PRINCIPLES APPLICABLE TO THE MAINTE ANCE OF THE FERTILITY OF CULTIVATE SOILS IN TROPICAL COUNTRIES*

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It is still twenty or thirty years since man in temperate countries generally thought lands in humid equatorial and tropical countries were of extraordinary fertility. He was wr in that, on account of the striking exuberance of the equatorial forests he believed that t corresponded to those lands filled with humus and saturated with nutritive salts necessary the life of plants. In fact, he could well be excused because our knowledge of pedogenesis a the dynamics of tropical soils displayed almost nothing and all the notions that we could ha on these questions derived from comparisons more or less crippled with verifications made temperate regions.

On the other hand, outside the specialists, the idea of fertility was above all a concept bou up with the chemical composition of the soil provided that water was plentiful and th permeability of the soil was assured.

We know today that fertility is the resultant of the action of climate on soil determine by its physical, mineralogical and chemical properties. Such land, permitting of an acceptab output in equatorial or tropical regions, thanks to a climate that is perpetually warm and ver humid, would be sterile under European rainfall and in a climate with a short, warm season.

If a luxuriant equatorial forest is established and maintained that is due much more t the climate than to the richness of the soil :

1. Showers relatively warm and very plentiful, supply nitrogen and constantly dissolv the mineral elements that are necessary for the life of plants.

2. Very active microbial life mineralizes the organic matter of the vegetation as soon a it falls on the ground.

3. Generally loose soils, light or sufficiently light, are very permeable and very aerated.

4. The powerful root system of large trees improves the soil to a very great depth.

5. The large variety of numerous species present makes it possible to have among them plants capable of adapting themselves to all situations.

6. Finally, the virgin forest in its natural condition is in a stable biological equilibrium as long as man does not intervene : all the decayed matter returns to the soil, thus rendering on the surface, elements drawn to a great extent from that which nothing is taken away.

But if this equatorial climate favours the natural vegetation, it presents serious inconveni- as soon as we look at it from the point of view of the economic exploitation of the soil by with the object of satisfying his own needs.

The warm and perpetually humid climate permits of an extreme activity of micro nisms ; there is never an accumulation of organic matter and the soils are relatively poor is precious elements 1 to 2 per cent on the average in the arable bed in Africa.

2. During the formation of soils by the disintegration of rocks, their decomposition is d, ten times more rapid than in a temperate climate. The evolution of clays proceeds very lly and nearly always they are in the stage of Kaolinites while, in temperate countries, they ng to that of Montmorillonites. Now, the kaolinites have a very weak retentive power egards water and as regards dissolved salts. That means that the bases put in solution by vial showers are not retained and disappear in depth very rapidly leaving behind an arable quite impoverished in potassium, chalk, and magnesium. The situation is better if as appens, the clays of the illite family remain mixed with the kaolinites, the illites having a ch superior retentivity.

3. The dissolution of bases brings in its train a permanent acidification of lands and the of equatorial soils is nearly always between 4 and 5.

This acidification of the soil, combined with a very great poverty in organic matter some- es causes in addition grave losses in phosphorus. When it is made up of phosphohumates ich are relatively not stable that the pH reaches 5.5. The phenomena of the immobilisation soluble phosphates are in certain cases very much emphasized.

4. In tropical countries with well marked dry seasons, the situation is better from these nts of view because, during the drought, the bases are accumulated and the pH, remain often tween 6 and 6.5.

Finally, while there are marked dry seasons, the high temperatures and the alternations of yness and humidity causes the laterization of clays, that is to say, a quick step towards e degradation of the soil.

The cultivated land exposed to the sun quickly loses its water because its retentive power weak, and the dry spells, though short, destroy the organic and mineral colloids, permitting en in humid countries the beginnings of laterization and accentuation of all the phenomena degradation.

The bringing under cultivation of virgin equatorial and tropical lands is a dangerous operation r their fertility which, as we have seen, far from being exceptional is in general clearly inferior the average fertility of good cultivated soils in temperate regions.

The bringing under cultivation of equatorial countries commences with a clearing of forest of Savanna accompanied most often until the present by the burning of hewn-down vegetation.

Some minute observations made at Yangambi (Belgian Congo) have shown that the felling a beautiful African forest followed by burning represents the immediate destruction of 500 to 00 t. of fresh vegetable matter and the decomposition of 80 to 100 t. of roots in eighteen months.

Further from the time the forest is felled all the climatic agents attack the denuded soil nd the humus reserves disappear at the rate of 10 t. per hectare, and per annum assuming 10 per ent of the total humus contained in the arable bed of 0, 50 m. thickness,

From the mineral point of view, the burning of forests causes the volatilization of t 2.5 of elementary nitrogen, assuming the equivalent of 7 to 10 t. of ammonium sulphate. the other hand, the same burning sets free a ton of chalk and of potassium per ha. Unfortuna this brutal liberation is of relatively little use to the cultivation carried on because the dilu showers take away the greater part of them, all the more easily, as we have said, the reten power of the soil is generally very weak.

In the course of the years, especially in equatorial regions, the destruction of humus contin at the rate of 10 t. a year per *ha* and the loss of nitrogen and mineral elements by washing rem very considerable. Two consequences follow from this which considerably differentiate in tropical agriculture from the agriculture of temperate countries :

1. If in temperate countries, the slowness with which the organic nitrogen is rende assimilable is one of the factors limiting agricultural production, in countries that are continu hot and humid on the contrary, the considerable losses that bring about too rapid a mineralizat limit productivity at the time.

2. In hot and very humid regions, it is not the exportation of nutrient elements remov by the very formidable crops which exhaust the soils, but the losses due to our agricultu practises (farming methods).

In fact, the studies made have permitted to establish that the case of well conducted cultu (coffee shrubs or palms, for example) that is to say in the case where all precautions have be taken against the destruction of soils, only 1/3rd of the losses in mineral elements sustain by arable land in ten years of cultivation, is due to the exploitation made by the crops. In t case at the same cultures that are ill-conducted, leaving the soil partially bare, without protecti against the sun, one observes for example that the total nitrogen lost from the arable bed five years is equal to 11 times the quantity carried away by the crops.

How is fertility to be conserved ?

From all that we have said, it follows that in all intertropical countries the cultivator w wishes to protect the fertility of his fields and his plantations ought to watch above everythin

1. To protect and renew to the maximum degree the humus, and consequently the organ matter of his soil.

2. To provide the arable bed with a quantity of mineral nutrient elements sufficient fo the development and satisfactory return of his crops. This cannot be attained except b chemical manurings (fertilizers) as the European farmer has done since a hundred years.

How are these conditions to be fulfilled in an economical manner ?

A. Choice of the Soil

It is necessary at the beginning that the starting point is satisfactory.

The planter or the cultivator should establish himself only on lands for an agricultura vocation. Good agricultural lands are rare in intertropical lands but the areas are vast and very often sparsely populated. With a feeble part only of these surfaces, man can find actually wherewithal to satisfy his needs. In the name of those who will replace us tomorrow upon this

land, in the name of the human populations that increase ceaselessly, he should be prohibited from bringing virgin lands under cultivation without a thorough going examination. One knows how much inconsiderate clearings favour erosion and are susceptible to influence climate. The pedologist (Soil-scientist) can today determine the value of a soil and classify it knowingly as fit or unfit for agriculture.

B. Conservation and Maintenance of Humus

1. When one clears a forest with a view to making an arborescent plantation, the felled forest should not be burnt. One should arrange in the spaces between the rows of the plantation all the felled wood and prepare a seed-bed of leguminous creepers to cover it quickly. The felled wood thus decomposes little by little in the shade and maintains the stock of organic matter of the arable bed.

This system is today in current practice in many lands and finally the cost of the plantation, in working in this fashion, is not much more than by the ancient techniques of burning.

2. Once the plantation is established, one should keep watch over the maintenance of the cover of the soil keeping it as dense as possible. The rubbish of this vegetation constitutes a permanent maintenance of the level of humus. The thick covers protect at the same time the soil against the sun and erosion. Under cover, the temperature of the soil diminishes by several degrees and this sole fact causes an economy of humus (temperature of soil under forest 24°C, under leguminous cover 28° to 35°C, under direct insolation, more than 40°C).

The use of mulch or dead cover is highly recommended in the rows of plantation where one cannot let a live cover grow.

3. When one carries on annual crops, it is necessary to protect carefully all organic waste, whether one prepares composts, or whether one buries it in the soil at the proper moment at the time of ploughing.

If cattle raising is associated with the cultivation, all the dung should be well treated and carefully protected; here there is a financial expense the value of which the cultivators of tropical countries do not realise sufficiently because it is not immediate.

Maintenance and Augmentation of Mineral Wealth

We have shown how important in equatorial regions were the losses of mineral elements, the bases of vegetable nutrition.

The maintenance of the mineral wealth in relation to chemical manure is strictly indispensable under pain of seeing the rapid decline of the returns of agriculture.

For a long time, planters have said that chemical manure cost too much to be used in tropical crops. It is because they tried manures that were not balanced in relation to their soil and which could not, on that account, give any more than very meagre results. A small dose of manure the formula of which is exactly appropriate to a certain situation, gives much better results than a large quantity of manure chosen at random without a preliminary scientific study.

I have heard planters say that they have tried chemical manures and that they did not yield any result in their land. The cause of these failures is today known. It is often because they tried those manures solely on a base of nitrogen, phosphorus and potassium when they lacked something else in their soil, magnesium for example. This element is often wanting

in equatorial lands and even if the potassium is deficient, it can be absorbed only if there is by its side, the required dose of magnesium. Here there is an example ; one could cite many others.

The age of empirical manure is now passed.

After having fumbled for a long time, today one disposes of methods permitting of determining rapidly the veritable nutrient deficiencies of a crop. I shall cite the best and the most practical that is at the moment employed : foliar diagnosis.

On principle, it consists in analysing the leaves of cultivated plants at a certain stage of their development. Taking first samples always exactly in the same conditions, one learns that in the same species, when it is well nourished, there is always nearly the same quantity of each element : nitrogen, phosphorus, sulphur, potassium, magnesium, calcium and that, under certain amounts of one or more elements, the plant is deficient ; it gives inferior yields and then goes rapidly to ruin if the chemical manure does not intervene to re-establish the nutrient equilibrium.

One knows that if in certain circumstances the amounts of essential elements increase or diminish, the normal physiological equilibrium is such that the relations between the nitrogen and phosphorus or potassium and magnesium remain constant. One knows that the total potash + calcium and magnesium is nearly constant; one knows that the equilibrium between anions and cations is very important, etc. . . . etc. . . . The quantity of trace elements, copper, zinc, manganese, iron, boron, molybdenum is not less important to consider. One cannot in a general exposition do anything else but cite some essential fact, but in fact, the specialist of these questions today proceeds as regards plants in the same manner as a doctor as regards man. The IRHO of Paris has focussed particular attention on the foliar diagnosis of the African Oil-palm and the groundnut plant. We shall point simply to some results obtained which show the value and importance of the method.

For the oil-palm (Elaeis guinensis) it has been established that the rates at a normal time and the minimum of principal mineral elements in the dry matter of its leaves was :—

for Nitrogen	.. ..	2.50 per cent
Phosphorus	.. ..	0.155 per cent
Potassium	.. ..	1.0 per cent
Calcium	.. ..	0.60 per cent
Magnesium	.. ..	0.24 per cent

In a plantation of 2,000 ha of the Ivory Coast, at Dabou, the productions became decisive (2 on 300 kg. of oil per ha), and the palms were so poor, so deprived of leaves that one believed the plantation was economically a loss.

The analysis of leaves will show that the percentage of potash dropped to 0.45 per cent or less than half of the required minimum when the percentages for the other elements remained normal.

An experiment was set up in 1946 in which diverse formulae were studied. It was established at the beginning, in keeping with foliar diagnosis, that only the potash increased the yields.

Since 1946 palms receiving one Kg. of concentrated potassium chloride each year, have not ceased to increase their yield while the debris has not ceased to be damaged. Palms manured with potash have given successively in the course of the years 124 per cent, 200 per cent, 300 per

cent, 400 per cent and 700 per cent of debris producing today the equivalent of 2,000 kg. of oil per ha, a very spectacular and almost unexpected result since this production has exceeded that obtained during the early days of the plantation. At the same time, the level of potash in the leaves rose again to 1 per cent.

From 1949, these experimental results were applied progressively to the entire plantation and the industrialresult confirms the experimental result. Since 1949, the manured surface passed from 849 hectares to 1,878 hectares in 1954 ; the total oil production (palm oil + palm kernel oil) has passed from 306 t. to 2,108 t. and the palms are reestablished. The result costs 143 kg. of concentrated potassium chloride per hectare per annum, a very small expense in relation to the oil produced.

It is remarkable that in keeping with what was caused to be anticipated by foliar diagnosis, the elements other than potash do not give any increase in output. On the contrary, the supply of nitrogen has a tendency to depress the yields.

The soil should therefore be given what it lacks in order to ensure the cultivated plant a balanced nutrition and nothing more. The IRHO has obtained many similar results, notably in Dahomey. Of course the results are less spectacular when the plantations are less damaged than those from Dabou, but they are not less extensively paying when the yields increase from 40 to 50 per cent and increase the production from 900 to 1,300 kg. of oil per hectare for example or from 1,200 to 1,600 kg. in other cases.

Let us point out again the case observed in French Congo where very heavy applications of nitrogen, phosphorus and potash, made during three years without any result showed immediately the susceptibility to increase the yields from 40 to 50 per cent when a small dose of magnesium was added to the manure.

Similar cases have been noted in the East coast of Sumatra.

This underlines the absolute necessity of determining the deficiencies not only in major elements but also in minor elements.

Thanks to foliar diagnosis again, the IRHO has been able to show so much deficiencies in phosphoric acid, so much in potash, so much in nitrogen, existing in the different region of Senegal and to determine some formula of manure necessary and sufficient for obtaining at the smallest cost of the maximum output in groundnut.

We shall say only this about it : in the present course of products the price of 1 kg. of groundnut is roughly equal to the price of 1 kg. of manure laid. The manures applied are of the order of 100 to 150 kg. (?) per hectare and the increases of output of the order of 300 to 1,000 kg.of husked groundnut shells, not to mention exceptional cases where they exceed a ton.

Similar results have been obtained on citrus fruits in California where the deficiencies in minor elements are sometimes very grave also on the *tung* (aleurites), sugar cane, etc.

The IRHO in Ivory Coast at the present moment gets some spectacular results on the coconut. The last results show, thanks to the detection of very acute potassic deficiencies in this species, that a judicious application of potash has enabled, in three years, to surpass the yield in copra by some hundreds of kilograms, more than 2,000 kg. per hectare.

Now, the output of 2,000 kg.† of copra is considered very exceptional in all producing countries in question, new Hebrides, South-East Asia or the Philippines.

†This is equivalent to 3·18 candies per acre. Editor *C.C.Q.*

Thus therefore, the legend of chemical manure not capable of being utilized economically in all tropical countries is destroyed.

It must be said, on the contrary, that it is quite profitable and that the only means of not having to witness the rapid exhaustion of tropical lands and not further helping the decay of the most varied plantations in Africa or in Latin America (notably the coffee plantations of Brazil) is to use it as regularly as in Europe.

The manure is all the more profitable as the doses of fat necessary are much weaker than on temperate lands, this thanks to the feeble fixation of fat by the soil.

But the success can reward their use only if each case is examined and studied in the light of agronomical data of the present time, as a disease is examined by the doctor.

In conclusion, the same facts are repeated in the history of tropical agriculture. Only where agronomical and scientific research is established and developed, does tropical agriculture flourish.

The Dutch East Indies, now Indonesia, have been the first at the head of progress in this domain and they have given the world the first great example of action that well-conduction research stations could perform, on the agriculture of tropical countries. The English have followed in Malayasia. The Belgians have transformed the agriculture of the Congo since 1930, the epoch of the creation of the National Institute for Agronomical Studies of the Belgian Congo (the I.N.E.A.C.). Since the end of the last war France has put up a series of Research Institutes and completely transformed, in amplifying it extensively, the total agronomic research beyond the seas ; the results obtained from now are more promising for the future of those Territories.

Latin America has in different countries, in Brazil, Venezuela and beyond schools and Institutes forming the bases of departure which only ask to be enlarged in order to permit, thanks to the exceptional quality of certain of her lands, the development of a tropical agriculture capable of playing a dominant role in world economy.

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