

C E I B A

A SCIENTIFIC JOURNAL ISSUED BY
THE ESCUELA AGRICOLA PANAMERICANA

LOUIS O. WILLIAMS, EDITOR

TEGUCIGALPA, HONDURAS

November 15, 1954

VOL. 4 - No. 4

THE PLACE OF TROPICAL SOILS IN FEEDING THE WORLD ¹

Robert L. Pendleton ²

WHAT ARE THE POSSIBILITIES AND LIMITATIONS of humid, tropical, lowland soils? What can these soils contribute to the feeding of the world? Why can they *not* contribute as much as many persons think they can?

Now that the airways offer more facilities and ease for travel, hundreds of passengers are flying over the enormous and magnificent equatorial forests of the Congo and Amazon basins. Literally from an armchair, high above these forests, the layman who has enough interest to look out of the plane window, down upon the lush vegetation, easily gets the idea that the potentialities of the tropics are unlimited.

Before it was possible to travel so easily above these vast and magnificent forests, the relatively few travelers who saw the humid, tropical river valleys such as the Amazon, did so from the vantage point of the small river steamer or dugout canoe. Usually gallery or fringing forests stand along the river banks; and not so far back from the river are open, worse than useless grasslands. Before the age of air travel, the occasional traveler on the rivers undoubtedly obtained an exaggerated idea of the extent of the tropical forests. But such travelers did have, from time to time, opportunities to go ashore, and perhaps to get something of a worm's eye view of the forest. A U. S. agri-

¹ The substance of a lecture delivered before "Friends of the Land" in Chicago, 1st July 1953.

² Professor of Tropical Soils and Agriculture, The Isaiah Bowman Department of Geography, The John Hopkins University.

cultural attaché in Venezuela, planning a trip up the Orinoco River, was being dissuaded by the river boatman with the remark, "Why do you want to go up this river? There's nothing up the river but the banks".

It is also true that a traveler on foot through humid tropical lowland forests gets the idea of lush vegetation, and the impression that the ability of the soils to produce plants is unlimited. Often these forests are so thick and dense overhead that seldom can he see the sky. If he is standing on the forest floor he does not know whether it is raining or whether the sun is shining up above the forest, until the raindrops begin to fall to the ground. Where he must keep to the trail, or cut his way through the vines and ground cover, and where he is continually oppressed by the denseness and gloom of the forest, to say nothing of the leeches reaching out for him from the shrubbery along the path, he finds travel in these forests extremely unpleasant. The difficulties of travelling through the equatorial rain forest of the Congo basin are described, with great restraint, by Stanley in his "Darkest Africa"; though the woodcuts are totally inadequate to represent conditions within an equatorial forest. Yet after many failures to get an adequate record photographically of conditions in the forest, the camera man is not inclined to be so critical of the woodcuts.

DIFFERENCES BETWEEN TEMPERATE AND TROPICAL REGIONS

The differences between temperate and tropical regions and the vast and rich, almost unexploited, timber and soil resources especially of the tropics continually appeal to the stranger. He cannot rid himself of the idea that there are vast fortunes to be made in tropical regions, or, at least, that unlimited quantities of raw materials needed in temperate zones can be obtained in such areas. An outstanding example of this is the so-called "groundnut scheme" of Great Britain which was undertaken in British East Africa. This resulted in a shocking loss of capital, and the final results in oil produced were disappointing, to put it mildly. Then there have been the efforts of others to produce food in South America. Recent eyewitness reports are to the effect that these schemes are producing most mea-

gre results, considering the investment of capital of something close to six million dollars.

The history of agriculture in Malaya, Ceylon and elsewhere in the humid low latitudes in the production of rubber and tea is scarcely known in America, but 50 years ago the soil erosion in the orchard-like tea and rubber plantations in those regions was appalling. Tea and rubber seem to be able to get along on soils with only modest amounts of plant nutrients, though for profitable production on exposed subsoils (for the surface soil has often long since been lost) both these crops respond well to appropriate applications of commercial fertilizers.

Too often, however, particularly in the vast interiors of equatorial Africa and equatorial South America, there has been too little erosion. The residual products of weathering have accumulated, after the principal nutrient materials have long since been leached from the soils: iron has accumulated as laterite, less often aluminum as bauxite, or more often as kaolinitic clays, and silica as quartz sand. It may seem rank heresy to emphasize the fact that any region can suffer from too little erosion, but this certainly is the case in considerable portions of the one tropical region which I know best, Siam, now officially known as Thailand.

THE SOIL-FOREST COMPLEX

It is likely that these magnificent forests in humid equatorial lowland regions started when the soil was not so poor, when rocks had not yet weathered so deeply, so that there was not such a scarcity of plant nutrients in the surface soils within the reach of the roots of the forest trees and other plants. The forest developed great luxuriance, while the tree roots went deeper and deeper. As long as there was no general destruction of the forest vegetation, there was very little waste or loss of plant nutrients within the reach of the tree roots, for as soon as one tree died and fell to the ground, it was quickly attacked by termites, mold, fungi, etc. and within a year or two, practically all of the plant nutrients were liberated in the mineralization of the plant materials. Roots of the surrounding trees and plants immediately took up all of these nutrients.

They were taken back into the forest vegetation without any considerable proportion being lost to the deeper percolating waters. In other words, the plant nutrients were being cycled—being used in the forest vegetation over and over again. But the soil itself was changing. Weathering had been progressing deeper and deeper. While most of the plant nutrient substances were being held by the roots of the vegetation, small portions were lost by too rapid percolation and perhaps some by erosion. The mineral soil itself was becoming poorer and poorer.

Felisberto de Camargo has described one of the most striking examples of a magnificent dense and tall equatorial forest (*selva*) which had developed on a soil which has proven useless for annual agricultural crop production. This is the country through which runs the railway from Belém to Bragança, state of Pará, Brazil.³ South of the mouth of the Amazon River is an enormous region of low rolling country on which once stood a magnificent high tropical rain forest. Some seventy years ago the government undertook to develop this region. The great need for development of the *selva* east of this region was because less than a thousand miles to the southeast in northeastern Brazil is a region where drought is almost chronic. Even during this last year thousands and thousands of villagers from this drought stricken region have been going some hundreds of miles by road to Sao Paulo for work because of the too rigorous conditions in the northeast. I remember clearly when in Sao Paulo in 1949 seeing the open truckloads of peasants coming in after a week or more of dusty travel by road from the northeast, when they could no longer find any way to make a living because of the drought in the arid and too often rainless country.

As a start in developing this Bragança region, the government built a railroad east from Belém and assisted villagers to come in from the dry regions to the east. Settlers came in, the land was cleared and crops were grown. The

³ Felisberto C. de Camargo, "Terra en colonização no antigo e novo Quaternario da zona da estrada de Ferro de Bragança, Estado de Pará, Brasil." *Boletim de Museu Paraense E. Goeldi*, Vol. X, 1948, pp. 123-147. (In English in: Dept. of State Publ. 3382, *Internat'l. Organization & Conf. Series II, Amer. Republics 4*, pp. 213-220, Section III).

first crop following the clearing of the forest was often very encouraging, but thereafter the crops were extremely poor. It soon became evident that it was impossible to cultivate these very poor sandy upland soils continuously and to develop a permanent agriculture on them.

Before his most untimely death in 1942, Geoffrey Milne, soil chemist to Tanganyika Territory, British East Africa, contributed greatly to a better understanding of tropical soil-plant relationships. As a result of his field studies in Trinidad and British Guiana ⁴ he pointed out that while "It is true that in better known floras there are always a few 'indicator' plants, but all plants must indicate something, and what most of them could tell about the soil is quite insufficiently known". Milne continues that "the difficulties due to the nature of the soil-plant relationship may be stated briefly thus:

"(1) However faithfully a natural vegetation may reflect the soil conditions that have promoted it, we usually propose to change or remove that vegetation for the purpose of our uses of the land, and we shall thereby change the conditions, perhaps fundamentally. A soil and its plant cover have interlocking identities; and what we have thought of as forest soils or prairie soils cease to be such within a short period after the trees have been cut or the sod turned.

"(2) The soil properties that are significant to a natural vegetation and receive expression in it are not necessarily those that will be of most significance to the crop proposed for replacing it. Crop plants will usually have a more urgent demand for nutrients and may have a different range of tolerances".

Milne visited a project on the island of Trinidad where natural forest of mediocre value had been cleared and the land used for annual crops. The settlers of East Indian stock had not been able to continue cropping the land for more than a very few years because the fertility had dropped very rapidly. Milne was convinced that neither the peasants' lack of skill nor soil erosion in any form could be blamed for the almost complete abandonment of the holdings when he visited the area.

Milne also describes conditions in a forest reserve in Trinidad, where temporary settlers for one year only, had

⁴ G. Milne, "A Report on a Journey to parts of the West Indies and the United States for the Study of Soils, February to August 1938." East African Agric. Res. Sta., Amani, Tanganyika Territory, Gov't. Press, 1940, 78 pp.

cut the forest, made charcoal, and raised one crop of food in lieu of wages. He stated that the Forest Department had, however, experienced the greatest difficulty in establishing the desired stand of valuable (indigenous) trees on the land that has been cleared and cropped in this manner. On the occasion of Milne's visit the Conservator of Forests expressed the opinion that giving over the ground to the cultivator for even one year had been an expensive mistake. The replanting operations had been handicapped thereby to the point of defeat. The only hope of replacing natural forest by commercial forest lay in *preserving the continuity of forest conditions through the transition* as far as possible. In other words, the forest soil must be maintained as an entity, without changing it first into something else by alien processes of tillage and exposure.

Milne concludes that "both these Trinidad soils had, in fact, a fertility quite sufficient to maintain mixed forest, or to grow satisfactory forests of commercial timbers, but they had this fertility *only so long as the reactions of forest upon soil properties were maintained without interruption*. It was not expressible through field crops, because the clear felling, burning and tillage necessary in preparation for such crops has, as it were, dismembered the soil as a working system, and the 'scrap' that was left did not provide the makings of an agricultural soil. Not even a good forest soil could be rebuilt from it; there had been loss of essential parts and the mechanisms of a year or two before could not be restored to working order".

Once a tropical forest is cut and burned, the land cleared, most of the minerals from the forest growth are dissipated. Of course, in the ashes the minerals are freely soluble, the young plant growth of the crop being grown can take in only a small part of the liberated nutrients, the rest are washed deep into the soil by the heavy rains of the summer. Certainly at least 90 percent of all the plant nutrients are quickly washed below the range of the roots of any crop or annual plant growth. A second year's crop is almost impossible to raise because the sandy soil is so poor; the farmers leave it and clear more forest land. The abandoned land is gradually occupied by wild bushes and small trees. It is obviously uneconomic to use commercial fertilizers on

the soils for the production of subsistence crops for they cannot, and do not, justify the expense. As Milne emphasized, once the soil-forest system is broken, the cycle interrupted, it is quite impossible to restore the forest-soil relationships. The Brazilian agricultural scientists who have been studying this problem are convinced that it is not economically possible to raise crop plants on these sandy upland soils. Therefore, they are urging the settlers to go down and dike the lowlands along the rivers, to use the lowlands for lowland rice and pasture, and use the uplands only for building sites for their farmsteads. The effectiveness of this system is being demonstrated on their governmental experimental farms near Belém, and it is promising. It should be remembered, however, that these river lowlands are branches of the local streams which discharge into the Amazon estuary so that their levels are not greatly affected by the changes in level of the Amazon River proper.

THE AMAZON VALLEY

The Amazon valley has been more often described by popular writers than almost any other tropical region, and its imagined possibilities for food production have been enlarged upon at great length.^{5 6} Most unfortunately, the potentialities seem to be very limited, even more limited than the just referred to experiments near Bragança would suggest. As Marbut and Manifold pointed out more than a quarter of a century ago, the alluvial plain of the Amazon Valley is relatively very narrow, often only a few miles in width.

"The alluvial soils constitute a sixth group. They are in general of two kinds. (1) Well drained loams and very fine sandy loams occupy the immediate banks of the rivers in a narrow belt ranging from a few feet to a few hundred yards in width. They lie on the natural levee and are moderately well drained, subject to flooding for a short period each year, but highly productive. (2)

⁵ Michael Scully, "Amazing Amazon." *The Rotarian*, Aug. 1952 pp. 35-36.

⁶ Earl Parker Hanson, "Mankind Need Not Starve." *The Nation*, Vol. 169, N^o 20, Nov. 12, 1949, pp. 464-467.

, 1949. "New Worlds Emerging." 373 pp. Duell, Sloan and Pearce. New York.

Heavy, imperfectly drained to poorly drained 'back swamp' soils are often dark in color and heavy throughout the whole section. They are subject to long periods of inundation. Considerable areas are treeless. The belts in which they lie contain many shallow lakes and swamps".⁷

The reports are that last year (1953) during the high water season the Amazon River levels were 15 to 20 feet *above* the street level at Manaus. Higher up the Amazon, as at Iquitos, the variations in the level of the river in different seasons of the year are from 50 to 60 feet or more. Obviously, it would be quite impossible to keep out flood waters by raising dikes high enough along the mid Amazon which would be needed in order to plant rice or other lowland crops in the remaining portion of the alluvium.

The largest scale experiments in the development of the Amazon Valley are certainly those of the Ford Motor Company. The engineers planned first to exploit the forest timber and by clear felling the forest, to make clearings in which to plant Hevea rubber. They built the largest modern saw mill in South America to work up the forest trees into timber for export to temperate regions. Undoubtedly one of the most serious difficulties was to market the large number of different kinds of tropical timbers. This has always been a problem in the Philippines where there are over 400 different kinds of timber trees which can be used but there is seldom enough of any one of these to make exploitation of most sorts economical.

It is not well understood how very diversified all forms of life are in tropical countries, not only trees but insects, birds, fishes, etc. As an example of diversity I may refer to Mt. Makiling in the Philippines; on whose slopes was our home for about 12 years. On this one small extinct volcano less than 4,000 feet high, and perhaps ten miles in diameter at the base, a *botanical survey showed that there were more different species of woody plants than in the entire United States.*

Returning to Ford's experiments in the central Amazon: It should be mentioned that at the start this project was in the hands of engineers, not agriculturists. The first

⁷ C. F. Marbut and C. B. Manifold, "The Soils of the Amazon Basin in Relation to Agricultural Possibilities." *Geog. Rev.*, Vol., 16, 1926, pp. 414-442.

timber mill and plantation, Fordlandia, was well up the Tapajos River. The site was found not suitable for the growing of rubber. A second site, called Belterra, was found nearer the Amazon River. In 1949 I visited this plantation, and was much impressed with the growth of the trees and with the general layout of the plantation on a plateau well above the river. It should be mentioned that *Hevea brasiliensis* (Pará rubber tree) does not require a very fertile soil. It is native on the poor upland forest soils of the Amazon Valley but it does not thrive where the drainage is very poor. Hevea trees should have reasonably good drainage. The development of the Belterra plantation had been expensive, in part, because of the South American leaf disease, so that double budding is necessary in order to get the highest yielding types of trunk panels to grow and to carry disease-resistant crowns. Actually three different kinds of tops had been budded onto clonal trunks to retard the spread of the leaf disease. When I visited this plantation in 1949, it was under control of the Brazilian Government; the management was tapping as many of the trees as possible with the available labor. In spite of inducements to labor there were never enough workers to tap the trees already large enough for tapping. The Brazilian Government bought Ford's \$ 11,000,000 investment for a mere \$ 250,000, but even on this basis, and without any capital charges to meet, and with a protected market in Brazil for all the rubber they produced, it was understood that the plantation was barely making ends meet.

However, in the Amazon Valley there are more serious difficulties than even the poor soil. Some of these are described very vividly by Vicki Baum in her novel, "The Weeping Wood".⁸ It is impossible here to discuss the social and economic relationships and the motives back of the conquistadores from Europe who explored the New World about 400 years ago, setting the pattern for development of the governmental, economic and social relationships, but as Vicki Baum describes them, certainly the feudal pattern imposed by the Portuguese has persisted with amazingly little change. I have elsewhere referred to this as the "Ibe-

⁸ Published by Michael Joseph, Ltd., in London, 1945. P. 508.

rian curse”⁹ which has been imposed upon so many of the tropical regions.

Central Brazil is a vast region of old plateaus and eroded uplands but with only a very moderate relative relief. One might say that there has been really too little erosion in this country where the laterite capping of the uplands has further retarded geographical erosion.¹⁰

THE PHILIPPINES

The Philippine Islands are a region of diversified rocks, relief and soils. The climate also is diversified. There are humid lowland rain forests and in the northern two-thirds of the archipelago typhoons are frequent. In Mindanao, by contrast, typhoons practically never occur. The Philippines have many volcanoes, some of them recently active. Fertile soil has developed from the volcanic ash. These volcanic soils are outstanding in their productive capacity. The relatively rough relief of the Philippines has maintained geological erosion on a considerable scale; as a result, almost no laterite has developed. In other words, normal erosion and good drainage have prevented the development of the iron hardpan (laterite) characteristic of considerable areas of older uplands of southeast Asia, of tropical America, and of tropical Africa.

Unfortunately the Philippines, too, suffered from the Iberian curse. During the early years of this century, when the United States of America was in control of the Philippines, and had the power to change conditions and to do away with the majority of the evils of the imposed feudalism, the opportunity was largely missed and such progress of this kind which the American government did make has been quite emasculated after 1916 by the activities of the Philippine government, as Karl Pelzer has shown in his chapter, “Landless Filipinos”.¹¹

⁹ Robert L. Pendleton, “Potentialities of the Tropics.” A lecture before the Graduate School, U. S. Dept. Agric., 18 April 1949.

¹⁰ Since this lecture was delivered there has appeared Preston E. James’ “Trends in Brazilian Agricultural Development” in the *Geographical Review*, Vol. 43, N° 3, pp. 301-328. The author presents maps showing vegetation and surface configuration of Brazil; but unfortunately he is not himself acquainted with the Amazon Valley.

¹¹ Chapter 4, “Landless Filipinos,” pp. 81-114, of Karl J. Pelzer’s *Pioneer Settlement of the Asiatic Tropics*, Amer. Geog. Society, Special Publ. 29, New York, 1945.

The failure of the Americans to keep in mind the desperate situation of the Philippine peasants has compelled the latter to try to find some other solution, one of which includes the activities of the communist inspired and helped Hukbalahaps.

BORNEO COMPARED WITH JAVA

For several centuries the two islands of Borneo and Java were under European control and direction. During the past century the Dutch made great progress in developing tropical agriculture and applying science to the development of the country. At the moment, for the purposes of this discussion let us limit the comparisons. Borneo is an island of very old rocks, worn down by erosion and weathering to a relatively low relief. The soils, as a whole, are typical of humid tropical lowland regions¹³, where a well-drained, heavy rain forest stood on the land. In places along the coast are extensive swamps. During recent decades some of these swampy lowlands have been diked, and the development of padi cultivation (lowland rice) agriculture has been under way.¹⁴ Not far away to the south, across the Java sea is Java, a much smaller island than Borneo but with at least fifty volcanoes, many of which are magnificent mountains. A considerable number of these volcanoes have been active in modern times, some within the last few years, spreading rock powder over the countryside, so that many of the soils are still very young and have good physical conditions, as well as abundant amounts of plant nutrients. Moreover, the natural or geologic erosion has been considerable, erosion and creep which gradually help the surface soil to move on down into the lowlands and toward the sea before it becomes senile and devoid of most to the plant nutrient substances which had weathered out from the parent rock minerals. Thus the non-volcanic

¹³ E. C. Jul. Mohr, *Soils of Equatorial Regions, with special reference to the Netherlands East Indies*. Pp. 383-403. Translated by Robert L. Pendleton. Edwards Brothers, Ann Arbor, Michigan, 1944.

¹⁴ C. L. van Wijk, "Soil Survey of the Tidal Swamps of South Borneo in connection with the Agricultural Possibilities." Contributions of the General Agricultural Research Station, N^o 123, June 1951, Bogor, pp. 1-49.

rocks are also, for the most part, covered with soils which are at least reasonably productive. The population on Java is overwhelmingly agricultural and where irrigation is available the farmers follow very intensive methods of plant production. The population on Java per square mile is at least 100 times as great as on Borneo. This is possible because the soil resources of Java are such that even a more dense population than this can certainly be supported on the land. By contrast, the crop-producing potentialities of the soils of Borneo are very limited.

SIAM (THAILAND)

Siam, a relatively small country in southeast Asia, lies between Burma and the Associated States of Cambodia, Laos and Viet Nam. The area of Siam is somewhat greater than that of California but less than that of Texas. Much of Siam is too poor to grow upland crops, that is, non-irrigated crops. Where the forest has been reasonably good, the general practice has been to kaingin the land (i.e., slash and burn the timber, and grow a crop of sugar cane, corn (maize), cucurbits, or similar crops, on the land so cleared). Where the forest is poorer, upland crops are grown only on the larger termite heaps, which may be as much as ten feet high and 20 feet across at the base. In some cases the termitaria are truncated somewhat to give a larger, flattish garden plot on which can be grown sugar cane for chewing, tomatoes, tobacco, pineapple, papaya and other upland crops. It should be noted that the wise Tai farmer never levels the mound completely.

Where the land can be flooded and the water held on it, at least during the rainy season, the soil is stirred, puddled, and seedling lowland rice plant set out in the standing water. Unfortunately, over much of the Kingdom the rainfall is inadequate to raise a crop of rice without some additional water either from streams or from higher slopes nearby.

Where the forest soils are too poor to be worth planting, and only the termite heaps are cleared, the farmers may go some miles to the steep slopes of the few hills in the region, kaingin the slopes (cut down the trees, burn

them) and plant the cotton or upland rice amongst the stones on the shallow soil, where there are still sufficient plant nutrients in the surface soil from the weathering rocks to grow a crop. Because of the soil limitations rice is produced on about 95% of all the land of the Kingdom. By assisting inundation, irrigation in a large way has been applied to some of the soils of the Bangkok plain, but as a whole, conventional effective irrigation by direct flow from large canals has not yet been developed. In the northern valley, farmers cooperatively dig local irrigation ditches to bring onto their fields the water from mountain creeks.

In some portions of the Bangkok plain the water naturally floods very deeply. These areas require a special type of agriculture using the so-called "floating rice". In this case the fields are plowed early, the seed broadcast before the heavy rains and the later deep floods, so that the water as it rises over the plain from the rain and the overflow of the rivers gradually raises the level of the water on the lower land between the rivers. The only danger is that when heavier rains fall earlier in the season the water in the lower portions of the plain may rise so rapidly that the plants cannot keep their heads above the water surface, in which case the rice may drown, but where the rice plants survive they may grow to a length of ten feet or more and produce a fairly good crop of rice. If the flood has not subsided, such a crop may have to be gathered from boats.

TROPICAL AGRICULTURE

There are two or three main divisions of this subject which should be considered separately. In the first place, we consider the upland subsistence crops, that is, crops which are not grown like padi on flooded fields. The average inhabitant in the tropics of the western hemisphere produces most, if not all, of his food by a process called "kaingining", a method, which, under different names, is employed in practically all of the humid tropical lowland regions of the world, a method which is called kaingining¹⁵ from

¹⁵ This method was erroneously described under the name "milpa" by Cook. It is generally called shifting cultivation, but this term is not desirable because it implies and has often been described as a means of food production by nomadic tribes, when in most cases the tribes live in settled villages and only go out during the crop season to their kaingins.

the Tagalog word (Philippines). On the usually poor soils of the humid tropical lowlands the forestes are practically the cover crops. The forests about a village are the common property of the village. Often a village will have a settled existence and location and permanent padi fields close about the village for certain crops, as in Asia for lowland rice. But the forest land belongs to the village as a whole. When a villager wants to make a kaingin he blazes his claim in the forest early in the dry season. Then he cuts the underbrush, and usually most of the big trees, felling them and allowing the slash to dry. Shortly before the rains begin, the slash is fired and all of the brush, and branches and at least most of the big trunks of the trees are completely burned. The ashes remain scattered over the ground. After the beginning of the rainy season the seeds of the crop desired are dibbled into the surface soil with a sharpened planting stick of some sort, often with a flat iron bit. A few seeds are dropped into each shallow hole then a little earth is pushed over the seed usually with the toe. Aside from a weeding or two, and the cutting of some sprouts from stumps, there is seldom need for any particular care of the crop plants, for the soil following the years under forest is sufficiently loose so that no cultivation or other stirring of the surface soil is necessary. Of course, if the crop is edible, it is necessary to protect the ripening crop against wild hogs, birds and other pests. No livestock is needed in this type of agriculture for no plows or similar types of tools are used. Usually several kinds of crops are planted mixed in the kaingin. The labor required for production of food by this method is high, but even on relatively very poor soil a crop of food can be raised in the kaingin. After one or two crops, or at the most, perhaps three, the field is left fallow; the villager hopes it will grow up to forest trees again. Whether or not it does, depends upon local conditions.

Unfortunately, in some humid tropical lowlands there are some very serious grass pests, especially the Asian *Imperata cylindrica*, often known as cogón, lalang or alang along. This grass has deep underground rootstocks and is disseminated by small seeds carried in the wind by a feathery down. If the soil is not too poor, and there are sources of seed,

cogón may spread rapidly and seriously. The most serious objection to cogón is that this grass burns readily even when quite green, so that fire is apt to sweep across the old kaingin, burning the grass, and at the same time killing most of the seedling forest trees which, in a few years, might otherwise reforest the land. It is probably this grass burning annually, which is causing most of the extension of savannas in low latitudes. Incidentally and most unfortunately, this grass is now getting a strong hold in the southeastern United States. Not only has it been introduced and distributed in Florida, but recent reports are that in Alabama ¹⁶ it is also well under way. Though it does involve severe forest destruction, kaingining makes it possible for the farmers to obtain something to eat, and some fiber for clothing from a relatively poor soil with little else but very simple tools and plenty of hard work. If the forest returns to the land within a reasonable time, perhaps after five, ten or fifteen years, the same plot of land may be kaingined again. *The main difficulty with this method of crop production is that it requires five to fifteen times as much land to produce the same amount of produce as can be obtained from a plot of reasonably fertile land year after year.*

In regions such as the western Belgian Congo, where *Imperata* already dominates the landscape and there is no chance for the forest to come back naturally, the natives employ a laborious system of hoeing the surface soil up in little heaps, perhaps 18 inches high and three feet across, and in the heap are planted cuttings of cassava. In this way the food plant seems to be able to survive and produce food without too much inhibition by cogón grass, especially if some dry grass or roots are collected and burned on the heaps before planting the crop.

But even if the forest does come back on the land within a reasonable time, so that it can be kaingined again, crops from these kaingins will do little more than maintain the family during the year. It is, definitely, a subsistence agriculture. Little can be produced for sale, even if there are buyers for any considerable quantity. Perhaps a

¹⁶ Reported by Dr. Mark Baldwin in a personal communication.

neighboring village will use some of the produce, but only at a low price, and usually only in trade for something else. There is no money for fertilizers. It is rarely that fertilizers are used even though they may be bought at a reasonable price. The transport of fertilizer to the fields where it is applied is, in itself, a difficult problem for roads are few. Good roads in tropical regions are usually costly, an expensive luxury. In humid tropical lowland regions, profoundly weathered rocks, deep plastic clay subsoils, and the often torrential rainfall are serious and expensive obstacles to contend with and to overcome in highway construction and maintenance. Thus transportation is expensive and reduces the likelihood of fertilizer use.

PLANTATION CROPS

In humid tropical regions, both at low altitudes and at higher ones, are certain agricultural crops which the world wants, and will pay for. Moreover, there are practicable ways of handling or processing the materials so that the products can be shipped overseas. These plantation crops may require a considerable amount of capital for developing the land, for building, operating and maintaining the processing plant, and transporting the product to tide-water ports for export to temperate regions. Sugar, fruits, coffee, tea, rubber and fibers are the usual plantation crops. These and others have usually been developed by foreign corporations with competent technical staff and with adequate capital to invest in plant and equipment, as well as for research on control of pests and diseases, development of better and higher yielding varieties and increase of effectiveness and economy of the processing plants.

Europeans who led in the development of plantation crops in the tropics made some terrible mistakes, particularly in the earlier periods, when they attempted to raise rubber as an orchard crop, clearing the land of wild trees, terracing it and keeping the land clean and well cultivated. This was not only expensive but was worse than useless; it led to serious soil erosion. Now it is realized that even in temperate regions it is not only necessary but preferable *not* to maintain the plantations in a "ship-shape" condition.

It is not difficult to understand that *Hevea* rubber, which is a wild forest tree not long nor far removed from its native habitat, can grow more effectively and produce rubber more economically if it is maintained under forest conditions. Moreover, rubber does not require much processing equipment and can be produced by a peasant with simple equipment. Even before the last World War about three-fourths of all the rubber coming out of the Netherlands Indies was produced by peasants from their own small plantings of *Hevea*.

Sugar cane is a different type of crop. High yielding cane of good milling quality responds to cultivation and adequate fertilization. The fertilizer can usually be delivered economically to the cane fields, for the need for rapid transportation of the cane to the mill necessitates an adequate transportation system, usually a light railway. To prevent serious deterioration of the cane and loss of sugar, the cane should be milled within 24 hours of the time of cutting. For effective, economical management of a sugar mill it is necessary to maintain chemical control, and this requires a sufficiently large mill to employ a chemist, and sufficient cane to maintain operation continuously, night and day. As a consequence, sugar cane growing for white sugar production for export is not to the same degree as *Hevea* rubber adapted to peasant farming.

Tea must be processed in a relatively large and expensive factory so that satisfactory quality can be maintained. The tea gardens are owned and operated by peasants to an increasing degree, and the fresh tea leaves delivered to the central factory every morning for processing. This gives a satisfactory quality of tea but, unfortunately, the peasant seldom seems to pay any attention to the maintenance of soil fertility of his garden and seems to be indifferent to the erosion of his soils. As a consequence native tea gardens are often in a shocking condition as, for example, in Ceylon and the deterioration of these valuable lands is sad to behold.

Coffee, too, requires considerable investment for proper processing of the berries in order to produce a good quality bean. Coffee plantations are often extensive and it is still mainly a capitalistic enterprise. The one important

tropical crop which is produced mostly by peasant farmers is cacao. This crop is grown extensively in the Gold Coast, British West Africa and in the American tropics. European agriculturists have not yet made significant progress in producing cacao under plantation conditions and on a large scale; probably an important reason is the lack of any need for elaborate machinery for processing the "beans".

One of the outstanding tropical plantation crops is bananas. It is obvious that rapid transportation and effective cold storage are necessary if bananas are to be marketed in quantity in the temperate regions. Before the general incidence of Sigatoka and Panama diseases in Central America, there were banana shipping companies which marketed peasant grown bananas in temperate regions. Now, with the need for rigorous control of diseases, and with the proven benefits of spray irrigation in even rainy regions, plantation growing of bananas has become the usual practice. The companies interested in producing and marketing bananas in quantity are careful in their selection of soils. Notably they did not settle in nor utilize any of the vast areas of the Amazon Valley. Rather, they have gone to Central America, Jamaica, and now to the Pacific coast of Ecuador. Where possible, they have selected volcanic soils. In general, banana soils must be well drained, nearly neutral in reaction and located near a seaport. All planting, spraying and irrigation must be carefully taken care of. It is interesting to note that in some cases the banana rhizomes are planted before the tropical forest trees are felled. After felling but without burning, the banana plants grow up through the slash with relatively little help in cutting of branches that are smothering some of the plants. By the time the banana plants are ready to bear the slash has decayed, or been eaten by termites, hence there has not been such a great amount of plant nutrients liberated at once by burning all of the tropical forest growth.

THE BELGIAN CONGO

The Congo River basin of Central Africa is another vast region where the rainfall is heavy and well distributed, and where the relief is relatively low. The Belgians have

spent a vast amount of time and effort in trying to rationalize kaingin and other agriculture practices which can be carried out in that region without the utilization of fertilizers.

To give some idea of the magnitude of their experiments, it may be mentioned that the Central Agricultural Experiment Station at Yanganbi has an area of 50,000 acres of tropical high forests where such experiments can be and are being carried out. In the Congo, it is particularly important to try to rationalize kaingin because of the severe limitations on the importation of fertilizers and their transportation. It is out of the question to obtain fertilizers in Central Africa at prices which people can pay. Transportation of products out and of fertilizer in are both difficult and expensive. Africa does not have good waterways permitting ocean going vessels access to the interior. Limited and expensive railway facilities must be used. Moreover, these involve repeated trans-shipment of freight.

In the Belgian Congo studies of the factors of plant growth under humid tropical conditions are being made. One of the things discovered is that it makes a big difference as to the kind of crops last raised on the soil before the abandonment of the kaingin. It is also important to keep the soil as continuously covered with crop vegetation as possible, to prevent loss of plant nutrients and other types of soil deterioration.

In the "educative" agriculture which has been worked out for the Congo peasants, production in quick succession of upland rice and corn, followed, where the climate is appropriate, by cotton then manioc (cassava), the main food crop, with which bananas are important as a secondary food crop. After the cassava is dug, the banana plants remain. Natural regeneration of forest trees occurs particularly well in the micro-climate under the banana plants.

AGRONOMIC PRACTICES IN HUMID TROPICAL LOWLANDS

As the Belgians and others have found, the most effective methods of managing agricultural soils in the humid tropical lowlands are not the most effective under humid temperate zone conditions. It is always difficult to differen-

tiate between what is traditional and what is empirical, and which will be the most effective soil management practices in the long run. The Belgian agricultural scientists in the Congo, for example, insist that it is not possible to build up organic matter to any considerable degree in the soil, and that leguminous green manure crops are even less effective than grasses. They insist that the perennial grasses are much better for rejuvenating agricultural soils than legumes. They also emphasize mulches and as nearly continuous a succession of crops on the soil as possible, to keep the soil protected from scorching sun and beating rain.

Tropical soils thus are in general low in plant nutrients, except the very small percentage of recent volcanic soils which are usually really fertile. This is for various reasons. In the first place, in the vast basins of the Amazon and the Congo, and in Borneo, the relief of the terrain is low. There is too little erosion to wash away the worn out surface soil and so expose the less fully weathered out soil material in deeper portions of the profile. This weathering is hastened by both the heavy rainfall and the constantly high temperatures. The result is that phosphorus, particularly, is strongly fixed in the soil because of the weathering processes which have liberated iron and aluminum; these accumulate in the soil and all too easily combine with phosphorus in forms which the crop plant cannot utilize. Without phosphorus, plants will not grow. Consequently, experimental work with fertilizers in Central Africa, in humid tropical America, and in southeastern Asia indicates that phosphorus is usually markedly deficient for good crop production. For certain crops, such as sugar cane, nitrogen is an important limiting factor, but for many other crops nitrogen, relatively, is much less deficient than phosphorus, and in only a few cases is potassium needed. In Malaya there seem to be other plant nutrients which limit padi growth but just what these are, and how they can be made good in plant nutrition, is not yet clear.

PADI OR LOWLAND RICE

As has been suggested above, lowland rice is a unique crop. Most of the principles of agronomy which apply to

the usual grain crops do not seem to apply to padi. Just why this is so cannot yet be satisfactorily explained. The fact remains that rice, if it is grown on a soil that is well puddled, and can have a few inches of water standing on it throughout the growing season, will produce some rice to eat when this soil is too infertile to produce any other grain crop. The puddling of the land eliminates most of the weeds, or at least so reduces their competition that the young transplanted rice seedlings can get a good start and grow well. It is obvious that the puddling of the soil materially reduces soil aeration around the roots of the rice plants, nevertheless the rice seems to get along without aeration of the soil in the usual sense. The transplanting of the young rice seedlings into the fields is a laborious process, but it does insure a considerably greater yield of rice per acre, and every year, than the use of any other method. Soils which are not so poor, but which can produce reasonable yields of upland grain crops, if planted to lowland rice, flooded, irrigated and weeded, can produce about a quarter more rice grain than of other grain crops.¹⁷

IN CONCLUSION

Humid tropical lowland soils can be used for crop production, and will have to be used more and more as the number of mouths to be fed increases. Lowland rice is undoubtedly the most effective food crop which can be grown on many of these soils, both because it is adapted to wet soils and also because on even very poor soils it will still produce something to eat. But the utilization of rice on an ever increasing scale in feeding the world calls to our attention serious nutritional problems. No people who eat rice habitually will willingly eat it unmilled or even only partly milled (polished). The flavor of less than fully milled rice is not appreciated by rice eaters. Where increased milling, particularly mechanical or power milling replaces hand milling as power is increasingly available, beri-beri and similar diseases also increase. There is the possibility of utilizing the parboiling system of rice processing before milling to

¹⁷ J. Lossing Buck.