Géo-Eco-Trop, 1978, 2, 175-187

A PRELIMINARY INVESTIGATION INTO SOIL EROSION ON CULTIVATED HILLSIDES IN PARTS OF WESTERN NIGERIA

by

L.K. Jeje*

RESUME

Certains versants en pente raide des districts d'Ilesa et d'Ekiti ont été défrichés pour la culture du riz (*Oryza sativa*). Etant donné l'intensité des averses, il fallait s'attendre à une forte érosion des sols. Malgré de multiples recherches sur le terrain, on n'a pu observer le développement de ravinements même là où la terre avait été cultivée pendant cinq ans avec seulement une ou deux années de jachère. L'érosion doit donc être le seul fait du ruissellement diffus.

Des échantillons de sol ont été prélevés tant dans les cultures que dans les zones adjacentes couvertes de forêts afin d'en analyser la texture et la teneur en substances nutritives. Voici les résultats principaux de ces analyses :

a) une diminution de la teneur en argile dans l'horizon A au fur et à mesure que l'on descend vers le bas du versant et cela uniquement dans les sols cultivés ;
b) une légère diminution de la teneur moyenne en argile et
c) une diminution significative en substances nutritives dans les sols sous culture.

Ces observations montrent que les sols cultivés, soumis fréquemment au brûlis, exposés à des insolations intenses et à des modifications rapides du taux d'humidité, ont subi, comparativement aux sols de la forêt, un lessivage plus intense des substances nutritives et une perte de matériel argileux. Le départ des argiles peut être attribué à la fois à une éluviation et à une érosion par le ruissellement diffus assisté par le splash.

Si l'on ne porte remède à cette situation, le sol des zones cultivées sera bientôt pratiquement stérile, entraînant une baisse importante des rendements.

---

* Geography Department, University of Ife, IFE, Nigeria.

Rice (Oryza sativa) cultivation is gaining ground in Western Nigeria at a rapid rate. First cultivated in 1849 at Ofada near Abeokuta, the crop spread into Ijesa and Ekiti districts by 1947. In these areas, as a result of heavy demand for rice by the rapidly growing urban population, the crop has displaced yam as the local staple foodcrop, and is gradually displacing cocoa as the most important cash crop. As cocoa was already occupying lands considered best for cash crop farming, rice was tried on the sandy loamy soils (the Okemesi Association of A.J. SMYTH and R.F. MONTGOMERY, 1962) derived mainly from the quartzites and quartzschists underlying the hills and ridges in Ilesa-Ekiti districts. The success of the crop on these soils has further encouraged the farmers to progressively utilize the hitherto uncultivated hillsides. Between about 1960 and now, most of the virgin forests covering the hills and ridges have been cleared.

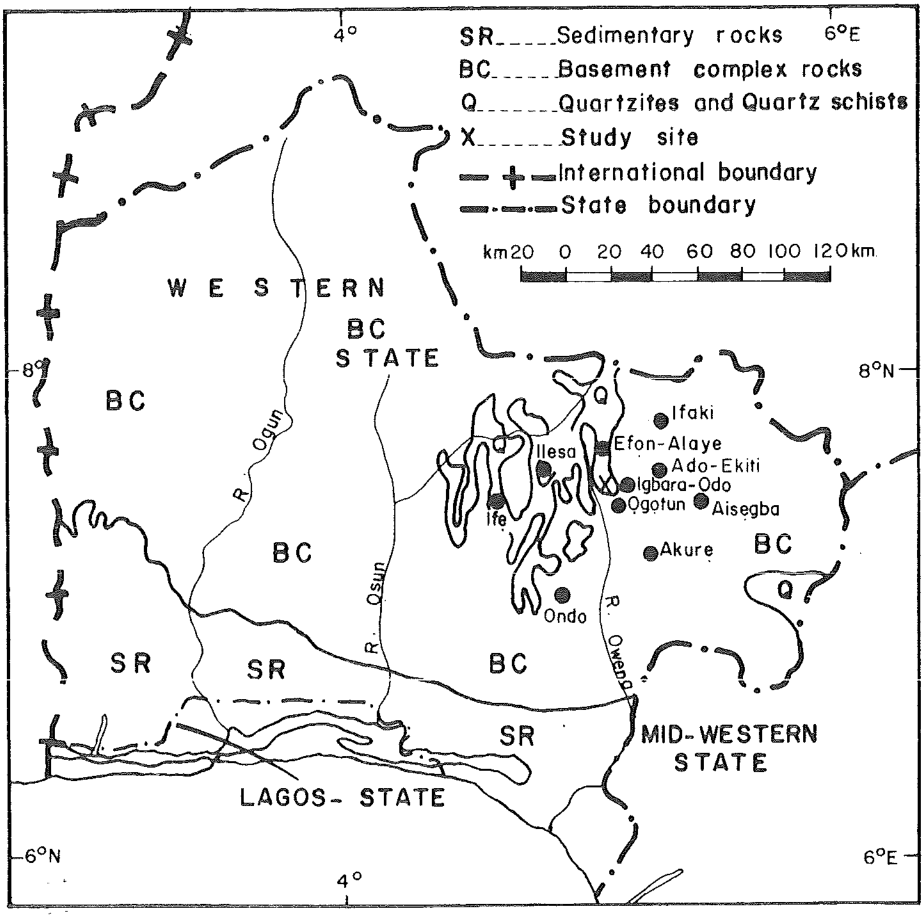

Figure 1

The forest is cleared and burnt, and rice sown in the undisturbed top soil at the beginning of the rainy season in March or April. Given the intensively violent thunderstorms characteristic of most parts of southern Nigeria, the exposed soils may be liable to erosion. This problem is further aggravated where farmers cultivate the same plot of land to rice for two or three consecutive years followed by a short fallow before the land is cleared and cultivated again. In some cases, within a period of seven years, the same plot would have been cultivated about four times with no application of fertilisers whatsoever. This pattern of farming can lead to soil deterioration and erosion either by sheet wash or gullying. However, preliminary field investigations showed a remarkable absence of gullies all over the cultivated hillsides visited. Sheet erosion except where seriously pronounced may not be quite evident, but given the deforested steep angled hillside slopes, and the violent thunderstorms prevalent for a significant part of the year in this area, it is possible that this rather insidious and devastating type of erosion is taking place on the exposed hillsides.

The aim in this report is to assess the extent of erosion on the cultivated hillsides. As the present paper is a preliminary report of an on-going research, it only presents the data obtained on a hillside near Igbara-Odo (Fig. 1), data from several other sites are still to be analysed.

STUDY AREA

The intensively cultivated hillsides are located between the watersheds of Upper Osun, Oni and Owena in Ilesa and Ekiti districts in Western Nigeria. The hills and ridges on what Pugh (1955) described as "Western Plains and Ranges" are bounded approximately by latitudes 7°30'N and 7°55'N, and longitudes 4°30'E and 5°30'E. The hillside examined here is located between Ogotun and Igbara Odo on latitude 7° 30'N and longitude 5° 02'N (Fig. 1).

Ilesa-Ekiti districts are located in the humid tropics under the Aw climate of Köppen. Mean annual rainfalls for some settlements in the districts are shown in table 1. The rainfall regime is marked by a double maxima. Dry season lasts for about four months between November and February. Rainfall intensity is high with 33 % of total rainfall experienced between March and May when the hillsides are still partially exposed. Temperatures as in other parts of southern Nigeria are constantly high ranging from a mean maximum of about 32° C in February and March to a mean minimum of about 21° C in August. Relative humidities are also high ranging from about 70 % (10 a.m. G.M.T.) in January to about 95 % in July. The area is located in the tropical rain forest belt, but bare rock surfaces and poor savannah are common on the hills.

Table I : Mean monthly rainfall (in mm.)

Station	No of years	J	F	M	A	M	J	J	A	S	O	N	D	Total
Ilesa	19	7.6	25.4	83.8	124.5	162.6	167.6	167.6	86.4	210.8	215.9	63.5	10.2	1325.9
Efon-Alaye	16	7.6	25.4	99.1	160.0	180.3	149.9	127.0	147.3	238.8	180.3	94.0	10.2	1419.9
Akure	21	12.7	35.6	111.8	142.2	167.6	195.6	175.3	114.3	205.8	177.8	55.9	22.9	1417.3
Ado-Ekiti	26	10.2	33.0	99.1	124.5	160.0	170.2	124.5	91.4	223.5	177.8	73.7	15.2	1303.0
Ifaki	21	10.2	43.2	106.7	134.6	175.3	193.0	154.9	132.1	264.2	210.8	50.8	25.4	1501.4
Mean number of rain days (rainfall exceeds 0.25 mm.)														
Ilesa		1	3	9	8	11	13	13	10	15	15	7	1	106
Efon-Alaye		0	2	7	8	10	10	9	6	13	13	8	1	87
Akure		1	3	8	9	11	13	13	11	14	12	5	1	101
Ado-Ekiti		1	4	9	8	11	11	9	6	16	12	6	2	95
Ifaki		1	3	8	7	9	10	8	6	15	11	6	1	85

The hills and ridges underlain by quartzites and quartzschists trend NNW–SSE and stand at 660-770 m a.s.l. Where underlain by quartzites, the ridges are massive, standing up to 400 m above the surrounding plains and are hardly dissected due to the highly resistant nature of the rocks. The rocks outcrop to form cliff-like slopes on the hillsides. Below such cliffs are large debris slope consisting of huge boulders immersed in a matrix of coarse sands. Quartz-schists give rise to series of low hills and ridges 60-250 m above the surrounding plains. Measurements of road cuttings show that the quartz-schists have undergone deep chemical weathering varying from a few meters to more than 10 m. Rock outcrops on these low hills and ridges are rare as steep slopes more than 30° are covered by deep soils.

STUDY METHOD

Cultivated hillsides were first identified on the 1/40.000 airphoto series of the study area flown in 1962. This was followed by an intensive field coverage of the hills and ridges to identify cultivated fields not shown on the airphotos. Local farmers were interviewed about their farming techniques and the length of time the hillsides have been under cultivation. On the hillside discussed in this paper, farms extended right from the crest of the hill to the base, but near the farmland on the same hill, a patch of virgin forest extended from the crest of the hill to the base.

It is quite apparent that the best method of assessing the intensity of erosion is by instrumental measurements of the eroded sites or by measuring

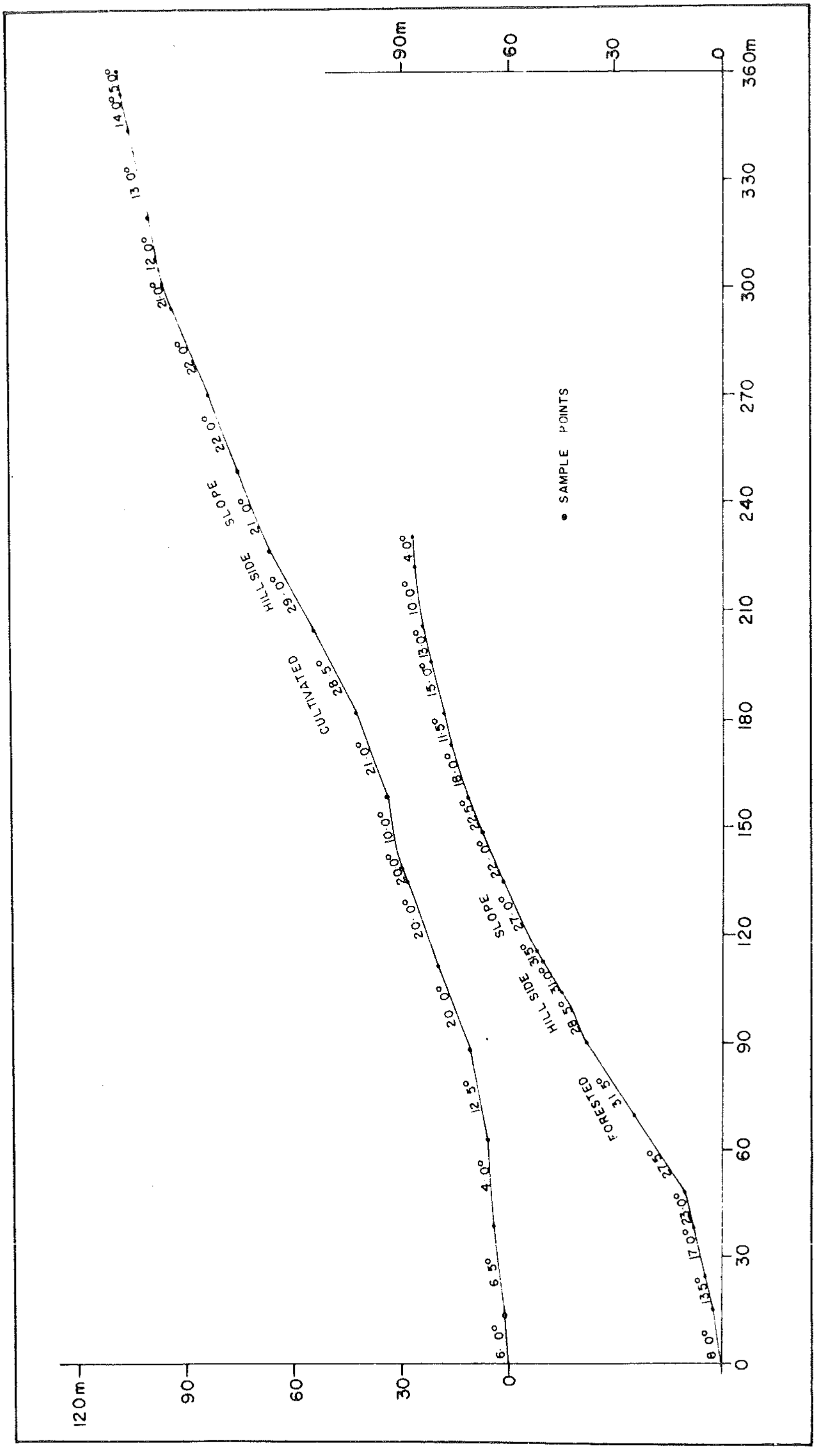
120m
90
60
30
0
0
30
60
90
120
150
180
210
240
270
300
330
360m
90m
60
30
0
SAMPLE POINTS
CULTIVATED
HILL SIDE
SLOPE
FORESTED
HILL SIDE
SLOPE

Figure 2

sediment and solute yields in the basins of rivers in areas under rice cultivation. However, the farmers did not cooperate with the first method, while the second method would not give yield from rice farms alone. The method adopted here is simply devised to assess whether or not erosion by sheet wash has occurred on the exposed hillsides.

On the farmlands, along a traverses cutting across the hillside contours, slope angles were measured from the crest of the hill to the base at 15 m interval with an Abney level. At each measurement site, top soil samples in the A horizon to a depth of 10 cm were collected. The same process was repeated in the patches of forest adjacent to the farmland. Pits, 120 cm deep was dug on the middle part of the hillsides under the forest in order to examine the soil characteristics.

The soil samples collected were analysed for texture ; pH, hydrogen, organic, phosphorous and potassium content were also determined by standard laboratory methods.

OBSERVATIONS

Figure 2 shows the cultivated and the forest covered hillsides. Both slope profiles are dominantly convex from their crests to near their bases where the convexities are terminated by relatively short concave elements. Slope angles along both profiles are rather steep ; varying from 4.0°–29.0° on the cultivated slope and 4°–31.5° on the forest covered slope.

The soil on the hillside is deep and well drained varying in colour from dark brown to brownish red with abundant quartz particles. Below is a generalised description of the soil as observed in the field :

0 – 5 cm	a well differentiated humic layer with abundant fine roots. Greyish brown sandy layer. Quartz fragments rather few.
5 – 15 cm	dark brown sandy clay with few fine roots and few quartz fragments.
15 – 30 cm	brown sandy clay with few quartz fragments.
30 – 60 cm	reddish brown slightly sandy clay with several small rock fragments.
60 – 120cm	reddish brown slightly sandy with several fist sized rock fragments.

The top soils are dominated by coarse and fine sand fractions, the content of the silt and clay fractions being very low. The percentage content of the coarse sand and other soil particles are shown in table 2.

Table 2 : Textural characteristics of the top soils

	% coarse sand			% fine sand			% silt			% clay		
	Range	x̄	s	Range	x̄	s	Range	x̄	s	Range	x̄	s
Cultivated hillside	30.6-60.6	47.45	7.29	15.4-29.5	25.42	4.03	2.0-15.4	10.39	4.03	9.4-26.8	16.7	5.54
Uncultivated hillside	38.0-60.0	47.00	7.20	14.7-30.8	22.70	5.40	6.8-17.4	9.50	3.90	10.2-34.2	20.7	9.80

x̄ mean : s standard deviation

ASSESSMENT OF SOIL EROSION

It has been observed that sheet wash in coarse grained soils as in the type under consideration involves the selective removal of the finest aggregates (H.H. BENNETT, 1939). If this is the case, it can be assumed that on any slope covered by coarse grained soils, the percentage content of the selectively eroded aggregates would decrease consistently downslope as the erosive force of the moving water increases with both distance from the divide and with consistent or increasing slope gradient. This is to say that an inverse correlation is expected between distance downslope from the hillcrest and the percentage content of the soil particles being removed. This assumption is not expected to hold under the virgin forest where little or no runoff is generated even by the most intensive rain storm. However, as shown in figure 2, the cultivated hillside is not regularly constant downslope, hence the above assumption may equally not hold.

Table 3 : **Correlation between distance downslope from hill crest and % soil particles**

Farmland	**r-value**	**t-value**	**L.S.**
Distance downslope related to coarse sand	0.11	0.40	N.S.
Distance downslope related to fine sand	0.24	0.91	N.S.
Distance downslope related to silt fractions	0.44	1.83	N.S.
Distance downslope related to clay fractions	–0.60	2.80	P.S.
Forested Hillslope			
Distance downslope related to % coarse sand	0.59	2.07	N.S.
Distance downslope related to % fine sand	0.69	2.69	P.S.
Distance downslope related to % silt fractions	0.42	1.29	N.S.
Distance downslope related to % clay fractions	0.24	0.69	N.S.

L.S. Level of Significance **N.S. Not significant**

P.S. Possibly Significant **Accepted level of significance is 5 %**

On the forested hillside, it appears that as one moves downslope, the percentage content of the fine sand increases while the other soil aggregates show no such definitive trend. The reason for this is at present not clear. On the farmland, while the other soil particles show no clear trend, it appears there is a possibly significant inverse relationship between distance downslope and the percentage clay content in the top soil except where the slope flattens out and the clay content increases. This trend could have resulted from selective erosion of the clay fractions on the exposed hillside. It could also have been due to chance occurrence caused by the irregularity of the hillside slope. A comparison of the sample means of the soil particles on the farmland and under the forest shown in table 4 shows that if the soils on the farmland have suffered erosion, the level is minimal.

While the sample means of the coarse, fine sand and silt aggregates in soils under the forest and on the farmland are remarkably identical, the sample means of the clay particles in soils under the forest are higher than those on the farmlands, although the difference is not quite significant. While not quite important, however, this difference may indicate that top soils on the farmlands are losing their content of clay fractions at a slightly faster rate than those under the forest. Alternatively this may result from the variations in the properties of the underlying rock.

Table 4 **Comparison of the sample means of soil particles**

	Farmland		**Forested slope**		**t-value**	**L.S.**
	x	s	x	s		
Coarse sand	47.45	7.29	47.00	7.20	0.154	N.S.
Fine sand	25.42	4.03	22.70	5.40	0.650	N.S.
Silt	10.39	4.03	9.50	3.90	0.560	N.S.
Clay	16.70	5.54	20.70	9.80	1.20	N.S.

DISCUSSION

Absence of Gully Erosion

In other parts of southern Nigeria, deforestation and exposure of soils on steep slopes to the violent thunderstorms characteristic of this part of the world and the repeated cultivation of the same plots with short intervening fallows have been considered among others to be the most significant factors promoting severe sheet and gully erosion (A.T. GROVE, 1951 ; B. FLOYD, 1965 and G.E.K. OFOMATA, 1965). In the study area, given all the above factors, gully erosion has not occurred. This can be explained in various ways. Time may be an important factor. It is quite possible that the time since the hillsides have been deforested and exposed to erosional agencies has been rather too short to permit gully erosion to take place. Equally significant is the fact that rice cultivation involves minimum disturbance of the soil as it does not require making of heaps and ridges whose furrows could furnish the surface irregularities necessary to initiate gully erosion. Probably more significant is the nature of the soil on the cultivated hillsides.

As observed by G.E.K. OFOMATA (1965) and M.J. KIRKBY (1969) among others, soils with high percentage of coarse aggregates as in the case of the study area (see table 2), tend to be resistant to erosion. Rain falling on a coarse textured soil in humid areas where there is some vegetal cover penetrates almost immediately so that ordinarily no runoff is produced. This means that the rate of water movement through a soil varies inversely with soil texture. Exposure of such textured soil may not necessarily reduce its infiltration capacity especially when covered by crops and when no hard pan is present in its lower horizons. Thus given any thunderstorm, runoff would be minimal, consequently little channelled erosion would take place.

Between March and April, following the period of bush clearing and burning in the study area, the soils are excessively dry. Also at this time intense thunderstorms are experienced which are expected to be effective in generating gully erosion. However, studies conducted be the staff of Institute of Agriculture, Research and Training, Ibadan (1974) show that the soils have infiltration capacity of 25-50 mm/hr.

Studies elsewhere (H.H. BENNETT, 1939 ; M.A. MORGAN, 1969 quoting Kohnke and Bertrand) have confirmed this. Although there has been no detailed study of the intensity of thunderstorms in the study area, studies by B.J. GARNIER (1953) at Ibadan have shown that only about 1/3 of all individual precipitations yield over 25 mm of rain water, while a further 1/3 yield 12.5 - 25.0 mm, and the rest yielding less than 12.5 mm. If this is the case in the study area, it means that the relatively deep coarse textured soils on the hillsides are probably capable of absorbing most of the rain water deposited at any given rainfall intensity between February and May when the cultivated hillsides are bare. Thus with the high infiltration capacity of the soil and the absence of any significant amount of runoff, gullies are remarkably absent on the cultivated hillsides.

Soil Deterioration and Erosion

As mentioned earlier, it appears that the soils under constant cultivations, at least in the A horizon have suffered a loss of their clay fractions to some extent. This may be ascribed to various factors including leaching, illuviation, raindrop-splash erosion, erosion by unchannelled runoff and by throughflow.

Monocultivation for several years without adequate application of fertilizers and with the very short fallows inadequate to permit the natural restoration of essential nutrients can lead to a serious deterioration of the soil. Nutrients could be lost through burning of the cleared rubbish which leads to loss of organic carbon, nitrogen and sulphur content of the soil and a decrease in the effectiveness of the colloidal material present in the top soil. Cultivation, at least before the soil is completely covered by crops further exposes the soil to extremes of temperature and widely fluctuating conditions of humidity which lead to soil dessication and the rapid oxidation of its organic content. Nutrients could also be lost through constant withdrawal by the cultivated plants and through leaching.

Table 5 shows the nutrient status of the soils under cultivation and those under forest in the study site.

Table 5 : **Comparison of the nutrient status of soils in the study area**

	Farmland		Forested slope		t-value	L.S.
	X	S	X	S		
pH	6.02	0.72	5.70	0.65	1.07	N.S.
% Total Nitrogen	0.57	0.30	0.68	0.27	1.71	N.S.
Organic Carbon	6.80	3.40	10.50	4.26	2.30	P.S.
Average Phosphorus lb per hectare	28.17	14.08	48.75	21.10	2.73	P.S.
Average Potassium lb per hectare	405.36	89.95	589.36	232.58	2.40	P.S.

P.S. Abbrevations as in tables 2 and 3

From the above table, it is apparent that soils under cultivation on the hillside have lost some essential plant nutrients as compared with the uncultivated soils under the forest. A significant aspect of this soil deterioration is the increase of the acidity and the decrease of the organic carbon in the cultivated soils.

As earlier observed, the coarse textured soils is highly permeable. Percolating rain water which is a dilute solution of carbonic acid can thus leach nutrient ions from the exposed clay-humus complex in the cultivated soils. Since the rate of replacement of organic matter into the soils is too slow due to short fallows, leaching continues leading to high level of acidity in the soil. With a fairly high degree of acidification, clay decomposes and could be subject to mass transfer either by percolating water or by through flow especially on the steep slope. Also it is well known that burning reduces the effectiveness of the colloidal material in the top soil. With repeated burning as in the study area, clay and humus colloids in the top soil may be deflocculated. The molecules become mobile and can be moved down rapidly into the soil by percolating water. The upper soil horizon thus tends to become poorer in clay and relatively richer in coarse particles.

With the exposure of the soil to the thunder-storms at the on-set of the raining season, rain drops can effect some amount of erosion. It has been observed that splash-back by rain drop impact on an exposed soil surface can transport coarse soil particles up to 40 cm and fine soil particles up to 150 cm in all directions (M.J. KIRKBY, 1969). It is equally significant to note that at any given rainfall intensity the distance of movement decreases with increasing particle size. On a steep slope as in the case of the study site, the movement of individual particles displaced by rain drop impact would be in a downslope direction, and this could lead to a net movement of soil particles especially the finer aggregates downslope. Soil materials could be displaced downslope not only when the soil is exposed to the thunderstorms at the on-set of the raining season in February to April, also when the soil is cultivated to rice. As rice grows in separate stands about 0.5 m apart and suppresses the proliferation of weeds, gaps exist between the crops facilitating rain drop impact with the bare soil surface to displace soil particles downslope.

Unchannelled overland flow and throughflow could also have contributed to the loss of finer soil aggregates in the top soil. As earlier observed, the soil on the hillside is coarse textured in the A horizon becoming clayey with depth. Its permeability and its infiltration capacity thus decrease with depth. Given the large amount of precipitation in this area, it is conceivable that by the end of the raining season, water may not be able to percolate into the lower layers fast enough as it is being transmitted by the highly permeable upper layer. Once this happens, water is deflected laterally downslope within the upper layer on the steep slope as throughflow. Throughflow moving in a downslope direction is capable of transporting the mobile clay molecules in the soil towards the base of the hill and to adjacent river valleys. Under exceptional conditions of rainfall when the infiltration capacity of the soil is less than the rate of fall, unchannelled overland flow may be produced which is equally capable of eroding and transporting the finer soil particles downslope.

CONCLUSION

In this paper, it is observed that given the intensive cultivation of steep hillside to rice in Ilesa-Ekiti districts, and given most of the factors that can promote erosion like deforestation, monocultivation over a long period, steep slopes and intensive thunderstorms, gully erosion has not occurred and sheet erosion appears to be minimal on the farmlands. Some reasons were adduced for this the most important being the texture of the soil and its high infiltration capacity.

The slight loss of finer soil aggregates in the cultivated soils is ascribed to bush burning, exposure of the soils to extremes of temperature and humidity conditions short fallows and the consequent acidification and leaching of the soil. Raindrop-splash erosion and erosion by through flow and unchannelled flow could also have been contributory factors. Although the level of erosion is minimal, it is apparent that if the present trend continues, severe sheet erosion and soil impoverishment with the attendant low yield may result.

It must however, be emphasized that the data on which this report is based is too scanty to permit any firm conclusion about the severity of sheet erosion on the cultivated hillsides. A firm conclusion about this must await the results of further investigations especially instrumental measurements from a large number of study sites.

REFERENCES

BENNETT, H.H. (1930) – Soil Conservation. New York.

FLOYD, B. (1965) – Soil Erosion and Deterioration in Eastern Nigeria : A Geographic Appraisal. *Nigerian Geographical Journal*, v. 8, pp. 33-44.

GARNIER, B.J. (1953) – Some comments on the rainfall at the University College, Ibadan, during 1952. *Department of Geography, University College, Ibadan Research*, Note 3, pp. 15-20

GROVE, A.T. (1951) – Land Use and Soil Conservation in parts of Onitsha and Owerri Provinces. *Geological Survey of Nigeria, Bulletin*, v. 21.

KIRKBY, M.J. (1969) – Infiltration, Throughflow and Overland flow, in Chorley, R.J. (ed.). *Water, Earth and Man*, London.

MORGAN, M.A. (1969) – Overland flow and Man, Chorley, R.J. (ed.). *Water, Earth and Man*, London.

OFOMATA, G.E.K. (1965) – Factors of soil erosion in the Enugu area of Nigeria. *Nigerian Geographical Journal*, v. 8, pp. 45-59.

PUGH, J.C. (1955) – The Geomorphology of the Northern Plateau of Nigeria. Unpublished Ph.D. thesis, University of London, London.

SMYTH, A.J. & MONTGOMERY, R.F. (1962) – Soils and Land Use in Central Western Nigeria. Ministry of Agricultural and Natural Resources, Ibadan.

DISCUSSION

J.P. de Queiroz Neto : Les données des analyses granulométriques montrent une diminution de la teneur en argile dans les horizons de surface des sols cultivés par rapport aux sols de forêt : la mise en culture déclencherait une migration (ou une augmentation de la migration) verticale de l'argile et un enrichissement de l'horizon B ?

L.K. Jeje : In the absence of any substantial surface run-off under the forest, it appears that rain water percolating into the soil has led to the leaching and illuviation of bases and clay aggregates from the A to the B horizon. The forest soil studied exhibits an increase in clay content with depth since the cultivated soil is covered most of the time by weeds and rice, and because of its high infiltration capacity, run-off on it is minimal. The same process of leaching and illuviation operating under the forest may equally be in action in the soil. However, in the absence of any detailed studies, one can not be sure of the clay enrichment of the B horizon of the cultivated soil.

J. Savat : Were you able to observe overland-flow ?

L.K. Jeje : The only time it rained when I was in the field, no overland-flow was noticed both under the forest and in the farmland. However the amount of rainfall was rather too low.

M.F. Thomas : Are the slope cultivated continuously from summit to the base of the slope ?

L.K. Jeje : In most places, this is the case except where the lower slopes have been found unavailable to the crop.

M.F. Thomas : Is it possible that the quartzite bedrock will have a high permeability which would contribute to the continued stability of the slope ?

L.K. Jeje : This may be an important factor in the stability of the slope, but the high infiltration capacity of the soil appears to be more important in this regard.

J. Dresch : Demande quelles sont les techniques agricoles de culture du riz sur versants qui permettent une conservation de l'argile du sol qui soit de peu inférieure au taux d'argile sous forêt ?

L.K. Jeje : Rice cultivation is done by simple planting of the seeds whithout heaping or ridging of the soil. The little difference noted between the clay content of surface soils under cultivation and under the forest may be because the soil surface has not been exposed for a long time. With longer exposure, one can predict that cultivated soils will be more impoverished of its clay aggregates at a definitely higher rate that uncultivated soils under the forest.