ST. LUCIA BANANA LANDS.*

OBSERVATIONS AND COMMENTS ON SOIL CHANGES IN RELATION TO TROPICAL AGRICULTURE.

THE present paper records soil changes observed when virgin forest land is subjected to exposure and climatic influences by removal of the natural vegetation and by the substitution of a temporary crop, followed by a final re-invasion of a low type of flora.

As a generalisation which holds true for most tropical countries, it may be said that tropical agriculture falls into two fairly well-defined categories; in the first, definite agricultural operations, such as tillage, fertilising, and soil improvement, are undertaken, while in the second category methods of clearing virgin forest and cropping with the minimum of cultivation necessary to plant and raise the crops are adopted, such as the firing of bush for planting roots, the digging of holes for root stocks which are merely covered with a layer of soil, and the annual brushing of weeds in established crops. Examples of both classes are of frequent occurrence in the West Indies and Central America. According to the methods pursued different kinds of biological processes will be set in motion which may ultimately become of very great agricultural significance. In short, the soil will either undergo progressive amelioration or progressive deterioration.

The writer has seen virgin land cleared for large-scale banana production, the raising of banana crops, the ultimate collapse of the industry, the withdrawal of all supervision from cultivated areas, followed by the re-establishment of a natural flora. Careful observations have been made over a period of five years, on the original soil conditions and its plant population, the exploitation of this soil under banana cultivation (which it should be noted falls into the second category as above) with a concluding survey of the present state of the soil in derelict banana lands. These observations have shown that there are certain important influences which will affect tropical agriculture conducted along these lines.

Opening of banana lands.—The Banana Company was probably the first to clear large areas of virgin forest in St. Lucia for a pure crop. New tracts of land had, in the main, been taken up cautiously and planted tentatively in a short period crop such as sugar-cane, which as a pioneer crop was utilized to break up the soil and promote a superficial tilth. One or sometimes two of the long period crops such as coconuts, cocoa or limes, usually followed in the second or third year, with plantings of bananas and other accessory crops.

There was thus little available information as to the changes resulting from the removal of the heavy and ancient forest vegetation and its substitution by a comparatively light crop, such as bananas. It is interesting to note that the large-scale physical effects occasioned by the loss of the protective forest canopy began to be obvious within two years from the

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removal of the forest, and took the form of landslides and eroded surfaces. Similar but more intensified conditions have been recently reported by Hill as appearing in Jamaica, following the replacement of forests by coffee plantations. In view of these and other instances such defects cannot be regarded as accidental but predetermined, given the coincident factors of soil formation, declivity and rainfall, with the absence of protective vegetation.

The apparent reason for the selection of forest land was the belief that it was naturally fertile and had a fairly high rainfall; there was the additional advantage that an extensive area was available for development.

Topography of banana country and climatic conditions.—The elevation of the site selected for banana cultivation was 400 feet above sea level, in a mountainous and broken region at the foot of Mt. Lacombe, a peak over 1,480 ft. high, arising from the central ridge and watershed of the Colony. The land in this area consists of a series of moderately steep slopes lying at angles of 25° to 45° mostly facing west and north and forming the foot of the central ridge. In the upper areas these slopes end in abrupt banks enclosing small streams and forming shallow embryo cañons, which on lower levels widen out and expose the underlying igneous rocks forming the bed of the stream. These wider river valleys appear to be an advanced stable stage of the cañon-like formations still found in the upper areas, and represent continued erosive action of rainfall and streams in washing out the soil in the upper and middle areas and generally smoothing down the projecting land masses. Much of the soil so removed has been transported down stream and has formed to some extent the larger and fertile alluvial valleys near the sea.

The upper lands around the sources of the cañon-like streams have not yet been smoothed out, owing largely to the protective effect of the forest canopy in reducing erosion. They show no rocks or consolidated material, and where exposed by removal of the forest trees, rapidly scour away and form landslides, which precipitate the surface soil into the streams and carry it into the lower valleys. Such lands are naturally in a state of instability owing to the effect of erosion and climatic stress, and these effects are greatly accelerated by the removal of the forest canopy. One purpose of this paper is to point out how the soil is degraded and agricultural operations are interfered with, unless means are taken to consolidate the soil *in situ* before degradation has progressed too far.

The banana lands lie within a yearly rainfall contour of 100 inches, the maximum precipitation being from 4 to 5 inches in one day. High winds are usual during rain storms and in combination with the rain drops produce a drilling effect on the exposed soil, which being of a clayey nature soon becomes water-logged and insecure on its bedding of weathered soft rocks.

The fairly wide range of air temperature (from 62° to 88°) which obtains in this region is an important factor in promoting denudation of exposed sites. In the forest, however, the range is less, the maximum temperature being depressed by the heavy shade and constant high humidity. An effect of this buffer action is to reduce evaporation and retard the upward movement of soil water. When the forest vegetation is removed other factors come into play to promote desiccation, the chief of these being the absence of transpired water vapour, the depression of humidity, the formation of drier air currents and an increased range of temperature, due to exposure to the direct rays of the sun. These factors combined with direct rainfall tend rapidly to remove the accumulated humus which is not replaced by natural agencies until a crop is established or some form of vegetation covers the soil.

SOIL AND FLORA OF VIRGIN FOREST.

(*a*) *Soil.*—The soil of this region consists of weathered volcanic matter derived from the washings and denuded material of the igneous agglomerates, tufas, brecchias and grits, which have decomposed in the direction of hydrated silicates of aluminium, iron and magnesium. The soil profile is thus influenced to a great extent, both in colouring and texture by the presence of these elements, and shows all gradations from a yellowish to bright-red lateritic clay on the surface to a vari-coloured kaolinized soft rock or soapstone below. As mentioned before no surface rock is present, and where the underlying decomposed rock is exposed as in road cuttings or landslides it quickly breaks up into granular fragments in which iron oxide is conspicuous, and is thus added to the soil. The absence of gravels and rock fragments in this type of soil renders natural drainage defective and this is to some extent responsible for the peculiar changes mentioned below which follow deforestation.

(*b*) *Flora.*—The vegetation of this region is of the tropical rain forest type, and has reached a stage of dominance and comparative stability (forest climax) until artificial agencies (biotic factors) intervene. These include selective felling and general removal of timber for agricultural development. So far as can be observed no natural afforestation takes place once the climax forest is removed, and the reason is probably to be sought in subsequent soil and climatic changes. The rain forest is composed of three well-defined strata of vegetation, the upper forming a fairly dense canopy at about 80 to 100 ft. above the ground, and consisting mainly of solitary specimens of Balata, Courbaril, *Inga, Andira and Richeria,* above which rise the loftier forms such as *Sloanea, Nectandra* and *Bursera.* Below the canopy is a sub-stratum of short trees and tall shrubs, including several palms, viz., *Asclepias, Clavija, Thrinax* and *Acrocomia,* this is discontinuous and varies according to light intensity and exposure. The ground vegetation consists of short shrubs and creeping herbs, the latter only being conspicuous where the light is more intense.

The absence of any form of close-growing surface vegetation on the forest floor, such as mosses, dwarf ferns, &c., is interesting in view of the strong succession of herbs which invades an area cleared from forest. It may be due to some extent to the absence of light, although the forest bryophytes generally have but a poor light requirement. It is probable that a more definitely inhibiting factor is the loose mass of slowly decaying vegetable matter which accumulates on the undisturbed forest floor to a depth of from two to three feet in the absence of sunlight or other desiccating agencies. This layer of "raw humus" resembles the Hochmoor peat formations, typical examples of which have been found in St. Lucia in undrained low-lying land under cultivation where remains of a buried forest flora still exist in a fairly well-preserved state.

Soil conditions at time of planting.—Two main soil types will be taken as instances conforming to general conditions observed at the time of planting bananas. Soil type No. 1 was observed in planting the nursery in 1923 and soil type No. 2 in planting the hillslopes of new areas opened up in 1926. Soil type No. 1 found in the site described as the nursery in this and a former paper was part of the first area of forest land exploited by the Banana Company. The site consisted of about 200 acres of forest land lying along the north-western slopes of a moderately steep ridge running out from the foot of the central peak previously mentioned and was more exposed to the prevailing winds than land described under soil type No. 2.

The soil consisted of a brownish-yellow clay loam and was typical of the forest soils in their area. It was covered by a loose layer of forest litter, the original deposit of which had apparently decayed and brought about a

definite colour and texture change in the first three to six inches of soil immediately underlying it. The top layer was distinctly darker and looser than the sub-surface soil. At twelve inches the latter was a brownish-yellow smooth clay loam becoming more compact and tenacious as depth increased. Only the stronger primary roots of forest trees appeared to penetrate more than two feet, the principal root section being the first 18 inches as seen in the root profiles taken in this area. The soil puddled readily in wet weather but responded to aëration and liming by changing in colour from brownish-yellow to brownish-grey and forming a definite crumb structure, a change observed in the strictly localised spots where bananas had been removed and the soil limed.

Soil type No. 2 found on the westward slopes of Mt. Lacombe (previously under forest) was not exposed to the prevailing winds as was No. 1. Its characteristics differed from the former by being apparently less weathered, and with less admixture of humus, while the forest litter was rather more matted and overlaid a shallow root stratum. The soil was a yellow clay showing little differentiation with depth and in its general character appeared to be an earlier stage of soil type No. 1. This soil became very sticky in wet weather and was naturally retentive and difficult to work; no observations on liming were made as no lime was applied at any time; the effect of aëration was temporarily to granulate the soil in large particles, but these broke up again when the soil became saturated.

Method of cultivation practised on banana lands.—It now falls to discuss how these soils were treated and the nature of their response. In the first place the object of growing of bananas in the forest land was to take advantage of the fertile soil and the moderately large areas available, so that planting and cropping could alternate without a break in fruit supplies. It is thus readily understood that sites found to be unproductive would be abandoned for new land taken from the forest, rather than an attempt being made to bring the unproductive soils into bearing. A further inducement was found in the presence of Panama disease of bananas, although this disease was not confined to the unsuitable types of soil. The type of cultivation practised thus falls within the second category mentioned at the beginning of this paper.

The method of treating the forest land preparatory to planting bananas consisted of felling the forest trees, and burning or moving aside the larger logs where these interfered with planting operations. The ground was then cleared of the remaining bush and holed ready for the banana plants. Contour drains were cut along the slopes to take off the surface water, and in some areas the banks of soil thrown up were levelled and planted with a legume, *Canavalia ensiformis*.

Forking and trenching was not practised as part of the cultivation programme and no manures were incorporated in the soil, as it was considered that sufficient organic matter would be supplied by the decay of forest logs. The application of lime was solely intended for destroying the chopped remains of diseased bananas.

Cultivation was thus a matter of direct exploitation and as elsewhere the first returns of the crop were sufficiently good to endorse this practice. The subsequent and rapid degradation of the soil goes to show, however, that the initial crop production was not a true index of the staying fertility of these lands when subject to intensive cropping. The latter could only continue in the presence of some natural agency which would replace the utilised plant-food and humus. In the absence of such safeguards, the regression of the fertility of the forest soil must be regarded as a natural consequence.

Progress and termination of banana planting.—The methods pursued in the earliest stages consisted of clearing and planting a stretch of land in bananas without discrimination as to soil types. It was soon found, however, that certain areas were unproductive, and the conclusion was drawn by comparison of earlier sites with present remains of cultivated areas that these unproductive soils had already been exposed and were already in a state of deterioration at the time of planting. As similar conditions can now be seen in large sections of banana fields attention may be drawn to the fact that the succeeding stages of exposed forest land can be roughly foretold by an examination of adjoining forest lands which have been subjected to intermittent cultivation without the modifying effects of cover crops and windbreaks.

The decision to end the banana industry was due to the want of capital to complete marketing arrangements and not to insufficient production. It should be added that for some time previous to total abandonment, several fairly large areas of banana land had been thrown out of cultivation through being unproductive, and a discussion of the conditions obtaining in such unproductive areas is given below.

Unproductive and derelict banana lands.—The most striking evidence of regression of soil type was shown in the nursery site previously described as soil type No. 1.

(*a*) *Regression of soil type No. 1.*—In comparing this soil at the time of abandonment, two to three years after deforesting, with that existing at the time of planting the most marked change observed was the loss of humus covering, and on a larger scale the looseness of the soil mass, evidenced by frequent landslips, whilst a further feature was the loss of the isolated clumps of forest trees at the top of the ridges.

The shallow layer of good soil had already been heavily drawn upon and now failed to support healthy banana plants, except in the pockets of good soil which remained at the bottom of some of the slopes. Exposed banks and hummocks were the first to give out and in the subsequent erosion which followed, detritus was carried down on to the good soil and effectually reduced the planting value of the lower areas.

More recent observations show that this degradation has continued until the greater proportion of the surface soil has been transported or covered up and has been succeeded by a soil type of lower agricultural value which supported a secondary flora where practically no bananas were found.

In such sites as remain undisturbed the soil characteristics are markedly different from those observed in the early stages of cultivation, and there is evidence that a definite pan formation has replaced the smooth clay loam formerly in existence. A characteristic soil profile examined in the vicinity of a small banana plant revealed several features: The plant was seen to be subsisting on the top three inches of humus, which was covered by a compact layer of *Commelina cayennensis*. The six inches of soil immediately below the layer of humus was brownish-grey in colour and of a rough, coarse structured loam in which no roots were found. The exposed eight to ten inches of subsoil below this was a compact grey and uniform silt free from fragments of loam or humus, and showing a well-defined pan formation. The general appearance of the soil, particularly the lower, suggested a thoroughly leached condition, whilst the surface mat of humus preserved from decomposition by the covering of compact vegetation suggested a podsol or peat formation.

(*b*) *Regression of soil type No. 2*—Soil type No. 2 when examined in profile at the present time showed the following characteristics.

I. Much less degradation of soil type as compared with No. 1 viz., soil-colour and texture and vegetation.

II. That vegetable mould tends to accumulate on the surface, and does not mix with the soil to form humus and cause darkening.

Exposed for a shorter period, soil type No. 2 had to a large extent retained its original forest soil characteristics, being protected by windbreaks which had been carefully preserved when clearing this area. The soil appeared as a bright-yellow clay with a high water content and no admixture of humus. A large number of bananas were still growing amongst the luxuriant vegetation which had covered this area. The roots of the bananas when examined were found to be water-soaked, with a blackening of the root tip and fine roots. These had in most cases died back after a short period of growth, and showed both fungal and insect attack. It was also noticed that few young banana plants were formed as in the normal course of succession.

A sufficient number of pH determinations were taken by the writer to fix the present reaction of the soil within the range pH 5·9 to 6·3 for the surface three inches, at 5·9 to 6·2 for the six inch sample, and 5·9 for the eighteen-inch sample. These reactions were distinctly acid, but not such as to prevent healthy growth.

PRESENT STATE OF BANANA LANDS.

(*a*) *Flora.*—Following the abandonment and exposure of the banana lands, an entirely new flora invaded and established itself on the exposed slopes. This consisted largely of weeds common in the distant lower valleys, such as might be sown by wind-borne seeds or arise from seeds expelled by birds, both groups being new to this area. These plants formed small communities existing in the shallow layer of good soil on the exposed sites and as isolated specimens scattered throughout the whole area. Most of them had shallow root development indicating a habitat alternating between drought and water-logged conditions.

A second important indication of soil conditions was the appearance of associations of *Pteridophytes*, including tree ferns, ground ferns and club mosses, with *Heliconia* spp. occupying a wet habitat on the lower slopes and ravine bottoms, where the eroded soil allowed a deeper root range. The Araliad, *Sciadophyllum*, appeared regularly as a solitary specimen on exposed slopes, where a specially adapted root system helped it to withstand the effects of erosion.

(*b*) *Soils.*—The replacement of a fertile soil by an infertile soil is still proceeding on the more exposed slopes and has been greatest in the areas exposed over a longer period (three to five years), so that these soils are at present of little agricultural value. In the areas which have not been totally deprived of vegetation and more recently worked, these changes have been less severe and the soil would respond to careful cultivation.

A detailed survey of these areas would probably reveal many local variations of soil conditions. In some, the exposed soil consisted of powdery volcanic material without quartz fragments resulting from rock decomposition, whereas adjacent areas showed similar denuded rock with fine quartz grit. The examination of road cuttings and many other exposures indicates the general nature of the soil to be as described, but the scarcity of fuller geological information on these soils is to be regretted in view of the importance of the recorded changes to agriculture, and it is recognised that this investigation merely records the main facts of agricultural significance.

CONCLUSION.

This paper would not be complete without some suggestions for the safe development of forest lands for agricultural purposes.

It has been said that there are two ways of utilising the soil wealth, (1) by systematic cultivation, where the soil is regarded as a reservoir of plant-food to be kept in good condition, with a replacement of the material taken off in the crop, (2) by progressive exhaustion, where the soil is regarded as a storehouse of plant-food to be drawn upon without consideration as to methods of replacement or the conservation of existing materials.

It has been shown that the latter method results in a rapid and progressive depression of the humus content of the soil and a loss of fertility, to a point when the soil is no longer fit for agriculture, and fertility can only be restored by the extremely slow processes of nature.

In tropical agriculture the conservation of humus is of great importance, as external conditions are largely in favour of its rapid destruction. Closely linked with the question of humus is that of soil conditions generally and these as already indicated may be such as to bring about a rapid deterioration of soil type. It is clear that such soils cannot be treated in a haphazard fashion, they must be worked or they will deteriorate rapidly, and one of the conditions of opening up land successfully is that a good standard of cultivation must be maintained.

The following suggestions appear to meet the principal difficulties in clearing forest land and maintaining agricultural conditions.

(*a*) *Felling and clearing.*—For various reasons this is usually conveniently done in the dry season as the soil is then exposed to desiccation and subsequently to heavy washing during the following rainy season. This can be largely remedied by the removal of the larger trees only, allowing growth of vegetation to cover and protect the exposed soil and surface humus. This can be followed up by the cutting of bush and final clearing on the approach of the wet season and planting time; areas not required for planting being left for the protective covering of vegetation, which can be subsequently cut for mulch or manure-making.

Where the soil is not protected by a planted crop a green manure crop such as *Crotalaria* or *Tephrosia* could be sown to replace native weeds. Burning bush is unnecessary and wantonly destructive.

(*b*) *Shelter-belts.*—It is highly important to protect forest land by reserving a series of shelter-belts of trees of moderate height at the time of felling. The belts should run across and *not down* the slopes, so as to hold up erosive action and modify wash.

Tops of ridges should also be left with a crown of trees of moderate height, as the larger forest trees are unsafe and invariably die when exposed. All belts should be strengthened by planting Galba or *Gliricidia,* both of which can be pruned.

(*c*) *Drainage.*—This should be attended to in the early stages to prevent the formation of many new channels and consequent landslips. Main drains should be carried along the upper and lower edges of the shelter-belts at a distance of about 15 feet from the belt, and should outfall into a natural ravine or gully which should be kept open. Planting could take place on both sides of these main drains so as to economise space. Secondary and crop drains can be decided upon as a full drainage scheme is developed.

(*d*) *Terracing or banking.*—The method of terracing on slopes is an important preventative of wash and facilitates cultivation and transport (a high proportion of the bananas in the Canary Islands is obtained from terraced fields). Terraces may be conveniently formed in the first instance by half embedding the heavy logs in a direction at right angles to the slope, so that soil and humus accumulate against the upper side of the log and can be consolidated by planting the crop, by green manuring, or by allowing short leaves to cover the surface. The width of each terrace may be determined by the steepness of the slope, a sharp slope requiring more terracing than a gentle slope, and it is not necessary that the terrace itself should be level as a moderate fall will facilitate run-off.

Following these initial operations (if the economic situation will permit) the land may be trenched, sub-soiled and manured, with applications of lime, as indicated by the "working" of the soil and reaction of the crop, and the more ordinary operations of cultivation may be introduced provided the soil is not unduly exposed thereby. Methods of openworking flat lands are not applicable to sloping forest lands, and it is considered that the above suggestions, if carefully carried out, will go a long way towards preventing soil deterioration and infertility.

SUMMARY.

1. This paper discusses the effects of deforestation and exposure of tropical forest lands, with particular reference to recent banana lands in St. Lucia observed to deteriorate under commercial exploitation.

2. The conditions of exposure, the effects of erosion, the sequence of soil changes and types of vegetation are described as evidence of soil degradation and loss of agricultural value. It is shown that the agricultural development of forest lands is a special case requiring special technique for the preservation and maintenance of the natural high fertility of such areas. Concluding suggestions are made for the improved treatment of forest lands by dividing the exploited area into self-protective blocks, with the use of shelter-belts and special drains, and the conservation of the soil humus by cover crops and crop production on terraced slopes.