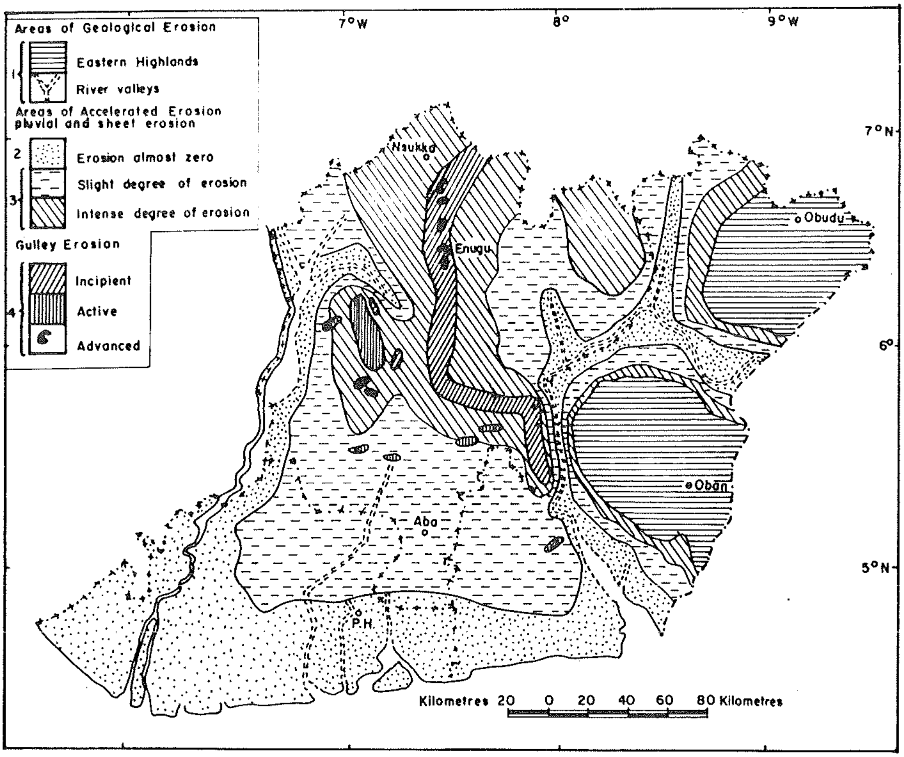


FIG. 1_ SOUTH-EASTERN NIGERIA : TYPES OF EROSION

Table 1 TYPES OF EROSION IN SOUTHEASTERN NIGERIA

	Area (Sq. km)	Percentage of total area of Southeastern Nigeria
I. AREAS OF GEOLOGIC EROSION		
(i) Eastern Highlands	17,620	23.34
(ii) River Valleys	4,840	6.41
II. AREAS OF ACCELERATED EROSION		
(a) Pluvial and Sheet Erosion		
(iii) Erosion almost zero	17,790	23.57
*(iv) Slight degree of erosion	18,570	24.60
*(v) Intense degree of erosion	15,450	20.46
(b) Gully Erosion		
(vi) Incipient	753	1.00
(vii) Active	427	0.57
(viii) Advanced	38	0.05
TOTAL	75,488	100.00 %

** See explanatory note at the end of* Conclusion.

FACTORS OF SOIL EROSION

Soil erosion results from two main factors – physical or natural factors and human or anthropogenic factors. Traditionally, therefore, two types of erosion have been distinguished – *physical* (often referred to as natural or geologic), which is a "normal" geomorphic process of landscape development, and the *human* (anthropogenic or "accelerated") type of erosion in which the normal geomorphic process of erosion is accelerated by one form of human activity (or environmental change) or another. Even though both types of erosion lead to some degree of soil loss, it is usually the *accelerated* which readily comes to the mind of the general public whenever one thinks of soil erosion. For our purposes, however, soil erosion means any process which leads to the loss of soil, no matter how small that loss may be, and includes both types of erosion outlined above -- physical and human.

The relative importance of the various factors in soil erosion had earlier been examined by the author for this part of Nigeria (G.E.K. OFOMATA, 1965). Our experience continues to show that the human factor in soil erosion has often been exaggerated, while the importance of physical factors has, at best, not always received the attention it so much deserves.

Physical factors

Physical factors resolve easily into three major components : climate, earth materials and surface configuration. The relationship between climate and soil erosion is fairly well known and, for the humid tropics, *rainfall* is

Sans nier les effets que les activités humaines peuvent avoir sur le développement de l'érosion du sol et le fait que, selon l'utilisation du sol et le niveau de la technologie, le degré d'érosion des sols peut être différent, il est cependant raisonnable de présumer que, dans une région habitée par un même groupe ethnique ayant des méthodes de culture semblables, toute différence dans la nature et le type d'érosion du sol doivent être attribuées à des facteurs non humains. Il est aussi significatif qu'une régression multiple exprimant l'érosion du sol en fonction des autres paramètres élimine les effets de la population et souligne le rôle de la pluie et du relief. Le modèle qui en résulte est le suivant :

$$x_i = 6 - y_{2i} - y_{3i} \quad \ldots\ldots\ldots\ldots\ldots \quad \text{(iv)}$$

où x, y_2 et y_3 ont la même signification que précédemment et où l'erreur estimée est de zéro.

Les éléments physiques sont donc probablement plus importants qu'on a l'habitude de le considérer, du moins en ce qui concerne l'érosion des sols dans certaines zones tropicales.

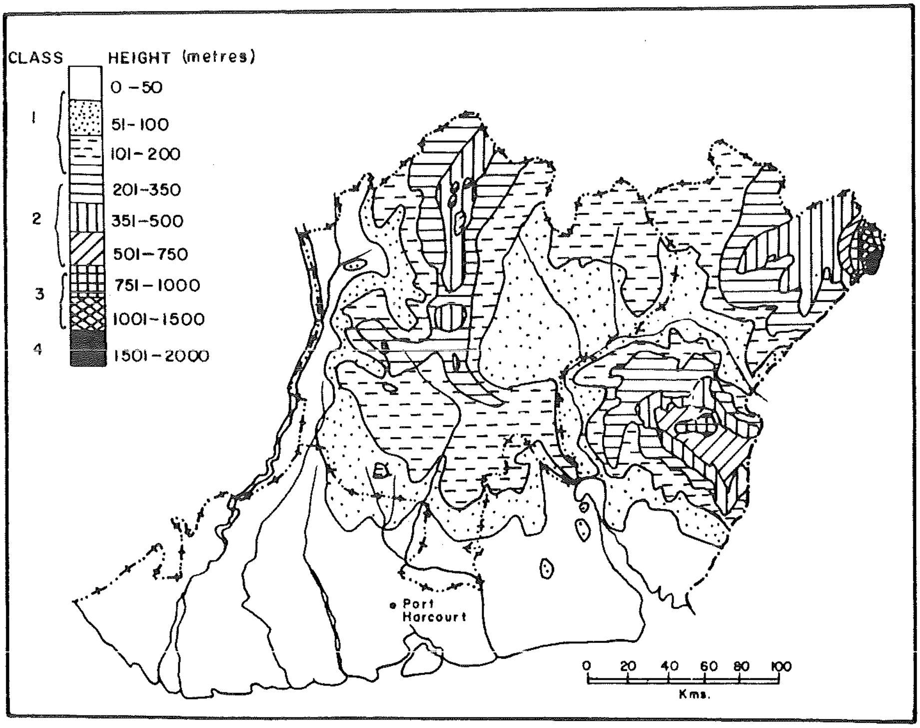


FIG. 2 - SOUTH - EASTERN NIGERIA — RELIEF

the most dominant sub-factor. F. FOURNIER (1960) has attempted an empirical consideration of this relationship but his outline serves only as a general guide in the attempt to correlate the two parameters.

Rainfall manifests itself in three different, though related, aspects. It gives rise directly to pluvial (splash) erosion as a result of the impact of raindrops on the ground surface. The erosive capacity of raindrops seems to result from three factors : the amount and intensity of rainfall, the diameter of the drops, and the velocity of the drops as they strike the soil, and a good account of the relationship between raindrop energy and erosion has been given by W.D. ELLISON (1952). Rainfall also leads to infiltration where conditions are favourable, like where the ground surface enjoys a good cover of vegetation and where the underlying rocks and/or their associated weathered materials are porous and facilitate infiltration. The third aspect is that rainfall leads to runoff which is the central agent in the soil erosion system. Where unconcentrated, runoff gives rise to sheet wash (sheet erosion), while gullying results from concentrated runoff, provided that lithology is favourable.

The nature of earth materials influences the rate of infiltration and, thereby, of slumping and/or sliding. It also affects the nature and rate of surface runoff and, thereby, the nature and rate of incision (G.E.K. OFOMATA, 1967).

Surface configuration (which is preferred to such terms as slope and relief) aids runoff, sheet erosion and gullying. The general tendency is for sheet erosion to be common over fairly uniform and gentle slopes, while gullying is expected to be more characteristic of steeper slopes. It is known, however, that gullying also takes place on very gentle slopes and is even more common on such gentle slopes than on very steep ones. For one thing, runoff requires such gentle slopes to be concentrated, and concentrated runoff is a prerequisite for gullying. G.W. MUSGRAVE (1947) attempted to evolve an empirical equation relating erosion (rate of erosion) to rainfall and slope, while A.W. ZINGG (1940) attempted an estimate of the relation between soil loss and slope. Zingg concluded that, other things being equal, soil loss varies as the 1.4 power of the per cent slope and as the 1.6 power of slope length.

A qualitative assessment of the relationship between surface configuration (relief) and erosion was made by the author in 1967 and revealed that :

– " areas of strong relief (elevation of about 244 metres and over above sea level) are, at least potentially, areas of the greatest degree of erosion. They are characterised by widespread and intensive runoff which sweeps the surface clear of fine elements. Unfavourable lithological and hydrological conditions militate against a wholesale degradation of the badland type. But where, within such areas, there is adequate surface drainage and where the underlying rocks are not sufficiently resistant, gully erosion becomes important ;

- areas of low relief (roughly less than 122 metres above sea level) coincide with areas of negligible degree of erosion ;
- areas of moderate relief (roughly between 122 and 244 metres above sea level) are characterised by an intermediate condition of erosion between the above "extremes", erosion ranging from mere sheet wash to gullying, and modified in intensity by lithological influence".

It may be useful here to compare figs. 1 and 2.

The indirect effect of climate on soil erosion is through the medium of vegetation. Areas under effective cover of vegetation are more prone to sliding and slumping as they are characterised more by infiltration than by surface runoff, while bare surfaces encourage runoff and, thereby, sheet erosion and gullying. As may be expected, vegetation is the one physical element mostly affected by human action.

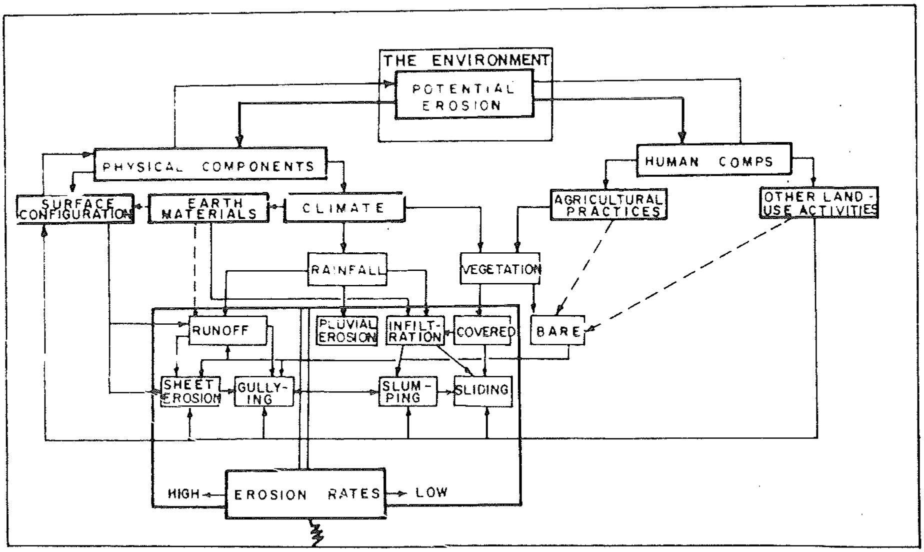
Human factors : the role of man

The *human components* in soil erosion in the area of study are connected mostly with agricultural practices and other land use activities. Agricultural practices in Southeastern Nigeria generally involve the destruction of vegetation by clearing of land for cultivation and by forest fires. These activities cause great change in the relative proportions of infiltration and runoff, with the dangers of erosion increasing with increased destruction of vegetation and, thereby, reduced infiltration and increased runoff.

Of the other land use activities, establishment of settlements, road building and similar engineering works appear most important. The consequences of these activities for soil erosion have been discussed elsewhere (G.E.K. OFOMATA, 1964 and 1973 ; A. SALBANY, 1960). It suffices here to mention that these other land use activities help deprive the soil surface of its vegetation and also contribute directly to sliding (G.E.K. OFOMATA, 1966), slumping, sheet erosion and gullying.

The various relationships between the factors of soil erosion and the phenomenon of erosion are given in fig. 3 as the *Soil Erosion Model*, which has been considered elsewhere (G.E.K. OFOMATA, 1975).

FIG. 3. SOIL EROSION MODEL
(HUMID TROPICAL AREAS)



Results from further studies have strengthened our earlier conclusions on the subject – that the most important of the factors to explain soil erosion in the areas are not human ; that the main contribution of man seems to have been to complicate an already existing situation or, at best, to have acted as an additional incentive to set off a more serious situation in an environment whose physical characteristics are totally disposed to the evolution of the gully type of erosion.

In a recent study, aimed at outlining a soil erosion model for humid tropical areas based on the experiences of Southeastern Nigeria, the importance of physical factors came once more to the fore (G.E.K. OFOMATA, 1975). The results revealed that about 79 % of the soil erosion phenomenon in the area of study could be explained in terms of population density, against 83 % for relief (surface configuration) and as much as 90 % for rainfall. This revelation lends support to the author's earlier observation (G.E.K. OFOMATA, 1967) on the relationship between erosion and relief in the area and the underlying influence of lithology. The paramountcy of rainfall as a factor of soil erosion in Southeastern Nigeria was clearly established by these results. However, this paramountcy of rainfall seems to be valid only for lower classes of soil erosion (the non-gully types). Further analysis reveals that only population density shows a positive correlation with soil erosion, while relief and rainfall both have a negative correlation with soil erosion. The regression lines between soil erosion(x) and population density (y_1), relief (y_2) and rainfall (y_3) are given by the following equations :

$$y_1 = 0.4x + 0.5 \quad \ldots\ldots\ldots\ldots \quad (i)$$
$$y_2 = -0.3x + 2.0 \quad \ldots\ldots\ldots\ldots \quad (ii)$$
$$y_3 = -0.7x + 4.0 \quad \ldots\ldots\ldots\ldots \quad (iii)$$

Without denying the possible contribution human activities make to the development of soil erosion, and the fact that different methods of land use and the level of technology of land users necessarily affect the soil differently, it is reasonable to conclude that in areas inhabited by the same group of people who practise similar methods of land use, any differences in the nature and type of soil erosion have to be explained in terms of extra-human factors. It is significant that a multiple linear regression relating soil erosion with the parameters selected for consideration in Southeastern Nigeria eliminated (the effects of) population and emphasised the role of rainfall and relief. The resulting model is given by the regression :

$$x_i = 6 - y_{2i} - y_{3i} \quad \ldots\ldots\ldots\ldots \quad (iv),$$

where x, y_2 and y_3 are as defined in the previous equations, and error estimate is zero.

CONCLUSION

There are many people who still believe that constraints to development and growth in Africa are only economical, social and political, not ecological. Such people would want to explain the problem of soil erosion along these lines also. However, our experience leads us to the conclusion that physical factors are perhaps more important in the evolution of the soil erosion phenomenon in tropical areas than has hitherto been recognised, while the part played by man has tended to be overemphasised. It is important to point out that many conclusions drawn so far on the constraints to development and growth in Africa are based on an inadequate knowledge of the environment. It is clear that most soil conservation measures in the tropical world cannot succeed if one remains ignorant of tropical soils, tropical agriculture and tropical forestry. For instance, what cover crops, shrubs and plants are best suited for effective conservation of the soils of tropical areas ? It is urged that future studies of the soil erosion phenomenon should take these points into account while evaluating the factors responsible for the increasignly disturbing soil erosion that plagues parts of the tropical world. Results from instrumented sample areas will, no doubt, make an important contribution to our knowledge of the soil erosion phenomenon and point the way to how best it could be tackled.

Table 1 : Types of Erosion in Southeastern Nigeria

Areas under categories (iv) and (v) are those is which sheet erosion predominates ; the sub-division only reflects the variation in the intensity of erosion. In (iv), "areas of slight degree of erosion", runoff is not only slow in motion (because of the low angle of slope of the ground which is generally of the order of $1° - 2° - 4°$) but also small in amount due to rapid infiltration of rain-water. Whatever is left as surface runoff does not accomplish much by way of erosion : it is not capable of removing any appreciable quantity of fine materials from top soil, and materials so removed are rarely carried far beyond their place of origin before the slightest obstacle results in their immediate deposition. This type of erosion is consequently not considered a serious threat to agriculture in the area.

In (v), that is "areas of intense degree of erosion", sheet wash is becoming more pronounced since increasing angle of slope of the ground (average of $3° - 5°$) leads to greater intensity of runoff. Such generalised runoff as operates is visibly sweeping the top soil clear of its finer elements, leaving behind coarse materials, especially medium - to coarse-grained sand. Again, runoff is not only generalised and violent, but minor obstacles easily lead to its concentration along defined channels and, subsequently, to the inception of rills and/or gullies.

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DISCUSSION

O. Slaymaker :

1) In your simple regression equations, why do you show your height, rainfall and population density classes as dependant variables ?
2) It seems to me that the use of ranked data in these regression models is inappropriate. Your population of classes is too small and the data are not ordinal data. Some form of non-parametric statistical technique (for example, the Mann-Whitney U-test) would be less misleading.

G.E.K. Ofomata :

1) The essence of these simple relationships is to find out whether increases in the "classes" of the parameters of population density, relief and rainfall lead to corresponding increases in the "class" of soil erosion.
2) You may be right in some of your observations, but I do not see why the use of ranked data is inappropriate. One has to see the paper in which I formulated the model to test the appropriateness or otherwise of the use made of ranked data, the results of which I have found satisfactory.

A. Jahn :

1) Looking at the slides from Nigeria I compare the shape of the gullies with this kind of form from other areas. The forms of gullying in the loess area of Eastern Europe are different. The forms from Nigeria resemble the american sandy badlands. The reason of similarity would be the material, sandy in both cases.
2) The other difference in the Nigerian gullies in relation to this form in Europe would be the processes of vegetation recovering which here is much faster than in Europe.

G.E.K. Ofomata :

1) The apparent similarity in the form of the gullies may rightly relate to the composition of constituent surface materials. The gullies of Southeastern Nigeria are developed in sandy, highly friable materials.
2) The rate of vegetation recovery and stabilisation of the gullied areas varies from one section of the gully to the other. Parts of the upper slopes on the bordering sides of the gullies retain such vegetation much faster and in a more stable state than the headward sections of the gullies. In most parts, vegetation stabilisation is merely ephemeral since the gullies are continuously reworked.

J. Savat: I believe that there is a relationship between rainfall and relief and on the other hand between relief and population density around Nsukka and Enugu. How can you stress the importance of one factor since it is interdependant ?

G.E.K. Ofomata : I agree that the factors are interdependant, but what is being stressed is the relationship between (the degree of) soil erosion and these other parameters of population density, relief and rainfall. On your other comments, rainfall generally increases with relief in the area, but there is no such direct correlation between relief and population density. If any, a negative correlation would emerge.

M.A. Stocking : I. congratulate you on a most interesting and comprehensive study of the influence of various factors of erosion. There is, however, one point that worries me.

The crux of your soil erosion model is the measure of erosion and what erosion is considered to be most serious. Unless one has exact measures of quantity (which we do not have on any sufficiently wide scale), the consideration of erosion must be subjective. I have seen that you have classified gully erosion as the most serious type of erosion. If one accepts gully erosion as the most serious (whether on a quantitative basis or on agricultural importance). then I think that your conclusion that man is relatively unimportant in erosion is probably valid. Observations in Rhodesia and elsewhere show clearly that much gully erosion is through local physical factors, especially relief and hydrological factors.

However, is gully erosion the most severe ? I think that on two courts it may not be the most severe. First, in areas that have some gullying ever, we have measured as much as 90 % of the contribution to sediments comes from the sheet erosion and not the gully erosion. Secondly, gully erosion from a agricultural point of view effects a relatively small area and sweeps away all the material, but sheet erosion is insidious and removes the finer particles, the most important ones agriculturally. Therefore, I would put it to you that sheet erosion is perhaps the most serious. And if it is the most serious I also propose that your conclusion is not totally valid and that man is, in fact, very important in the erosion process.

G.E.K. Ofomata : A lot would depend on what we mean by "most severe" and "most serious". But in our system of classification, gully erosion is not only the highest class of erosion but invariably the most serious type of the soil erosion phenomenon. No matter what is removed by sheet erosion, there is always some land to cultivate, but with gully erosion, nothing remains for man's use.

P. Michel : Vos photographies montrent un ravinement très spectaculaire. La végétation ne peut-elle pas s'installer dans les ravins en fin de saison des pluies ? N'existe-t-il pas des phases de stabilisation du ravinement, comme nous en avons pu observer pendant notre excursion dans le Shaba, ou comme je l'ai montré dans mon exposé sur la dynamique actuelle dans le domaine soudanien ?

G.E.K. Ofomata : Oui, il arrive que la végétation s'installe dans les ravins en fin de saison des pluies. Aussi, il existe des endroits où le ravinement se stabilise suivant l'installation locale de la végétation. Mais dans d'autres secteurs des ravins, cette stabilisation n'est qu'un événement éphémère, car il se produit toujours un remaniement du fond des ravins en de tels endroits, et surtout pendant la saison des pluies.

J. Dresch : demande comment ont été calculés les indices de densité de population, relief et précipitation. Un classement en tranches de chiffres ne permet pas d'établir les seuils au-delà desquels les changements quantitatifs deviennent qualitatifs. En outre, certains facteurs non introduits interviennent comme la lithologie, l'évapotranspiration, la couverture végétale, etc.

G.E.K. Ofomata : Ce qu'on a fait avec ces paramètres, ce n'est que d'essayer de les grouper convenablement. D'autres facteurs ont pu jouer un rôle important et nous l'avons souligné dans le texte à propos de la lithologie, par exemple.