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Oil palm and coconut soils in West Africa

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In the previous number (4) we presented the soils formed on quaternary sands and tertiary sediments. In the pages which follow we describe other soils developed on the basement complex rocks and volcanic and river deposits.

Part II. — Basement complex rocks. — Volcanic and river deposits.

III. — BASEMENT COMPLEX ROCKS

The basement complex rocks is below the quaternary sands and tertiary sediments. For more than two milliard years its crystalline and metamorphic rocks have undergone many processes of soil formation such as weathering, decomposition, leaching desaturation, truncation, redeposition, etc... These processes have worn down the peaks of the mountains and ancient hills and filled hollows and valleys. It is in this way that the South of West Africa has become a quasi-peneplain slightly inclined towards the coast.

1. — Physiography.

The quasi-peneplain of the basement complex rocks is composed of flattened hills surrounded by valleys. The width of the hills and the density of the more or less swampy valleys depend partly on the permeability of the soils and partly on the local rainfall regime. Thus, for the same rainfall, a region with permeable soils of medium texture has wider usable interfluves than one with fine-textured, almost impermeable ones; in the first case, the width of plantable land may be as much as 1,000-2,000 m or more, whilst in the second the hills or interfluves are rarely more than 500-700 m wide.

The influence of the type of parent rock on topography and hydrography is clearly illustrated by the contrast between shaly and granitic zones. In general, land made up of granite material forms a large plain of wide, flattened hummocks surrounded by broad valley bottoms, whereas that composed of schists often has low hill chains closer together and cut up by numerous deep valleys. One of the consequences of this soil formation is a very great variety in the relief and morphology of the profiles.

In other respects, the annual rainfall and its distribution are dominant factors determining the surface relief. For example, an annual rainfall of 1,500-2,000 mm evenly distributed usually goes with a landscape which is very little cut up. On the other hand, a region which gets the same rainfall but has one or two very rainy months (nearly 1,000 mm) will be excessively carved up and make rational plantation lay-out impossible.

The altitude of the lands on the base ranges from about 20 m close to the coast to nearly 200 m inland.

The topography of areas chosen for plantations on the base is generally flat to gently rolling, with slopes of less than 10 p. 100 in most cases.

2. — Vegetation.

Evergreen forest of *Diospyros* spp and *Mapania* spp covers the humid tropical zones with a short dry season, whilst that of *Eremospatha macrocarpa* and *Diospyros mannii* occupies the humid tropics with a long dry season. In both types Sodefor (1977 [28]) has inventoried many marketable species in the Ivory Coast.

Tree counts made by the I.R.H.O. in Liberia [15] suggest that areas with a very high rainfall (3,900 mm) have fewer big trees with a diameter of 60 cm or over than where annual rainfall is close to 2,000 mm (Table IX).

3. — Soils

The substratum of the West African quasi-peneplain consists chiefly of gneiss, schists, migmatites, quartzites, granites and, to a lesser degree, of diorites, amphibolites, green rocks, etc.

The climatic cycles of alternate dry and wet periods in the last two milliard years have been responsible for the pedogenesis from which the following three elements are derived:

- fine soil particles often with a clay sand to clay texture;
- quartz pebbles and ferro-manganese or ferro-aluminum concretions, frequently called laterite gravels;
- pieces or blocks of decomposing and exfoliating rocks and pieces or crusts of indurated laterite.

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a) Land use classes and nomenclature.

Depending on the proportions of the above three elements [3] (colluvial and/or collo-alluvial), and the degree of hydromorphism of the locality, four Land Use Classes are distinguished :

Very good soil — Land Use Class 1 (LUC 1) (1).

Healthy soil, humiferous topsoil, sandy to sandy clay, subsoil clay sand to sandy clay, little or no gravel down to 110 cm and no signs of hydromorphism before 80 cm.

Good soil — Land Use Class 2 (LUC 2).

Healthy soil as in LUC 1, except for the 80-110 cm horizon, which can be indurated or cemented.

Medium soil — Land Use Class 3 (LUC 3).

Soil with the characteristics of LUC 1 except for :

- the proportion of gravel, which is about 30 p. 100 : LUC 3g ;
 - signs of hydromorphism starting 60 cm deep : LUC 3h ;
- with suitable drainage these soils can be classed with the good or even very good ones.

Poor soils — Land Use Class 4 (LUC 4).

In this class are found all the soils formed of leached sands and those more gravelly or more hydromorphous than the above :

- 4 a or 4 b : 50 p. 100 gravel or more ;
- 4 h : signs of hydromorphism in the first 50 cm ; these soils can be improved by drainage of the topography permits.

Also in this class are :

- soils with a leached sand or compact clay texture ;
- permanently hydromorphic gleys and temporarily or semi-permanently, hydromorphic pseudogleys.

Table X gives the physico-chemical characteristics of a few soils planted in oil palm and coconut, and Table XI the equivalence between the LUC and the different classifications.

b) Physical and chemical properties (Table X).

* Physical properties.

The soils derived from the basement complex rocks have a silty clay loam topsoil, grey-brown to reddish brown (5YR 4/8), structure medium crumb to fine subangular blocky, brittle, and a very clayey to silty clay loam subsoil (20-50 p. 100 clay), red to ochre (2.5-5YR 4-5/6-8), fine to medium blocky structure, slightly to fairly hard (Soil No. 21). Their water-holding capacity is usually satisfactory.

Soils derived from acid rocks such as quartzite have a grey-brown clay sand topsoil (10YR 3-4/2), granular structure, brittle, and a silty clay loam subsoil, yellow to brownish yellow (10YR 6-8/6-8), lightly developed angular blocky structure, slightly to fairly hard (Soils No. 27 and 28). Their water-holding capacity is usually lower than that of soils derived from base rocks.

Soils formed of colluvial mellow deposits are mainly found on the foot slopes and have profiles similar to those developed *in situ* on the plateaux. However, their topsoil is lighter than in soils at a higher altitude.

The colluvions derived from the base rocks are red and have a heavy texture, with 30-60 p. 100 clay (Soils No. 29, 30, 33 and 34).

The colluvions from acid rocks are paler — ochre or brown to yellow — and have a lighter texture with 10-30 p. 100 clay (Soils No. 31, 32, 35-37, 39-43).

Soils formed from volcanic deposits within the basement complex are few ; they are mainly to be found in West Cameroon, near Mount Cameroon. Their topsoil is black to dark grey-brown silty clay loam (10YR 2-3/1-2), the structure fine crumb, friable, and a clay to silty clay loam subsoil, brownish yellow to yellowish brown (10YR 4-6/4-8), breaking into medium subangular blocks, greasy and slightly firm. They are mellow and have a good water-holding capacity (Soils No. 44-48).

* Chemical properties.

The N and P levels in the soils of the basement complex are variable but often low. Moreover, there are K and Mg deficiencies

in soils derived from different types of parent rock. Exchangeable K levels are mostly low. Mg levels vary (Table III, Part I).

Soils formed on volcanic ash generally have high N, K, Ca and Mg levels, but P, on the other hand, is low (Soils No. 44-48 and Table III).

4. — Management practices.

The combination of slow internal drainage in soils of heavier texture and torrential rains during part of the year favour overland flow and formation of a dense network of gullies, water courses and swamps. Therefore the plantable plots on soils of the basement are smaller and more cut up and scattered than on tertiary sediments. Mapping them requires much more detailed soil and topographical surveys than on the other formations.

Clearing and windrowing of land on the base is done with the same equipment as in the tertiary sediment zones. These operations should take place during the dry season only, or at least during the least rainy periods, so as to preserve the good structure of the surface soil as far as possible.

Construction of the road network is the same as on tertiary sediments, but the network has often to be adapted to the relief. Secondary roads stop at the watercourses and large swamps. Main roads must be laid so as to disenclose all the plots, and should preferably follow the skyline to reduce embanking. Side drains will dry the road surface.

It should be borne in mind that the greater the area of very gravelly soils unsuitable for oil palm, the smaller the plantable area ; also, if there is a high proportion of gravelly soils, the plots will be much more cut up and scattered.

Figure 2a shows the case of a terrain in which the soils are chiefly gravelly. Note the long, narrow shape of plots K and J.

In Figure 2b, on the contrary, most of the soils in the area have little or no gravel. Plot Q is larger and more compact.

The high proportion of gravelly soils also reduces the ratio « plantable areas (SP)/areas studied (SE) » (Table XII).

5. — Fertilization.

Because of their low P level soils formed on the base often require phosphate manuring, both for oil palm and for coconut. Even then, not much is needed, and the annual rates are between 0.5 and 2 kg single superphosphate (20 p. 100 P₂O₅)/tree at maturity.

As on tertiary sediments, N manuring is limited to the first years and annual rates do not exceed a few hundred g of urea/tree.

K fertilization is a key factor in yield, as it is on sedimentary soils. The annual rates required are mostly 1-2 kg KCl/mature tree. In the early years of planting, little or nothing is needed. This similarity between the two soil formations is due to the common characteristics of their absorbant complex (kaolin, acid pH, low C.E.C.).

Where there is a need for Mg manuring, it rarely exceeds 500-1,000 g Kieserite/tree/year.

The development of the middle Ivory Coast was undertaken in 1973, with the promotion of hybrid coconut smallholdings on colluvial soils on the foot slopes and in hollows. This region has a low rainfall and a long dry season, and mineral nutrition experiments have shown that :

- KCl is always essential for yield and also for drought resistance ; annual rates starting at 0.2 kg at field planting to reach 1-1.5 kg by the fourth year are sufficient ;

- Kieserite is needed for the first six years only ; the root system of adult trees can explore the soil sufficiently after that ;

- urea and phosphate are limited to the first three years, and a few hundred g/year are enough.

Volcanic soils are not very demanding of fertilizer. On the basis of experimental results, Ochs [18] advises small doses of ammonium sulphate and KCl in the early years of planting (Table IV — Part I).

6. — Potential.

The potential yield of hybrid coconut is about 5.5 t/copra/ha/year for zones with an annual water deficit below 100 mm. Where the deficit is 400-100 mm/year, yield is between 3 and 5 t copra/ha. A performance trial at Daloa, Ivory Coast,

(1) Soils which are good or very good chiefly from the physical standpoint. Any chemical deficiency can be corrected economically by manuring, if this deficiency is not excessive.

planted on red clay soils, produced 2.5 t copra/year at 8-9 years in spite of a mean annual deficit of 520 mm.

With oil palm, yields depend on annual water deficit, as shown already in Table VIII (Part I).

IV. — TAMABO RIVER ALLUVIAL PLAIN IN THE IVORY COAST

Alluvial plains in zones of favourable ecology are often small, and there are few large oil palm and coconut development projects on this type of land. The alluvial plain of the Tamabo river (a tributary of the Bandama River) is exceptional in that it covers nearly 10,000 ha. At the present time the development of large alluvial zones in other countries, i.e. the Oueme and Mono valleys in Benin and especially the Niger delta in Nigeria, where higher yields could be obtained than on the neighbouring plateaux is blocked by the cost of the special improvement required (diking, for example).

1. — Physiography.

The topography is flat, slightly tilted in the direction of flow of the main waterway. There are many secondary watercourses and gullies which can be used later to drain excess water during heavy rains.

The difference between the overall level and that of the bed of the main watercourse is about 5-10 m, and the average width of the drainage basin is 8,000 m. The slope is therefore 1-2/1,000, sufficient for proper drainage.

2. — Vegetation.

The alluvial plain is occupied by three types of vegetation :

— swamp forest, with *Symphonia globulifera* and *Mitragyna ciliata*, covers the gleys and pseudogleys ;

— evergreen forest with *Eromospatha macrocarpa* and *Diospyros mannii* predominates in the areas of emergent land near the ocean ;

— evergreen forest with *Diospyros* spp and *Mapania* spp covers the emergent zones upstream.

There are few large trees in the swamp forest ; fewer than 160 per ha have a diameter over 30 cm. In other respects, the trees often have aerial roots. On wet lands which have been cleared and are now fallow, *Marantaceae* predominate.

3. — Soils.

Generally speaking, there are three groups of soils :

— SFFD typiques or remaniés (helvic ferralsols), occupying the old outliers, already described in para. III-3 ;

— SFFD appauvris, hydromorphes (dystric gleysols) covering the transitional zone between the outliers and the alluvial plain which surrounds them ;

— Sols hydromorphes minéraux à pseudogley (ochric gleysols) of the alluvial plain itself.

Where the water deficit is low, good yields can be obtained from both oil palm and coconut on all these soils on condition that they are correctly improved. On the other hand, with a high water deficit the soils of the outliers produce much lower yields than the hydromorphic soils in which there is a water table 1-3 m down which will feed the plant during a large part of the dry season.

a) Nomenclature

The soils of the outliers and foot slopes are among those derived from the basement complex rocks already mentioned in para. III-3.

The hydromorphic mineral gleys and pseudogleys of river origin are called « gleyic fluvisols » and « dystric fluvisols » in the FAO-UNESCO classification.

b) Physical and chemical properties

The pseudogleys (gleyic fluvisols) have a dark grey-brown to dark yellow-brown topsoil, medium crumb structure, friable. The texture is medium to heavy and the clay content from 20 to 30 p. 100.

The subsoil is grey with red to ochre stains. Its structure is massive, breaking into slightly hard angular blocks. The texture is heavier, the clay content ranging from 30 to 40 p. 100. Kaolinite and, to a lesser degree, montmorillonite and illite, are the chief clay minerals.

Porosity is satisfactory and there is a good water-holding capacity. The effective water reserve between the field capacity and wilting point is usually more than 10-15 p. 100.

The pH is generally acid, 4.4-5.8. The organic matter, C, N and P contents are middling to low. The C/N ratio is from 7 to 12 and indicates good mineralization of the organic matter. The exchangeable cation contents are medium to low, and the C.E.C. satisfactory (Table III).

4. — Management practices.

The topsoil of alluvial soils is of good porosity and well drained internally. Land preparation for oil palm must be done with light machines so as not to destroy the good soil structure.

Felling can be done by wide-track, medium h.p. caterpillar tractors fitted with Rome plows. Chain saws will be used for trees of more than 60 cm diameter, the stumps being left in place. It is preferable to windrow with Fleco-type rakes to avoid shifting the topsoil.

The recommended dimensions for oil palm plots are always 252 m N-S and 1,006 m E-W. The roadways of all the collection and service roads should be raised with a thick layer of laterite as well as bordered by side drains.

It is also possible to install simple sluices towards the end of the rainy season to dam the water in the drains and slow down the fall of the water table during the dry season which follows.

5. — Fertilization.

Fertilizer trials determine the types and quantities of fertilizers necessary for oil palm plantations on reclaimed alluvial plains.

6. — Potential.

Oil palms planted on alluvial soils are provided with water from the water table during most of the dry season, and will have a yield about 20 p. 100 higher than that of plantations on the neighbouring plateaux (13 t B/ha/year on an average).

CONCLUSION

It will be seen that West African soils offer vast areas of land suitable for oil palm and coconut stretching from Guinea to Cameroon. The extension of these crops is limited more by climate than by edaphic conditions. Where the ecology is favourable, oil palm and coconut are among the most profitable crops, and many countries have undertaken large development programmes in the last 20 years, often in the form of a nucleus plantation surrounded by smallholdings, so as to meet their growing domestic needs.