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RECONNAISSANCE SURVEY FOR THE SELECTION OF TRANSMIGRATION SITES IN CENTRAL KALIMANTAN

Phase 1
SOIL AND LAND SUITABILITY

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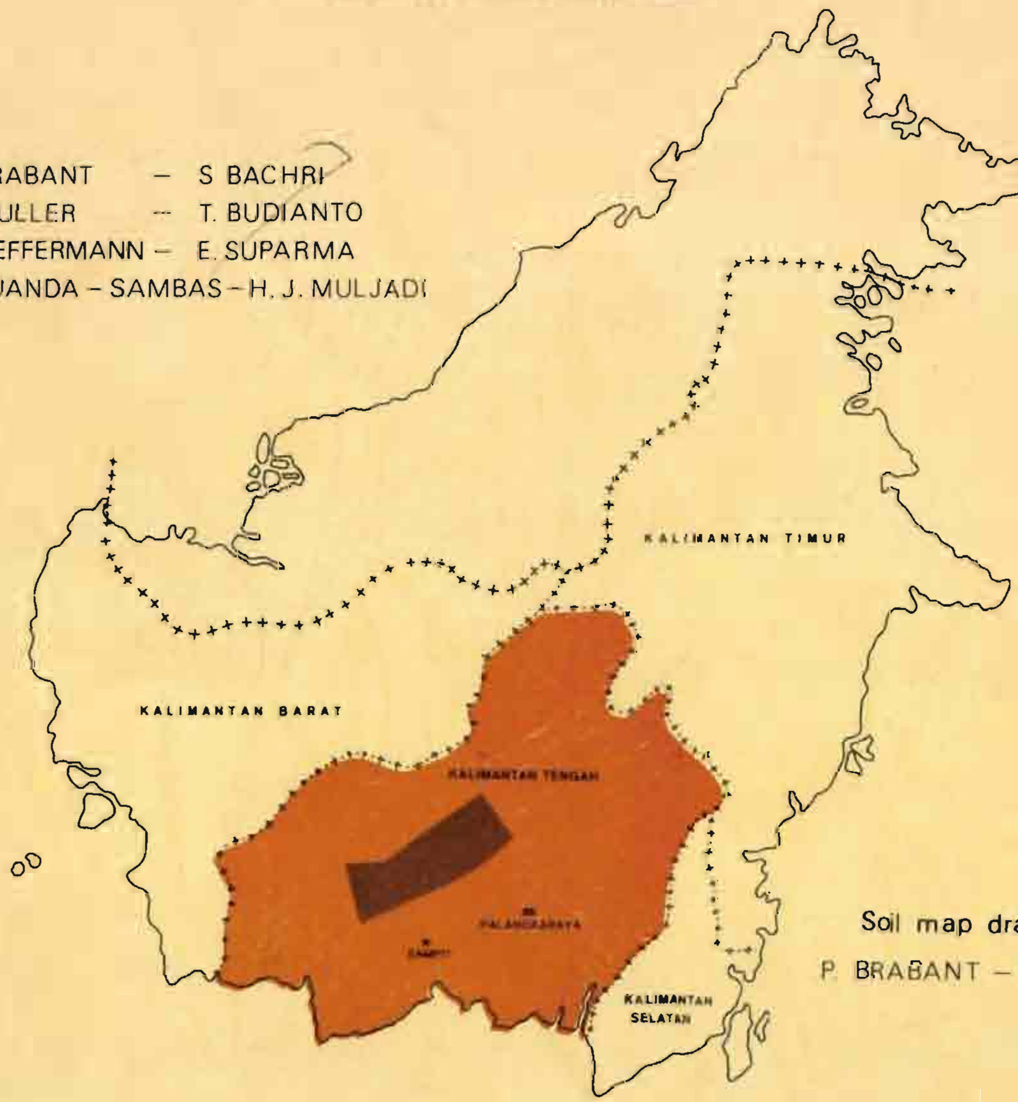

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INDONESIA - ORSTOM TRANSMIGRATION PROJECT (PTA-44)

JAKARTA - 1981

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Phase 1
SOIL AND LAND SUITABILITY

(Translated from French)

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INDONESIA - ORSTOM TRANSMIGRATION PROJECT PTA-44
Jakarta, 1981

CONTENT.

SOIL MAP REPORT - MAIN CONCLUSIONS

1. Weathering horizons are not very thick for equatorial forest soils. However, the upper horizons favourable to rooting, are always deep and homogeneous for at least 2oo cm. This seems to indicate that the soil coverage of these areas is well preserved and that it has not undergone any major erosive stage, at least since the beginning of the quaternary.

2. The soils are subjected to the effects of a very rainy climate. The main consequence is the very high amount of drainage water in the water balance equation. This produces an intense leaching of the soil by 20 to 25 million litres of water per hectare per year.

3. A major geological event, that occured toward the beginning of the tertiary, now determines the distribution of two large natural areas. This event has provoked a fault on a line running from south west to north east; it cuts across the whole prospected area from Durian Kait on the Seruyan, Tb Kuling, Tb Merah, Tb Samba, and Tb Jutuh. To the north of this fault are the upland areas on acidic or basic rocks, containing ferralsols and covered by dipterocarp forest. To the south are the sedimentary plains containing acrisols and podzols and they are covered by the "health forest".

4. There is a narrow correlation between the nature of the soils and that of the parent materials. Ferralsols are formed on all consolidated acidic or basic rocks and old sedimentary deposits, clayed textured. Humic ferralsols are the most dominant soils on basic rocks, xanthic ferralsols on acid grained rocks and orthic ferralsols on intermediary rocks. Rhodic and acric characteristics are associated with very dark rocks. Inclusions of acrisols are only found on very silicious rocks which sometimes have a very coarse texture.

Acrisols and podzols are associated in varying proportion on sedimentary deposits with some inclusions of ferralsols. Acrisols occur on clayed sandy parent materials and podzols on sandy parent materials ; inclusions of ferralsols are limited to shale deposits containing kaolinite, goethite and fine quartz. On the kaolinitic clays without goethite (1) occur acrisols or gleysols.

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(1) clays of very pale colour white to grey.

Inclusions of intrazonal soils are scattered around the former large areas : gleysols of the valley bottoms, fluvisols of the recent floodplains, cambisols of hilly areas, regosols, rankers and lithosols of eroded high hills.

5. There is also a correlation between the regional topography and the nature of the soils. An hilly topography is always associated with the presence of ferralsols ; a flat or undulated topography is always associated with the presence of podzols and acrisols. But a few exceptions can occur; for example, fluvisols of the flood plains and podzols in the areas bordering the basement. Schematically and on the regional scale, one can however, confirm that an undulating topography usually corresponds to low quality soils.

6. Whathever their nature, soils always have unvarying physico-chemical properties, probably in relation to the bioclimatic environment : pH acid between 4,0 and 5,0, exchangeable bases less than 2 mq., base saturation less than 10%, abundant exchangeable aluminium, low permanent charge and aluminium saturation over 60%. Mineral reserves are very low except in a few soils enclosing potassic micas and their weathering products.

7. The main differences between the soils are : their morphology, the physical properties, the organic matter and the moisture regime properties. Schematically, one can distinguish on the one hand clayed soils, with high content of organic matter, very well structured and well drained ; on the other hand sandy soils, with deficient structure and drainage.

8. Despite the abundance of rains, the water does not run off but it infiltrates very quickly to supply the hydrographic network, especially in the area of ferralsols. There is, therefore, no permanent free water storage in the soil or in the weathering horizons. This lack of available water reserves can have repercussions on the land management.

9 Some soils contain an association of clay minerals unusual for tropical forest soils. These are 2/1 clays of the illite group and interstratified illite-vermiculite, the charge of which is balanced above all, by aluminium ions ; because of this, they have a moderate exchange activity.

10. The traditional system of shifting cultivation and the derived system of recurrent cultivation does not cause any apparent damage to the soils, providing that they are ferralsols. On the other hand, serious degradations can occur in acrisols if the fallow periods are too short.

SOIL MAP REPORT - RECOMMENDATIONS.

We would like to make a few comments about this reconnaissance survey of the soils in Central Kalimantan. This work has been carried out by means beyond normal limits because we do not have the basic documents, especially the aerial photographs. However, we think it would be useful to learn some lessons because similar situations can occur for the survey of other areas in Indonesia where the soils are slightly known.

A few recommendations could also be useful for detailed surveys of sites selected on the soil reconnaissance map.

1. It is possible to carry out a soil reconnaissance map under similar conditions in order to choose favourable sites for transmigration or for regional development projects. Under similar conditions, this would mean without reliable topographic map, without a small-scale aerial coverage and without SLAR pictures. To carry out this reconnaissance, the following conditions must be met ; one must have at one's disposal :

- a satellite imagery of good quality that can be interpreted by simple visual examination ;

- a reliable geological map ;

- a logging roads network allowing to penetrate the forests to make observation on the soils in depth ;

- light and rapid logistic means to move about on the field.

The area surveyed in one year by two small teams including a senior pedologist could be that of a map sheet of 1/250.000 standard series P.I.T., that is to say 18.000 KM2. The result obtained should be sufficient to figure amongst the basic necessary documents for a regional planning.

2. The soil cartography to be carried out on sites selected from reconnaissance mapping 1/250.000 should fit in with the different types of landscapes and with the level of the knowledge acquired during the first stage of the survey. We could suggest :

a - a detailed survey at the scale of 1/10.000 in the alluvial valleys usually well delimited on the reconnaissance map. This 1/10.000 map could be used directly by the land management offices.

b - a detailed survey at the scale of 1/20.000 of the selected sites in the area of the ferralsols. The distribution of different soil categories according to the land configuration is such that this 1/20.000 scale is the minimum scale required to delimitate the main soil units (ferralsols and gleysols) and especially to represent them on a map which can thus be used directly by the land management offices.

At this stage, a pedologist is no longer necessary. (1) it will be the role of the agronomist and topographer who will study the land management schemes.

This type of survey at the scale of 1/20.000 obviously requires two essential basic documents : an appropriate aerial coverage and a detailed topographic map or a map which, at least, includes all the talwegs and the main contour lines.

c - A semi-detailed survey at the scale of 1/50.000 of the sedimentary plain. The objective would be to define precisely the areas of acrisols, of podzols and inclusions of ferralsols. At this stage, the aerial photographs can be used without detailed topographic maps. This done, a detailed survey could be carried out on the selected sites at a scale adapted to the types of projects ; this survey would still be under the pedologist responsibility. The result of this detailed survey could therefore be handed back to the land management offices for the conclusive stage.

3. We recommend the planners to take a care approach if they have to choose development or transmigration sites in the province of Central Kalimantan without having the soil reconnaissance studies at their disposal. In fact, the sites of a flat or undulating topography, which are usually sought, are often sites of very unfavourable soils. The only sites with a flat topography, where the soils are favourable, are the alluvial plaine along the rivers which have been cleared and are occupied by local populations.

4. We would not advise multiplying the current chemical analyses of soils during the detailed surveys in this area. The range of variations of chemical properties is roughly known in the unit or in the soil units of the reconnaissance map where the detailed survey is carried out. Besides, this range is very narrow. The surplus of information obtained seems minimal taking into account the cost of analysis.

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(1) possibly as a consultant.

On this other hand, particular attention could be placed on the soil morphology, on the aspect and distribution of organic matter, on the detailed examination of physical characteristics and their measuring with simple techniques, and on everything that might bring information on the moisture regime of the soil. Interesting additions could still come from the comparative survey of the natural forest soils and of their equivalent cleared and used since various periods of time and known through the information obtained from the inhabitants. This method of approach is advantageous, relatively inexpensive and above all the results obtained are immediate. But it is understood that each survey team has an experienced pedologist taking an active part in the fieldwork.

5. The use of satellite images is a very quick, economic and reliable way to determine the extension of soils occupying the cleared areas, to follow the evolution of these clearings and, in consequence, to determine the extension of the forest soils.

MAP OF LAND SUITABILITY - CONCLUSIONS AND RECOMMENDATIONS

1. The objectives of the project , the edaphic and environment conditions lead us to propose a type of land management. This gives priority to food crops production and indicates the conditions of optimum use to restrict erosion and the degradation of the environment. Under these conditions :

- 10% that is to say 222.500 hectares, of the lands are suitable for annual food crops.

- 56%, that is to say 1.246.000 hectares, of the lands are suitable for perennial crops with a permanent grass cover of the soil.

- 34%, that is to say 756.000 hectares, of the lands are unsuitable.

2. The scheme for the suggested land management gives priority to the development of the alluvial valleys which are usable for permanent agriculture and for the intensive production of food crops. As a second priority the landscape system including slopes with ferralsols and valley bottoms with gleysols can be chosen as a basic unit for the development of food crops associated with perennial crops.

3. The climatic agressivity combined with steep slopes create conditions which cause very strong erosion. The soil protection by the natural or artificial vegetal cover is an essential necessity of land management. These methods are less expensive and eventually more efficient than anti-erosion works if one considers the results obtained during the last ten years.

4. Chemical erosion, provoked by the great quantity of leaching water is an environment constraint that cannot be prevented. It is the cause of the low level of chemical fertility of all the soils and it constitutes a restricting factor to the use of fertilizers which should be adapted to these conditions.

5. The living and dead vegetal biomass is the reserve of nutritious elements for the plants. After clearing, only the dead part would remain, that is to say the organic part of the soil that must be preserved and used with care. Cultivated plants would benefit first from these easily accessible reserves which have accumulated and recycled for thousands of years and cared for by a traditional agriculture protective of the environment. The reserve would run out if it was not renewed artificially. In case,it is believed that after a permanent cultivation during a period of 4 to 8 years (depending on the type of soil), cultivation difficulties would occur and become more serious. An intensive fertilization would then be necessary.

6. To determine the type and level of fertilization adapted to the bioclimate of the area, an experimentation conducted in a test farm seems indispensable. The constraints due to the low level of natural fertility can partly be compensatedby a bioclimate that is favourable to the plants. Only field tests can determine the suitable level of optimum fertility. The first practical result would be to avoid the wasting of fertilizers.

7. One know the difficulty to clear the soils under forests for agricultural management. However, we advise against the use of heavy mechanical means without taking precautions. The resulting damage would have its effect a few years later. Careful methods using manpower are advisable. The only obligation is to leave the soil bare for the shortest time possible. Stripping the soil is in fact, the worst treatment to which one can submit the soil in this area.

8. From a regional point of view, one can see that the area of lands suitable for the production of food crops is restricted in this large mapped area which covers 2.225.000 hectares. The northern half of the map, that is to say the ferralsols, would be more suitable for perennial crops. The southern half covering the sedimentary plain seems to be marginally suitable for agriculture. It is possible that the forestry production here is more profitable than agriculture. This calls for a detailed study.

Finally, we could recommend a reconnaissance survey of the soils between the southern limit of this map and the seashore in the province of Central Kalimantan. The objective would be to determine the limit between the tertiary plain with sandy soils and the clayey quaternary deposits which could extend the series of deposits located in the south east of the province in the lower part of the river Kapuas. These soils on clayey quaternary deposits, if they exist, could constitute a more attractive pole for an agricultural development in the province with a view to the production of food crops.

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Finally, we thank all those who, in other respects, took part in this programme.

INTRODUCTION.

1. OBJECTIVES

The object of the soil reconnaissance is this of agreement described as follows :

"ORSTOM and the Ministry agree to proceed jointly to pedological and geographical extensive researches in the Province of Central Kalimantan to draw an inventory of the resources and environmental constraints. This inventory will be used as a basic document to prepare regional development plans within the framework of the Transmigration scheme.

These researches have to establish in Central Kalimantan a classification of the areas according to the types of development within the framework of the Transmigration program.

The accuracy of the collected data will be dependent on the amount and the quality of the basic documents such as aerial photographs, topographic maps, censuses and administrative inquiries as well as the possible access to the whole areas under consideration.

STAGE 1 . Programme, localization, identification.
Article 1. - Pedology and agronomy.

Object : reconnaissance mapping to the 1/250.000 of the regions of Kotawaringin Timur and Kotawaringin Barat. The soil mapping depends on material coverage of good quality. The soil maps will be accompanied with maps of land suitability and explanatory exports.

Article 2. - Identification of the transmigration sites.

Objects :Identification of the sites suitable for transmigrants in the regions of Kotawaringin Timur-Kotawaringin Barat.

Methods : Starting from the above-mentioned soil map to the 1/250.000 identify the sites suitable for transmigration projects.

Classify these sites according to :
- land suitasility.

- accessibility

-land availability for a project of migrations (land tenure)

- programme of regional development.

2. MEANS

In order to carry out this programme, scientific means and a logistical support were anticipated.

SCIENTIFIC MEANS

Among the basic documents, the essential ones were missing. These were the aerial photographs which were not supplied. The existing topographical maps are probably sufficient for the aerial navigation but they are too elementary for the survey on the field. The geological maps, sometimes very old, contain understandable inexactitudes as the geologists have prospected with the same basic documents and without aerial photographs.

Under these conditions we had to improvise and try to use the satellite imagery supplied by NASA and treated by ORSTOM remote sensing Office in Paris. Unfortunately, the available images of Kalimantan generally show a heavy cloud cover. The western part of the perimeter from the Seruyan river to the Mentaya river on the northern part of the Kuala Kuhayan-Durian Kait axis is visible on one image (1). All the rest is hardly visible on the images due to the cloudiness except small sized sections north of Tb Samba.

The laboratory support was supplied by the Center for Soil Research in Bogor. It was quick and efficient. Some special mineralogical and microelements analysis were carried out in Paris in ORSTOM Central Laboratories.

LOGISTIC.

These were put at our disposal by the persons in charge of the Central Kalimantan Province. Some difficulties arose due to the distance of the survey areas from urban centers and the absence of rapid communication ways. After a first period of fairly slow preparation, the logistic support then worked sastisfactorily. Finally we have found that the most efficient and economical means of survey on the field were the following ;light boats with low-horsepower engines on the rivers and the use of motorbikes on logging roads ; we have also used all-purpose vehicles when this was possible.

3 METHODOLOGY

The first step is to take one's bearings on the field. An approximate locating is generally enough for the reconnaissance survey. It is first made through the visible hydrographic network on the satellite in the channel 7,

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(1) Image of 13 th July 1073 n° E 81 355 02 133.

then by the visible logging road network in the channel 5. The survey proceeding from these penetration axes has enabled us to get, in most cases, an acceptable density of observations.

The first stage of prospection consists in identifying the main types of soils on different parent materials. For this, we have prospected and observed the soils along the logging roads where the weathering horizons and the parent rock are visible. One knows in fact that in these areas it is always difficult to identify the parent material of the soils in the pits by boring or on natural sections. We have thus selected some environment and edaphic characteristics enabling the nature of the parent material to be identified, when it is not directly visible on the field. These main characteristics are the type of organic matter, the colour and thickness of the topsoil, the texture, the soil colour, the weathering residue, the structure, the hydromorphic features, the slopes, the landform and the type of vegetation. Then controls on the field were carried out in order to test the visual interpretation of the relief on the satellite imagery. On a certain range of slopes, it is possible to discern the type of relief when the primary forest has not been cleared.

Having acquired these preliminary data, we then went on to the final survey stage. It was carried out over 6 surveys from April 1980 to April 1981, by two teams. One of the teams including 2 pedologists surveyed along the rivers, the other including also 2 pedologists penetrated in the forest along the tracks and the logging roads.

4. RESULTS

The mapped area covers 2.225.000 hectares. As the text of the Convention indicates, the accuracy of this map can only be in relation to the number and quality of the basic documents : aerial photographs and topographical maps.

The reader or the user can well imagine the difficulties that a survey in the dense equatorial forest represents without the use of these documents. We should ask the users to show a certain indulgence if some limits of the mapping units later appear approximate. Taking these restrictions into account, we think that the main soil units have been defined and localized with sufficient precision in order to contribute to the local planning.

The results of our works include :

- a soil reconnaissance map at 1/250.000 and an explanatory report,
- a land suitasility map at 1/250.000 and an explanatory report.

This last map is an interpretation of the data from the preceding map.

These data have been also used in the drawing up of agronomical maps for various annual and perennial crops.

Our results associated with the geographical and economic data constitute an inventory of the resources and constraints of the environment. These integrated data have again been analyzed and represented on a map of selection of sites which can be proposed for the transmigration projects or for regional development projects,in conformity with article 2 of the Agreement.

ENVIRONMENT

1. THE CLIMATE

One of us carried out a detailed study of the available climatic data for the Central Kalimantan Province. Also the specialist looking for particular information can refer to this study. For this reason we will limit this report to general data, giving special attention to those which have a particular incidence on the soils and their use.

The meteorological data which are available and statistically reliable only concern the rainfall and there are not many as the province only has an average of one rainfall for 5.680 km2. In comparison, this is one station for 580 km2 in the South Kalimantan Province and 1 station for 450 km2, calculated over the whole of Indonesia. The temperatures have only been read in one station for one year (1978). We have found no measure relating to the sunshine, to the wind speed, the hygrometry, the evaporation and the solar radiation. Banjarmasin is the only station where more detailed meteorological readingsare available. However, we are concerned with a coastal station situated 250 km to the south east of the perimeter. In our opinion, it would be imprudent to use these data in order to calculate the climatic and above all agroclimatic parameters. Thus, in most cases one must rely on the simple estimates of these parameters.

1.1. RAINFALL.

This is the main characteristic of the climate of this region and it has the following features :

a) very heavy rainfall : the surveyed area is situated between the isohyets 3.000 mm and 4.000 mm ; it is possible that the rainfall increases further towards the north near the border of the Schwaners Mountains.

b) the annual cycle does not have a dry season according to the average rainfall figures. The average monthly rainfall does not go below 130 mm. But in fact there can be successive periods of 2 to 4 decades when the rainfall can be less than 100 mm.

The examination of the annual repartition of the rains shows the existence of 2 maxima and 2 minima. The most important maximum is in March -April and the second in November-December. The first minima are more or less perceptible and the second are more marked in July-August. This last period is usually called the dry season in Kalimantan. But in fact, it is only a period of rain abatement. Also, the frequential analysis shows this so-called dry period is susceptible to large variations in rainfall.

c) The number of rainy days is relatively low. It varies from 145 to 180 days and is thus low in relation to the total annual rainfall. In addition, the nocturnal rains will be of the higher frequence than the diurnal rains. Here is an important parameter for the agro-climate which needs to be verified by field measurement.

d) The monthly and annual variations are large. The interannual variation is about 20% in relation to the annual average. It can reach 45% of this value during successive years and 60% in the extreme cases. Naturally these variations, which are very important for agriculture are totally unforseeable.

e) The rainfall is very intense. Without rainfall recording, it can be estimated by deduction and by experience. The very high rainfall is spread over a restricted number of rainy days. Daily rains measuring 100 mm and more are not infrequent. Finally, the heavy intensity of the rains is noted by everyone frequenting these areas. It is a parameter which should be determined more precisely as it is one of the main factors occurring in soil erosion.

f) The frequency of climatic accidents is decennial. These are exceptionally dry periods where it does not rain for a month. Very humid periods also occur periodically; but their effects; locally spectacular, are of less consequence ecologically.

1.2 OTHER CLIMATIC PARAMETERS

The annual average of the air temperature is estimated between 25° C and 27° C. Near the equator and on low altitude (1) the annual variations of around 3° C are less than the diurnal variations. It is the same thing as regards relative humidity which stays well over 90% most of the time. During sunny days and towards mid-day it probably drops to 70% and maybe even lower.

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(1) less than 50 meters above sea-level.

It is known that the global radiation at the level of the equator is higher in South East Asia (150 gk/cal/cm2) than on other continents. The number of rainy days, their nocturnal frequency and the effects on the soil enable us to suppose that the annual sunshine hours are relatively high for an equatorial area. Besides, several naturalists have pointed out the surprising facility with which they dry their botanical and zoological samples on the field. Of course, measurements will be necessary to determine the rate of sunshine (1)

As regards the winds, one can see that the storms are not preceded by strong gusts of wind as in other tropical areas. Because of this fact, one does not see wind fallen woods in the forest in spite of the very superficial uprooting of the trees. The trees on the ground are usually old trees.

1.3 One can conclude by saying that the climate is a hyper-humid climate with small variations in temperature. Its characteristics are a large range in the monthly and annual variations and climatic accidents of decennial frequency.

A strong sunshine and a high intensity of rain have a direct effect on the use of the soils. It is favourable in the first case but unfavourable in the second. A heavy intensity of rain can provoke serious soil erosion if it is no longer sufficiently protected by the vegetation.

2. MOISTURE REGIME OF THE SOILS - THE PEDOCLIMATE.

The soils thus receive large quantities of rain varying from 3.000 to 4.000 mm per year, that is 30 million to 40 million litres of water per hectare per year. After the rain, certain soils dry out rapidly, others remain saturated with water. Some rapidly become dried out after several days without water, others remain moist. This behaviour shows a different pedoclimate and a different moisture regime.

A convenient mean of defining this behaviour is to know the water balance, that is the way in which the rain water is distributed. One can thus reason out the favourable or unfavourable consequences for land development.

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(1) one estimate is at 1700-1800 hrs. annually by analogy with certain areas of the Malaysian part of Borneo.

But this knowledge requires a great number of systematic hydrological and pedological measures which it is impossible to carry out during a first stage of soil reconnaissance. One must, therefore limit oneself to the estimate based on bibliographical information and above all on very detailed and recent studies made by ORSTOM in other equatorial forest environments comparable to that of Kalimantan.

2.1 THE WATER BALANCE

A soil water balance is as follows :

P = R + E + D + Delta S.

R gives the rainfall . This is only known approximately. We will choose the figure 3.500 mm of annual rainfall which is an average amount for this area.

R designates the running off :It is the rain water which runs on the surface of the soil, without penetrating it and which is evacuated directly into the hydrographic network. One finds in print considerable variations of the figures of this parameter for the equatorial forest soils. This comes sometimes from an interpretation or an inexact translation of the term "running off" which is confused with flowing. In any event, we know that there is only a small amount of running off water under dense forest. Qualitative observations made in Kalimantan during the storm rains confirm this. The rate of running off is between 1% and 3% of the total rainfall. Taking this data as a basic, one obtains by calculation and for R a sheet of water equivalent to a maximum of 100 mm.

PET is the potential evapotranspiration. It is a parameter of which the theoretical value is determined by calculation. It expresses the maximum quantity of water transpired by a continuous vegetal covering (1) permanently fed with water. The PET figure depends on climatic parameters such as the temperature, the sun radiation and the wind speed, for example. In this area the monthly rainfall is always higher than the monthly PET. In this case the natural vegetation is always fed with water and its effective evapotranspiration is at least equal to PET. On the other hand, the albedo of the forest is relatively low compared to that of a turfed surface so that the evapotranspiration of a dense forest is 9% superior to the PET. We call this the effective evapotranspiration maximum or RET maximum. The results by direct or indirect methods of the rainfall balance are concordant. One can thus estimate RET of this forest

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(1) Turf covering

environment to a sheet of water equivalent of 1.200 mm. Daily RET oscillates between 2 mm and 3,8 mm and rarely over 4 mm during the dry period (1).

Deltas is the variation of water storage in the soil. It is the quantity of rain water necessary to reconstitute the water soil reserves after a dry period.

The distribution of the rains is such that variations of the soil water content, are small. One estimates that this variation does not go above a sheet of water equivalent of 100 mm during a normal year. One also considers that the control section does not dry out or only dry out for several days a year, as the monthly PET is always superior to the monthly rainfall. This moisture regime characterizes a perudic regime.

D represents the drainage. It is the quantity of rain which penetrates into the soils, then comes out again to run into the hydrographic network after a more or less long way through the soil. The flow of water in the rivers between the swelling periods is fed by this drainage water. In general, the passage through the soil is sufficiently long in order to distinguish by hydrological measures the amount of water which runs off on the soil that which percolates. But, in this area of Kalimantan, there is a special phenomenon, already observed in the same environment in Africa or South America. After the rain, the level of water rises rapidly in the rivers, then it decreases also rapidly after several hours as in a country of deforested savanna. It all happens as if the rain water ran off the soil. In fact, the water penetrates the soil but rapidly comes out again if there were a kind of quick drainage. The phenomenon is known, it has been studied but still badly explained. Hypotheses have been put forward but none has been able to be proved as yet. The main thing to be remembered is that the water percolates through the upper part of the soil and it flows rapidly away.

If we again take the water balance equation, we obtain the drainage amount by calculation. The evapotranspiration, the running off and the variation of the soil water content, total up to a sheet of water equivalent to 1.400 mm : 1.200 + 100 mm + 100 mm. If one deducts this value from the total rainfall (R = 3.500 mm) one obtains 3.500 mm - 1.400 mm = 2.100 mm. The drainage is thus 2.100 mm, which represents 60% of the total annual rainfall. This figure tallies with data already published.

This equation also indicates that all the rain which falls above 1.400 mm constitutes an excess which can percolate through the soil.

This excess is of 2.600 mm for a rainfall of 4.000 mm

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(1) RIOU C. ORSTOM. Paris. 1975.

that is 26 million litres of drainage water per hectare per year. This is a considerable amount.

The very high drainage figure is the main characteristic of the estimated water balance of the soils in this area.

2.2 THE PEDOCLIMATE

The large amount of drainage is an element of the water balance. But the moisture regime of the soil will generally depend not on the atmospheric climate but on the behaviour of this soil relation to the water. Some hours after a heavy rainfall, some soils are already dry whereas others are still saturated with water. This behaviour characterizes a different pedoclimate that the observer can determine by the examination of the morphological features of the soil. For example, a very clayey soil on a moderate slope (10%) can be better percolated than a sandy soil on 20% slope. These signs of deficient drainage are visible in the soil.

To an uniform atmospheric climate in the area can thus correspond different pedoclimates. These are in close relation with the porosity, the permeability, and the soil structure.

Thus the quality of the physical properties of the soil is the second important characteristic to be considered.

2.3. CONCLUSION.

The climatic and hydric data have been the subject of more detailed analysis than that of other factors as we consider that they are of primordial importance for the management of the soils which are uniformly very low in chemical fertility, as we shall see in the second part of this report. For this reason, particular attention had been given on the field to the observation of the physical properties of the soil and to the indications about the water.

3. THE GEOLOGY AND PARENT MATERIAL - RELATIONS WITH THE SOILS.

If one compares the maps of appendix 3 and 4, one can see that the distribution of the main soil units coincides with that of the rocks. In addition, the studies on the field have shown that, in these units themselves, some characteristics of the soils closely depend on those of the parent material even if that does not always appear on examination of the analytical results. Thus, we have tried to identify, as much as possible, the parent material (1)

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(1) More than 2.000 observations have been made, 500 examples have been sampled, then determined macroscopically.

3.1 Outline of the geological history

The massive aspect of Borneo suggests that it consist of a relatively stable block in comparison with other islands of the Indonesian Archipelago submitted to an active and actual tectonic. But we think Borneo has undergone the consequence of this activity. What we know of its history since the paleozoic indicates that the island has a troubled geological past which expresses its great geological complexity.

Opinions differ the era from which the last important orogenic movements of the basement date (1). We will set aside this geological debate. That the basement is raised or the level of the sea drops, the result on the evolution of the soil and the weathering is more or less the same. We will thus only use the most marked facts which can explain the present distribution of the soils. They are as follows :

a - a former period of indeterminate age where the weathering was moderate compared with the actual one. The clastic products of this weathering have formed feldspathic sandstones. The products of pedogenesis would have constituted the sedimentary deposits rich in micaceous clays.

b - the formation of large batholiths of granite across the older volcano-sedimentary formations ; they form a great arc from the Kahayan to the Seruyan River. These granites date from 78 to 95 million years ± 5 (2). This puts them towards the end of the mesozoic period.

c - A very important tectonic accident oriented N 60° E to N 80 E is the major faulted limit between north and south Kalimantan (map annex 3). This fault crosses the perimeter diagonally from the Tewah area to Durian Kait then is prolonged towards Pankut and the north of Pankalunbun. Volcanic effusions correspond to the tectonic accident. This fault dates from the beginning of the tertiary period but we think it underwent readjustments during the tertiary and perhaps at the end of that time.

Alkali granite intrusions appeared around the same period (3) ; measures of absolute datation (2) indicate - 68 million years ± 5.

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(1) ANDRIESS J.P. 1972

(2) Method Rb/sr Geology Laboratory of Britanny France 1975

(3) In about the neogene.

d - On the tertiary period a phase of continental and lagunal sedimentation produced a considerable mass of deposits with a dominance in quartz and kaolinite. All these deposits are situated south of the faulted limit, with the exception of a 5 km wide band, orientated north south, which recuts the Katingan basin to the north of Tb Samba.

Their thickness, weak at the border of the basement increases towards the south submerging all forms of earlier relief with the exception of some rock granite outcrops. Basic rock intrusions crop out in these deposits but we do not know if they are from earlier effusions or ones occurring later. They are the outcrops of Bejarau, Pundu and Kawanbatu.

e - Finally, there are the quaternary sedimentary deposits visible all along the banks cut by the rivers. The thickness of these deposits varies from 6 to 12 m. The serie starts by coarse deposits overlying on the basement or on the tertiary formations. These deposits are gravely in the upper part of the Mentaya and the Kahagan where they slow a torrential type of flow. Above the gravely sands one observes clayey deposits produced by slow flowings and reorganized by the pedogenesis. This level ends with a brown layer containing organic matter and vegetal debris which looks like a A horizon of buried soil. The serie ends by silty clay deposits from which the actual soils are differentiated.

3.2. The igneous and metamorphic rocks.

There is a wide variety : acid rocks, basic and alkaline rocks which stretch from the great fault to the north of the perimeter at the foot of Schwaners mountains. These rocks are covered locally by small sedimentary basins.

We can divide these rocks into 7 main groups in this wide area which corresponds also to the area of ferralsols (1).

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(1) Refer to annex 3 and 4.

The alkali granites.

The two main batholiths are situated one to the west of Tb Jutuh and the other to the west of Tb Kalang. The pale rocks has a coarse to very coarse texture with pegmatitic facies. The weathering produces a sandy-clay to clayey-sand material whereas in the valley bottoms sand colluvium accumulates. Among all the igneous and metamorphic rocks, this granite is only the rock (with aplites) which are capable to produce acrisols and not ferralsols.

The common granites or orthogranites.

They are granites pale in colour and medium textured containing less than 10 % of mafic minerals, biotite and amphibole. They form large batholiths to the north east of Rantaupulut, to the east of Kulakayan, the west of Tb Kalang, the north of Tb Samba and in the area of Tb Jutuh. Their weathering produces a dansy-clay to clayey-sand material for the coarsest facies. The hue of the weathering horizon is often very pale, rose to grey white.

The biotite and amphibole granites and the granodiorites.

These are mesocratic rocks forming a continuous series with increasing proportions of mafic minerals. One associates with this group of rocks the quartz diorites of which the composition is little different. They form important batholiths of which the largest is found to the north of Tb Samba.

When the granite is not directly visible, one can often determine its nature by observing the colour of the soil. This is yellow to yellow brown on alkali granite and orthogranite. It is ochre yellow to ochre red on granite with mafic minerals and on granodiorites.

The diorites and microdiorites.

They form rather large blocks, or they appear in the form of veins in the granite batholiths. The aspect of both weathering and soil varies with the respective content in feldspars and in mafic minerals. Even though these rocks are theoretically devoid of quartz, the soils and the weathering always contain a little, which can be detected by magnifying glass. When the content in mafic minerals is very high and quartz very rare, it is not easy to distinguish the weatherinf of these diorites from those of basic volcanic rocks. In practical manner, we also link up the gabbros to this group of diorites.

The andesites and basalts.

These are the most abundant basic rocks localized to the north of Kualakuayan, to the north of Tb Baraoi and to the north of Tewah. Towards the south, intrusions crop out over 3.000 to 8.000 hect.in the sedimentary plain : the outcrops of Pundu, Bejarau and Kawanbatu.

In the basin of the river Kuhayan, these rocks often form rock domes or high hills, associated with trachy-andesites or tachytes. Some outcrops are given on the map but they have not all been identified on the field due to the lack of basic documents. When the rock is not visible, one can often determine that the parent rock is a basic rock by observing the soil, but it is more difficult to determine the exact nature of the rock.

The rhyolites.

The main outcrop is that of Rantaupulut which associated rhyolite and rhyolitic tuff in a hilly landscape The other outcrops form the rock domes which one sees to the north of Tb Baraoi, Tewah and Tb Miri.

The metamorphic series

They include the phyllites, the sericite schists, micaschists and gneiss. These rocks seem to weather with difficulty as it usually happens in tropical areas. They remain uneven and form the lines of the ridge like that separating the Katingan basin from that of Kahayan.

Diverse rocks

They include rocks in the form of very localized intrusions or veins: migmatites, aplites, ultra basic rocks, lamprophyres. These small outcrops have not all been identified or drawn on the maps.

Volcano-sedimentary formations.

They are series looalized in the upper part of the Katingan to the north of Tewah and Tb Miri. The observations show that it is a complex serie of a generally basic nature with intercalation of metamorphic facies. A more detailed study would be necessary in order to differentiate them. Taking into account the dominance of the basic facies, we include them in the group of andesites and basalts.

3.3 Sedimentary formations

The pretertiary sediments.

Their exact geological age is not known. They are formed of shales associated with siltites, veins of quartz and small andesite intrusions.

They crop out on a large strip orientated south west to north east from Durian Kait to Tb Sanak at the edge of the faulted limit. These deposits contain a particular group of clay minerals including micaceous clays, illite vermiculite interstratified clays, even small quantities of vermiculite. The proportions are 60% of kaolinite and 40% of 2/1 clay or the inversed proportions. The weathering produces a material containing the same mixture of clay and sometimes iron nodules variously hardened.

The tertiary sediments (1).

These continental and littoral deposits are made up of sandstones associated with shales. These sediments cover a large strech south of the fault, from the west of the Seruyan to the east of the Kahayan. The unweathered parent rock has not been observed, but only the products of its weathering which are quartz and kaolinite. The area of acrisols and podzols corresponds to these sedimentary formations. One distinguishes four series of sediments, according to the texture and the associated materials :

The Bejarau serie :It extends from the left bank of the Cempaga up to the western limit of the perimeter of the survey. The parent material is a medium textured sand more or less clayey. The inclusions of more sandy material and shales are spread out to a varying degree. The topography is undulating to slightly rolling.

The Katingan serie :It is a more sandy serie spreading from the east Cempaga to the Manuhing and the Rungan The sand texture is heterogeneous : medium sand to coarse sand or even locally gravels. Intercalations of shales are very rare. The topography is slightly undulated.

The Tumbang Jutuh serie :

This serie ,like the next one, is a fringing facies. Because of this, it is more heterogeneous and its topography is more hilly. It outcrops from west Manuhing to the Kahayan along a line Tewah-Tb Miwan. This serie contains fine clayey sandstones, medium clayey sandstones, shales, banks of pebbles and lignite, concentrations of platy iron hydroxydes in fine slabs very hardened and some

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(1) Tertiary age according to the geological maps consulted.

coral limestone banks. These deposits are crossed by some basalt and gabbro veins. The dominant facies is a fine or medium textured sandstone.

The Kualakurun and Upper Katingan series : It is situated in the area of Kualakurun and to the north of the Katingan where it cuts the upper part of the river Samba. They are deposits of weak thickness bordering the basement in a very hillocky and even very hilly topography. On some sections the discordant contact of the sediments with the basement has been observed, for example above Tewah on the Forestry Concession on the Company P.T. Indomas. This series contains a medium textured clayey sandstone associated with shale banks, conglomerates gravel banks, lignite deposits, silicified woods. In the outcrop of the Samba river the clayey facies decreases towards the south to the benefit of the sandy and even gravelly facies on the border of the Katingan.

The intrusions of igneous rocks.

The small intrusions of acid or basic rocks emerge from the sedimentary plain, especially in the Bejarau and Katingan series. They form spectacular reliefs (1) or reliefs which are hardly above the average level of the plain. Several of these intrusions have been identified and are drawn on the map. Others probably exist but they have not been marked because of the absence of basic documents and nebulosity of the satellite imagery. Their identification will be very easy as soon as the aerial photographs are available owing to the relief or to the aspect of the vegetation. Their reconnaissance is of double interest. Firstly because they are spots of soil which can be used for agriculture in a wide area of very poor soil ; on the other hand they are the only outcrops in the plain where it is possible to find materials for the construction of roads and constructive works..

The silty clay quaternary alluvions.

They occur in the valleys of the rivers during their course across the igneous rocks or at the beginning of their course in the sedimentary plain. They are products of the erosion of the basement by the rivers, which have not reached their equilibrium profile upstream showing a lot of rapids. The silts contain K-mica and microfragments of slightly weathering acid or basic rock. The lateral contact of these deposits with the basement is well marked by the topography. Periodically flooded during the swelling of the rivers these alluvions each year receive a variable quantity of clay and silt.

The clayey quaternary alluvions.

They are situated in the downstream part of the rivers

(1) For example that of Tenkiling 30 km month of Palankaray

during their course across the sedimentary plain. They are clayey and kaolinitic deposits. These deposits are sometimes associated to sandy banks and peats on the border of the tertiary series. The contact between the two formationsis locally progressive and difficult to detect on the field without aerial photographs. The topography of the alluvial valley is such that this valley or a part of it is flooded for long periods by waters which cannot run off laterally.

The colluviums of the valley bottoms

They are accumulations of clays, silt and sand, eroded on the slopes and accumulated in the valley bottoms. The composition and superposition of the deposits is very heterogeneous. They vary from coarse sand to clay according to the nature of the soils and the gradient of the slope. In the cleared areas accumulations of small fragments of charcoal mixed with sand and clay can be found. These are the lighest elements coming from the burning which are carried along by the waters in the plots which have been recently cleared. We shall see in the third part the consequences of this particular type of accumulation.

CONCLUSION.

More detailed indications will be supplied in the third part about the nature of the relations between the soils and the parent material. One can thus conclude this chapter by giving some general indications :

- On the regional level, the distribution of soils depends on the type of parent material on either side of a large tectonic ground feature which separates the basement from the sedimentary. On the one side, the ferralsols and on the other one the acrisols and the podzols.

- On the parent materials which are richest in quartz occur the podzols.

- The proportions between the quartz residue of the weathering and the nature of weatherable minerals determine, to a large extent, the properties of the other soils.

4. THE TYPES OF FOREST - THEIR RELATIONS WITH THE EDAPHIC CONDITIONS.

As we did not have the help of a botanist, we have no inventory of the flora of this area. However, an Indonesian team has carried out a localized study in the Kualakuayan area under the direction of Dr R.E. Soerjaatmadja (1).

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(1) Dr SOERJAATMADJA and his team from ITB, Bandung.

Thus our account will be limited to briefly described the principal types of forest at the same time as the edaphic conditions of the observation sites. Obviously, this procedure offers no floristic interest but it allows to get data on the relations between the soil and the vegetation and some indications on the natural fertility of the soils.

The natural vegetation is the lowland perhumid evergreen equatorial forest represented by the two main formations : the upland dipterocarp forest and the "health forest" (1). To these climatic forests small streches of edaphic forest and degraded formations are associated. The examination of the map (annex 2) shows that the repartition of the vegetal formations coincides remarkably with the main unitsidentified by the geological substratum and the soils (annex 3 and 4).

4.1. DIPTEROCARP FOREST

It covers the northern half of the map growing on the soils from granite or volcanic rocks, from the metamorphic series or from the most clayey layers of the old sedimentary deposits. It, therefore, covers all the area of ferralsols.

Although this forest has a fairly uniform aspect, it does, however, have perceptible variations in the density and size of the trees or the appearance of the undergrowth. We have distinguished 3 variations of the dipterocarp forest : a type of high productive forest, a medium productive and a poorly productive forest. This term of productivity requires some explanations.

The only quantitative data available come from an inventory carried out by the Services of the Forest Directorate (2) with a view to a forestry development. The figure used in the inventory reports corresponds to the average cubic measurement of timberwood in m3. This last is measured from the height of the chest or at 20 cm above the buttress for all the trees of which the diameter is 35 cm or higher. In addition, we have calculated from the inventories the percentages of dipterocarp in relation to the total cubage. But we would not venture to give these approximate figures a scientific value as the object of the inventory was of an economic order.

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(1) heath forest : name usually given to a particular type of sempervirent forest in south east Asia (T.C. Witmore 1975.) This forest usually grows on sandy and poor soils.

(2) Directorate of Forest Inventory and Planning. Bogor, Indonesia.

This is why we have expressed these quantitative data in terms of productivity, which enables us to support our quantitative remarks made on the field which are, therefore more or less subjective.

HIGH PRODUCTIVE FOREST

It is a beautiful forest whose canopy is 30 meters high or higher for the emergents and it has many large diameter trees. The underwood is scattered enough to walk through easily. In fact, they are supposed to be the most beautiful forests of the area.

The dipterocarp rate is at least 75% and the cubage of timber wood has a mean average of 175 to 200 m3 per hectare. This forest grows on two kinds of substratum. On the one hand, on mountainous landscape of which the soil is very thin, the mineral nutriment coming from the weathering of the rocks can be directly available for the roots of the trees. On the other hand, this forest can grow on rolling to hillocky landscapes, where occur very poor and deep soils coming from the weathering of the basic rocks. The mineral nutriments included in the deep bedrock seem to be difficult actually for the roots to reach. It is as though this forest was growing by turnover, because of a very quick mineralization process of the organic matter, as shown by the soil observation. The natural fertility is in fact very high, but one cannot prejudge about this fertility after the clearing of the forest.

MODERATELY PRODUCTIVE FOREST

This corresponds to the usual type formed on acid or alkaline rocks but not often on basic rocks. The height of the canopy is almost the same, locally lower but there are not many big trees, and the underwood is thicker. The usual emergents of the Shorea and Kompasio genus are in this case replaced by Quercus sp and Syzygium sp genus ; it seems that the soils are chemically less poor ; but this has to be controlled.The dipterocarps are still prevailing (about 75%) with a timberwood cubage varying between 125 and 150 m3 per hectare.

LOW PRODUCTIVE FOREST.

This extends along the heath forest border where it forms either a transition type or mosaic patterns when the edaphic conditions are very contrasted in a small area. This forest usually grows on soil from old clayey sediment deposits or from siliceous and acid eruptive rocks. Compared to the above mentioned kind, the canopy is lower, the trees density seems to be the same, but tree trunks of a small diameter are usually found. After clearing, the regrowth of secondary forests develop slowly, contrary to what we noticed in the above mentioned kinds.

The dipterocarps are less representative (from 50 to 70%) and the timberwood cubage has an average of 80 to 100 m3 per hectare. The relation between this forest and the edaphic conditions is particularly significant in heterogenous sedimentary deposits. For instance, to the north of Bejarau we notice this kind of forest on the clayey soils whereas the heath is located on the surrounding sandy soils.

4.2 HEATH FOREST.

Compared to the dipterocarp forest, this forest has a specific structure and physiognomy This forest is dense and composed of small diameter tree trunksof the same size ; the canopy is low and we notice just a few emergents (1). The name "heath Forest " is often used in the scientific publications. The local population use the vernacular name "Hutan" Gagas", which reminds one of the Iban word "Kerangas to name a cleared forest which is unable to produce upland rice. This definition seems fitting. The heath forest extends to the south of this area, and its extension coincides with the sandstone deposits. This is the area of acrisols, podzols and peats. When a fault obviously separates the basement from the sedimentary, we suddenly pass from the dipterocarp forest to the heath forest. But most of the time, the transition is progressive and when it is, we can notice intermediary vegetal formations between the dipterocarp forest and the heath forest. We have already observed three kinds of heath forest with different edaphic conditions.

HEATH FOREST OF THE NONSWAMPY LOWLANDS.

This ordinary kind is precisely what we call "Kerangas".From a plane, the canopy seems very homogeneous and without emergents. On the field, it looks quite regular and we do not often find trees of which the trunk diameter is more than 60 cm. Despite the density of the trees the light can still penetrate into the forest, reaching the relatively scattered underwood. Most of the trees have roots without any important buttress, and this forest is easily penetrable. The rate of dipterocarps do not reach 50% and the timberwood cubage is around 75 m3 per hectare.

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(1) The floristic composition seems different from the dipterocarpous forest. But we have no data available.

In some parts of this forest, there is a concentration of conifers, especially in Agathis Borneesis. They are usually located in the areas where the podzols are dominant.

HEATH SWAMP FOREST

The french translation of the "peat swamp forest" (1), can be misunderstood because of the meaning of the word "peat". The "peat swamp forest" is a swamp forest peat in the littoral and sub-littoral areas where the peat overlies recent clayey deposits. We think that this forest has developed from a mangrove swamp forest.

The heath swamp forest is located on very oligotrophic peats overlying prequarternary sandy materials; these peats are always associated with podzols. The distinction has a practical importance. The above mentioned peat forest can be used for agricultural developments whereas this one is unsuitable or not so suitable. To differentiate, them, we call this forest the 'heath swamp forest' which is another kind of heath forest and of which the physiognomy is quite similar.

This forest corresponds to the "Kerapah forest" described in the Malaysian Sarawak. This forest is wetter than the other one because the soil saturation by a water table lasts many months. A lot of trees have buttress which make the forest difficult to penetrate. The rate of dipterocarps is between 25% and 50%, the timber-wood cubage is around 50 m3 per hectare. But in some special areas, where the soil is sandy, deep and less flooded, there is a lot of conifers which give a more important wood cubage.

HEATH FOREST WITH LOW CANOPY

We do not often find this kind of forest and it can only be found in special areas. It is a very thin forest of which the canopy does not exceed 10 to 15 meters in height, and of which the diameter of the trunks is more or less 30 cm. The treetop allows a lot of light through but this doesn't much help the already very thin underwood. This forest had been observed on the left side of the river Katingan in a flat area on a typical podzol, formed on a coarse quartzous material saturated until the topsoil for many months by a perched water table ; there are also some Agathis which appear to grow much better than their partners.

4.3. EDAPHIC VEGETAL FORMATIONS

These are peat swamp forests, located along the

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(1) Commonly used.

rivers, on recent fluvial deposits. We can distinguish two categories :

TEMPORARILY FLOODED FORESTS

These are located on silty clay deposits along the upper course of the Tualan, Cempaga, Katingan,and Rungan rivers. These river banks are densely populated and the land around is all cleared. The former vegetation has disappeared. Now, it is locally a dense forest of which canopy is high with a bushy underwood.

SEMI-PERMANENT FLOODED FOREST

This forest grows on the alluviums where the rivers widen during their course through the tertiary sediments. The appearance of the forest is variable because the alluviums are made of clays,peats or sands on the border of the tertiary sediments. Sometimes, it is difficult to know the limits between the edaphic forest and the heath forest which borders on the former. This forest is also located on other large areas of which the soils, flooded for months, are unsuitable for cultivation during this period and therefore not cleared.

4.4 DEGRADED FORESTS

These are vegetal formations located on already cleared areas. All the different types occur between the recent fallow and the restored dense forest. In the forests, it is almost impossible for someone who is not a specialist to differentiate between a true primary forest and an already cleared forest but now mestored and looking like a primary forest structure (1).An inventory should be necessary

The surveyor only discerns the existence of a former clearing by the observation of the soil profile containing charcoal concentrations at variable depth. Elsewhere, the degraded forest is a pattern of recent fallows, old fallows, rubber and rotan plantations mixed with the natural regrowth in varying proportions. The only limit known with a good accuracy is that which separates uncleared forest from the recurrent cultivation area, called 'ladang area', because of its aspect on the satellite images. On the detailed scale, we don't find a systematic relation between the location of the cleared area and the edaphic conditions. But, on the regional scale, we state that the most cleared areas are located on the soils the most suitable for agriculture. Concerning the regrowth of the natural vegetation, there is an interesting observation to be made in the already cleared areas: This gives significant indications about the natural fertility of the soils

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(1) But maybe, with a different floristic composition.

which is usually difficult to appreciate otherwise, even using analytic data. We will talk about it in the fourth part of this report.

4.5 USE OF THE SATELLITE IMAGES

An important result has been obtained. The distinction between the primary forest and the cleared areas immediately becomes evident on the satellite imagery because of the very different reflectance of those two areas. This can be put in concrete form by using a magnetic tape for the automatic tracing of a map. Then, the mapped areas are calculated. This is therefore a very quick, economic and reliable way to know hte extension of the forest and to follow its development.

Another interesting result is the marking of the limit between the heath forest and the dipterocarp forest. We have indications about the detection of this limit between the Seruyan and the Mentaya rivers on the west of Kualakuayan. But, this has to be confirmed in other sites towards the east, which has so far been impossible because of the cloudiness of the actual images. Areas of peat forest appear in the lowest reflectances because of the water flooding or the water saturation of the soils.

When it will be possible to get quality satellite images, a joint survey including pedologists and botanists could be carried in out those areas. It would consist in studying all the visible variations of the canopy to the naked eye on using instruments in relation to the edaphic conditions observed on the field in some selected sites. The soil reconnaissance cartography of the tropical forests principally depends on a pertinent analysis of the vegetation aspect on the aerial working documents. We do not have many data about that and this is one of the main reasons this kind of cartography is still so difficult to carry out.

4.6 CONCLUSION

The evergreen equatorial forest doesn't offer an unvarying physiognomy. Here, it is a very beautiful forest there, a puny one. The regrowth after the clearing is luxuriant, there it is brush growing slowly. A same natural vegetation appearance can be due to different edaphic conditions and to different potential fertility. This difference can only become evident after some cultural rotations. It is therefore a question to know by the soil observation in what way the edaphic factors are able to influence the growth of the plants. Is it the nutritional level, the rooting conditions, the moisture regime or some other factors ?

5. TOPOGRAPHY

It is not possible to make a study of the landscape or even a geomorphological outline without topographic maps or aerial photos. This kind of study would have been very useful because the relief is one of the most important parameters for the choice of areas to develop, especially in this very rainy climate.

On the field, we have only observed the mains forms of the relief and taken some measures of the slopes. The result of those measures is given in the legend of the soil map. We did not identify all the relations between the forms of relief, the soils and the parent materials because some data like the geomorphological history of this region are still unknown. Nevertheless, one will give some general information about the forms of the relief. They show the relations between the topography and the parent material which, are the most evident on the field.

The great south-west/north-east faulted limit separates two areas. To the south, an area of undulating topography with slopes inferior to 15%, and usually inferior to 10%. From a plane, this area looks like a wide plain where emerge a few inselbergs. To the north, it is hilly topography where the slopes exceed 15% and often 25%. A lot of hills and inselbergs can be seen in the background and we can also see the counterforts of the Schwaner's mountains.

THE SOUTHERN AREA.

On the sedimentary deposits, the wide interfluves have a rather rectilinear slope and they are fitted together by concave slopes to valley bottoms which are only cut by the rivers in the lower part of the river basins. The topography can, locally become more rolling when the deposits have a clayey facies or when they are thin on the border of the basement taking then shape of the former topography ; the flattest areas correspond to the most sandy deposits where occur podzols and peats.

In this area, the lowest of flattest slopes are also those of the alluvial plains along the banks of the rivers.

THE NORTHEN AREA.

Each main type of parent material generally correspond to a kind of relief ; but this is not true in every case; there are exceptions according to the geological structure, the rock facies and their location in the river basins.

ON GRANITE.

The dominant slopes are convex slopes with rounded tops which suddenly fit together to narrow and flat valley bottoms which do not often exceed 50 m in width except near the main rivers.

At the top of the hills, the slope varies from 5% to 10%, increases to 25% on the versants and finally reaches 45% at thè break of slopes. These average values increase more especially as the granite is coarse textured, has a low mafic mineral content and is located upstream in the river basins; If we consider the serie from the granodiorite to the coarse alkaline granite, the topography is more hilly and the valley bottoms more and more narrow.

ON BASIC VOLCANIC ROCKS

The slopes are variable. Sometimes we notice depressed interfluves with flat summits and convex and concave versants of which the slopes reach 8% to 15%. They are separated by valley bottoms of 100 to 150 m width. Sometimes, these interfluves are rather short with narrow tops and slightly convex or rectilinear steep slopes fitting together abruptly with narrow valley bottoms cut by the rivers. In this landscape occur high hills and inselbergs. At their foot we observe slightly depressed circular areas. We did not observe distinct relationsbetween the topography and the position in the river basin. Thus, on the same type of parent rock, the landscape can abrutly change from undulating to hilly.

ON ACID VOLCANIC ROCKS

The topography is generally hilly, with high hills, mountainous reliefs or rock domes. The deep and narrow valleys are filled with colluvial deposits. Many slopes from 25 to 30% are found.

ON METAMORPHIC ROCKS

The topography is very hilly. The rectilinear slopes with narrow ridges fittogether with narrow valley bottoms cut by the rivers. This kind of relief is located upstream of the river basins where the slopes reach 30%. We have already mentioned above that these rocks form the high parts of the landscape because of their very low speed of weathering.

In brief, we can say that in the northern part of the Durian Kait-Tewah axis, alluvial valleys and valley bottoms are the only flat areas ; everywhere else the topography is hilly to hummocky. But in the southern part of this axis the topography is undulating to rolling.

6. THE HUMAN ACTION -INFLUENCE ON THE SOILS

The human action exerted on the soils of this area is of two kinds : the forest clearing for cultivation and the lumbering.

CLEARING.

The cleared area covers about 470.000 hectares, that is to say 21% of the mapped area. Comparing the distribution of the cleared areas and the soil distribution, we notice that the soils of the alluvial valleys and the soils on the basic rocks are the more occupied areas. The soils under the heath forest and the low productivity dipterocarp forest are the less cultivated. That shows at least the empiric knowledge of the local population about the quality of the soils. The traditional agriculture is called "shifting cultivation' (1) but recurrent cultivation could be a better term as, in fact, the fallows are periodically used for cultivation from the permanent habitations. In the last years, the opening of the logging roads network has increased the extension of the clearings at the expense of the primary forest.

The rotation cycle of the fallows is variable according to the soils and the areas. The average is one year cultivation for 10 to 12 years of fallow.

What is the result of this type of cultivation on the soil ? Is it destructive or not for the soils ? According to our observations, the consequences vary with the soil type. Schematically, we will differentiate between the soil degradation and the soil erosion.

SOIL DEGRADATION

It appears on the soils having a very low natural fertility and already submitted to several fallow rotations. Usually, these soils are acrisols associated with podzols in the sedimentary plain where the slopes vary from 3% to 10%. The observations mentioned a very obvious degradation of the physical properties of the top horizon : degraded structure, decrease of porosity and permeability, specially on the soil surface. The organic matter undergoes some modifications, gets more acid and becomes less associated to the mineral fraction. Some special kinds of plants which usually grow on the very acid soils proliferate . The tree stratum grows with difficulty and keeps a puny appearance. We have noticed that the soil moisture regime changes because the grass cover gets dry enough to be burned though under a very humid climate. This reduces furthermore the content of organic matter and the already very low mineral reserves which are swept down by the rain. These soils, naturally of low fertility, obviously advance towards degraded lands. The process can reach an advanced stage such as the forest cannot grow again normally. Even a longtime fallow cannot probably restore the original fertility of the soil. We have not observed such advanced stages in the surveyed area but in some surrounding areas like Pankalunbun

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(1) Commonly used.

and above all Palankaraya which is a typical example.

SOIL EROSION

This is the removing by the running off water of the superficial part of the soils. It is usually the result which can be foreseen when cultivation practices are carried out without anti-erosion measures on the steep slopes, this is the traditional way of cultivation used in those regions. We could suppose that when these very steep slope are cleared for paddy fields, the soil erosion would be very important. But observing the soil in those plots, we notice that the erosion is very weak during the first year of cultivation and goes down the next year as soon as the weeds appear on the soil already planted with banana trees, corn and cassava. What is the cause of this weak erosion ?

Firstly, even a good burning still leaves vegetal debris on the soil and above all large tree trunks which protected the soil from the running off water accelerated by the steep slope. The dense root covering protects the soil from the kinetic energy of the rain drops. More, the exclusive use of the dibber for the seeds does not make important disturbances on the topsoil. At the harvest time, the ears are cut in such a way that it leaves the stems and the root clusters which hold the soil and protect it during the regrowth of the weeds. All this is added to the natural physical qualities of the soils on the uplands in order to limit the effects of erosion. In conclusion, the traditional cultivation does not cause the destruction or erosion of the soils, which stay on a very moderate level. This cultivation, if it is well done, uses a lot of space (1), but gives the people the opportunity of using the soils for their subsistence and at the same time of preserving the main equilibrium and the environment.

LUMBERING

They provoke important soil damage (2), but are limited in the space. These works alter the soil on a deep thickness and lead to the soil destruction along the roads and the surroundings of the working sites.

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(1) Report to geographic data.

(2) Without mentioning the genetic damage.

On the timber working sites in the forest, the visible damage is less obvious ; but the top horizon is very altered by the machines scraping the soil. We consider that the damage by lumbering covers more than 20.000 hectares of land in the surveyed area.

THE REGROWTH OF THE VEGETATION AFTER THE CLEARING.

By observing the forest, we can estimate the natural soil fertility, but this is sometimes deceptive because the forest can survive with her own reserves due to the fast recycling of the mineral elements. Once cleared, the soil can become very poor as regards cultivation within just a few years. Observations carried out on fallows, on cleared cultivated lands since a few years are significant for they give the potential fertility level under natural conditions. On some soils, the regrowth of the plants and trees is slow ; the secondary vegetation and the underwood are clear. On the contrary, on other soils cleared since the same period, we observe a luxuriant and invading vegetation of lianas, shrubs and wild banana trees.

The population uses these indices to look for soils more favourable for cultivation and where the fertility potential is quickly restored by using the fallow process. Those indications are also useful to the pedologist and the agronomist, because the laboratory analyses are often unable to reveal those fertility differences, however obvious on the field.

III

SOILS

1. SOIL DATA - THE SOIL MAP.

This soil survey has not been carried out as a systematic inventory of the soils, but rather as a programme with a clearly defined objective. This objective is firstly the identification of the most suitable soils for cultivation and secondly the selection of the most suitable areas for transmigration projects or regional development. According to the standards which are usually used in this type of programme, this selection has two main requirements: a part of the land has been used for food crop production and the topography has to be favourable to agricultural works ; this means slopes less than 8% for the foodcrop cultivation and less than 15% for the perennial cultivation. The survey has been conducted so as to collect, on the one hand, the adequate and necessary data to reach this objective , and on the other hand, to give information in order to make easier the detailed studies on proposed and selected sites. These data are shown on a reconnaissance soil map at the scale 1/250.000. But as specified in the Agreement, the accuracy of the studies depends on the quality of the basic working documents. The essential elements of these working documents were not available and because of this the mapping is approximate, especially in the areas where satellite images are not clear and in the forest areas where it is too difficult to penetrate.

2. MAPPING UNITS (1)

The soils are distributed into 20 mapping units. They are delimitated according to the nature of the soils and their type of association, the kind of parent material and the landscape. There is often a correlation between these three parameters. The topography is an important parameter as it corresponds to one of the two main criteria for the site selection. So, we have paid special attention to the landform and to the slope. The parent material has been also considered as a main criterium because there is always a correlation between the parent material,the soil type and its fertility.

Consequently, the parent material can be selected as a criterium for making the difference at the level of the mapping units between soils having the same denomination (2) and occurring in the same type of topography.

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(1) Report of the legend of the soil map.

(2) cf. The soil nomenclature according to the F.A.O. system.

GEOMORPHOLOGIC UNITS

We have selected four main units : the alluvial plains along the rivers, the tertiary plain, the upland hills, the rock domes and mountaineous areas.

PHYSIOGRAPHY.

The legend of the map, first of all, gives the relief with the degree of dissection and the slope of which the percentage corresponds to an averag gradient. We know the slope inclination can vary on the same mapping unit according to the location in the river basin and to the degree of dissection ; but an indication of the average value could be sufficient for a reconnaissance survey.

TOPOGRAPHY

The topography is shown on the legend by a draft which represents the general landform and the width of the valley bottoms. The numbers give an estimation of the distance between two talwegs and the width of the valley bottoms. The initials above the draft correspond to different soil type occurring on the slopes according to their relative proportions.

3. - SOIL DENOMINATION - CLASSIFICATION.

The mapping units are called by the name of the taxonomic soil units they contain. The Agreement plans to use the "Americain classification , the French classification and F.A.O. if necessary and then to make the correlation between them". In fact, this causes some difficulties. To the usual difficulties of correlating classification established from different concepts is added the difficulty to classify some soils in the Kalimantan area if one strictly has regards for the taxonomic standards. Here is an example about the Soil Taxonomy.

It is not possible to classify some soils according to the field observations and even the usual analysis alone It is necessary to resort to laboratory techniques which are not always available or which take a long time. This is the case for the clay mineral determinations and forthe micromorphologic examinations often necessary to identify the argilic horizons. The interpretation of these last data can sometimes be debatable. This is so for the illuvial clay and the weatherable secondary minerals.

These ambiguities lead to differentiate at a very high level of the classification soils showing the same aspect, the same physical behaviour, the same moisture regime and on which the plants grow in the same way. An example is the differentiation made between dystropept and haplorthox in the surveyed area.

We have partly avoided the difficulty by choosing any classification, but the F.A.O. System which is presented on the map legend. Nevertheless, the correlation between the different classifications will be made in Appendix : American, Indonesian, and French Classifications. The F.A.O. System is international. It is here more adaptable than the Soil Taxonomy and seems more fitted to these tropical soils of Kalimantan. This System is pragmatic for us and it gives the opportunity to differentiate mapping units capable of the same kind of management with a level of accuracy sufficient at the reconnaissance survey stage of our project.

4. KEY FOR THE LEGEND.

These indications refer to the last column, that of soil units. The soil , written in capital letters is the dominant soil. The soil written in small letters represents the soil associated to the former. If this soil associated to the dominant soil is written in italic letters, it represents an inclusion, that is to say its outcrops cover less than 10% of the mapping unit.

The soils which cover less than 5% of the mapping units are not mentioned in the legend but only in the report. But the soils of the valley bottoms even though occurring with a low percentage, are always mentioned in the legend because of their practical interest. The sign + means that the soils are associated in toposequences.

5. GENERAL CHARACTERISTICS OF THE SOILS (1)

All the soils of the area have common characteristics independent of the parent material and topography, but in relation to their bioclimatic environment and probably with their history. These common characteristics relate to the depth of soil, the organic matter, the physico-chemical and mineralogical properties.

The soils including their weathering horizons are relatively shallow. The average depth is 6 to 8 meters on consolidated rocks which is low compared to the average depth on other continents (Africa or South-America) where the depth commonly varies from 20 to 25 meters. On the contrary, the "solum" (2) lying on the weathering horizon is always

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(1) When not otherwise stated these always refer to soils under natural forest vegetation.

(2) The solum is defined as the part of the profile where the weathering horizon with a lithologic structure has disappeared and where the constituents are reorganized by the pedogenesis.

deep. Its thickness reaches 2 or 3 meters of homogeneous material with a low content in coarse particles as quartz or iron nodules. Nevertheless, at the limit between the solum and the weathering horizon, one often finds a 20 to 25 cm depth horizon containing a high concentration of varying, disjointed and coarse elements hardened with iron or aluminium hydroxydes, and rarely with silica. This stoneline takes the approximative shape of the surface topography.

<u>The soils of the area have thus the following profile</u>

. from 0 cm to 40cm	: A horizon, sometimes E horizon.
. from 40 cm to 250/270 cm	: B horizon
. from 250/270 cm to 300 cm	: horizon with a concentration of coarse elements.
. from 300 cm to 600/800 cm	: the weathering horizon in gradual transition with the weathered rock.

There are two exceptions to this general rule : on the one hand are the soils of the mountainous and very hilly areas where the soils are not so deep, and on the other hand are the soils on grainy and coarse textured rocks where the depth reaches 15 meters or more.

The most important is to know the solum generally is deep , homogeneous and rarely eroded.

<u>ORGANIC MATTER.</u>

The soils have a high content of organic matter. This is unusual in the low tropical areas, that is to say in the areas less than 500 meters above the sea level. We can make 3 observations about the properties of this organic matter :

- There is no definite relation between the soil colour and the organic content. In some cases, morphologic examination is unsufficient in order to get only an estimation ; a chemical analysis is necessary.

- There is a close relation between the nature of the organic matter and the type of parent material. The "mull" "moder" and "mor" definitions which the French classification refers to (1) are particularly well adapted in order

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(1) CPCS, 1967 - P. DUCHAUFFOUR 1967.

to define this organic matter. This criterion among others has been used to identify soils of which the parent material was not visible in the profile.

- Whatever the organic matter type, some of the physical and chemical properties of the humic horizon are uniform : low pH, low base saturation of the exchange complex, high exchangeable aluminium content (1).

These organic matter properties are interpreted as being a variable dependent on the bioclimatic environment.

THE PHYSICO-CHEMICAL PROPERTIES

The soils are very acid, in a range of pH water of 3,8 to 5,3 with extremes of 3,0 to 5,6. The exchangeable bases content varies from 0,5 to 2,5 meq (2)in the topsoil. and from 0,2 to 1,5 meq in the subsoil where a 2 meq content is exceptional. The base saturation of the exchange complex is usually less than 10%. The exchangeable aluminium saturation rate of 60 to 80%. Most of the values which are above these norms come from soils sampled in recently cleared and burned areas.

MINERALOGY.

The clay mineralogy has to be mentioned because it is a characteristic of some soils of this area. It is known that the clay constituents of the equatorial forest soils including ferralsols are mostly 1/1 clay type, gibbsite and iron compounds, goethite and hematite. Here we have found deep soils with the appearance, the physical and hydric behaviour as the ferralsols. But these soils have 1/1 clays mixed with 2/1 clays : illite, interbedding illite-vermiculite, and even vermiculite. The proportion of 2/1 minerals can reach 40% to 60% of the mixture. However, these clays have relatively low activity because of the large quantity of aluminium absorbed on the sites of exchange. The presence of these secondary minerals considered as "weatherable minerals" contrasts with the missing primary minerals completely weathered with the exception of the more resistant ones such as quartz, zircon,...Until now we cannot give a precise explanation about the presence of these 2/1 clay minerals in the soils of this equatorial forest.

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(1) Complementary studies would be necessary in order to define the nature of the organic matter beyond its pH properties and exchange complex

(2) Meq = meq/100 g of fine earth dried at 105 ° C.

on the Cempaga, to the south-west of Tb Kalang, in the upper course of the Rungan river.

Description.

The topography is hilly and the relief dissected. The hilltops are not so flattened ; the hillsides have a convex shape and they are abruptly linked up with flat and rather narrow valley bottoms ; the landscape is almost identical to the rounded hills on granite.

Ferralsols are widely the dominant soils and the proportions of gleysols are about 5% or less. On the diorite veins more frequent than in the precedent sub-unit occur orthic or humic ferralsols.

Particularities.

Upstream Tb Samba, in the area of the Katingan, the ferralsols show some particularity. The base saturation is higher compared to the usual rate of 10% since it reaches 20 to 40 %. This anomaly is due to the very low CEC of the B horizon which is less than 5 meq./100 g of soil. The permanent charge is less than 2 meq. These characteristics are marks of acric properties that are always unfavourable for the soil utilization.

Land occupation.

It is estimated that 85 to 90% of this unit 12 is under forest. Clearings have been carried out along the main rivers. But for a few years now the clearings seem to be carried out along the logging roads in the Katingan basin (1).

Recommendations for the survey.

Indications given for the unit 11 are available for this unit.

MAPPING UNIT 13.

Extension-location.

77.340 ha. 3,5%.

Ten outcrops ; the two main ones appear to the north of Kualakuayan, and in the upper basin of the Cempaga and the Tualan. All the others are dispersed in the Rungan and Katingan upper course. Small inclusions of the unit 13 have been identified in the unit 11 and 12 but they cannot be drawn on this small scale map (1/250.000).

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(1) Report to the geographic data.

This results from a difference in the interpretation of the soil characteristics and, consequently, in their appelation. This question is part of a scientific debate which is out of place in this report. Nevertheless, we will briefly talk about this problem.

We have called these ferralsols because they have a B horizon which is not cambic , nor spodic, nor natric. Neither it is an argilic B horizon but rather an oxyc B horizon, or at least its nearest characteristics have those of the B oxyc. Theorically, the B oxyc horizon has no illuvial clay content ; this is one of the main features which differentiates it from the argilic B horizon. On the other hand, its exchange capacity does not exceed 16 mq per 100 g clay and it does not contain weatherable minerals. From these first definitions we begin to have two main difficulties to classify the soils of this area : to differentiate with accuracy between the argilic B and the oxyc B and to determine whether the secondary minerals are weatherable or unweatherable.

To clear up these difficulties due to the strict application of the defined standards, we have chosen another solution which is not altogether orthodox but of practical use for the objectives of this mapping.

The ferralsols have been divided into two categories :
1° - the typical ferralsols in which the oxyc B horizon has exchangeable properties according to the standards : CEC equal to or lower than 16 mq/100 g of clay.

2° - The ferralsols with 2/1 clays showing the following properties in the B horizon.

- a CEC of 17 to 24 meq per 100 g of clay.

- the presence of illite clay, interbedded illite-vermiculite and a small amount of vermiculite, mixed with 1/1 clays.

- Total base reserves equal to or over 20 meq /100 g of fine earth , mostly potassium.

6.1.1 GENERAL CHARACTERISTICS OF FERRALSOLS.

The common characteristics of ferralsols will be firstly defined and then we will describe the particularities of the 3 identified kinds of ferralsols : humic, orthic and xanthic ferralsols. They all have the same dystrophic and Al-dominated properties (1).

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(1) a rate of saturation lower than 35%, and an aluminium saturation rate over 50%.

ENVIRONMENT.

The two caracteristics concern the topography usually hilly but rarely undulating or rolling and the vegetation which is always the dipterocarp forest. The population generally located along the river valleys in the areas wher occur acrisols and podzols begin to disperse and to occupy the hinterland as soon as the ferralsols area is reached.

This is apparent on the Map of the area under shifting cultivation. The ferralsols appear to be undamaged although they have been under shifting cultivation for a long time. The rapid growth of the vegetation after clearing is locally related to the natural fertility of the soil.

MORPHOLOGY.

The ferralsols have an ochric A horizon, rarely umbric on a transitional AB horizon lying on a B oxyc horizon. There is never an eluvial E horizon between the A and B horizons.

A HORIZON.

It is ochric because its colour is not dark enough to be umbric or if it is, its thickness is unsufficient because it is not thicker than 10 to 15 cm ; in this horizon, the density of the roots and the biologic activity level are very high. The designation of A ochric covers three types of humic horizon, recognizable on the field by the surveyor.

FIRST TYPE.

The A horizon, of which the depth is 10 to 15 cm, is easily recognizable in the profile because of its brown colour which becomes lighter in the subjacent horizon. An examination by magnifying glass shows that the organic matter is not well linked with the mineral fraction and a lot of particles of quartz not integrated in the aggregates ban be seen.

The litter, which is 3 to 5 cm thick, is reddish in colour where it is in contact with the fine roots covering the soil. This type of organic matter often occur in xanthi ferralsols formed on granitic and acid rocks and some metamorphic siliceous rocks.

SECOND TYPE.

Under a litter of 1 to 2 cm thick, the A horizon cannot be easily recognized by its colour, except in the first 2 or 3 cm. The organic matter is closely linked with the mineral fraction in the aggregates. This second kind charac terizes the humic ferralsols, sometimes orthic ferralsols on basalt and andesite or on basic rocks having the same composition.

THIRD TYPE.

This is intermediary between the two types mentioned above. The brown colour of the topsoil is visible only on 6 to 10 cm thick, then it quickly becomes lighter. The organic and mineral matter forming aggregates include most of the quartz grains. This type often occurs in orthic ferralsols on moderated acid rocks : granodiorites, quartzic diorites.

If we consider the balanced stock of organic matter in the soil between 0 and 50 cm between 0 and 100 cm, the soils with an A horizon of the second type have the largest stock and those of the first type the lowest stock. So, the total organic matter content cannot be related to the brown colour of the soil.

A.B. HORIZON.

This is a transitional horizon, always more compact than the A horizon, where the biological activity is also lower and the rooting less dense. One can also distinguish three types of AB horizon, homologous to the above mentioned A horizon. In the first type, the penetration of the organic matter is very apparent and located around the aggregates of which colour is deeper than the one inside ; sometimes hydromorphic features in the shape of grey fated spots of a gley aspect and rusty iron hydroxide deposits inside the root channels.

The second type constitutes a very gradual transition between the A and B horizon ; often difficult to differentiate by the colour without the Munsell book. The penetration of organic matter associated to the aggregates is not visible. The third type is intermediary. Humic penetration appear on aggregates but hydromorphic features are not often noticed. This AB horizon gradually changes into the less compact and different in colour B horizon.

B. HORIZON.

An examination by the naked eye or magnifying glass does not reveal the existence of illuvial clay. The micromorphologic examinations made on the thin sections probably will confirm the field observations.

Equatorial forest soils of similar morphology on the same type of parent rock have been examined in thin sections in several areas (1), in Central Africa and Sarawak, for instance. They did not reveal illuvial clay. Microscopic examinations revealed that clay skins on the surface

(1) ORSTOM - studies in Africa/J.P. ANDRIESS in Sarawak in 1975.

of the aggregates could not be considered as illuvial clay. We have also noticed that the water percolating through these horizons is very clear. This means that the colloidal complex is stable in the water and this contrasts with the water charged with colloids which percolate through the typical B argilic horizon in the acrisols. The content of granulometric clay in all these soils progressively increases according to the depth ; but this does not mean that this increase comes from a clay accumulation by illuviation.

In the reverse, we also could say that the clay content decreases from the depth to the surface. Recent studies on African ferralsols have showed a loss of fine particles in the surface horizons under both biologic activity and water effect but without clay accumulation in the depth. The French classification gives to this process the name of 'appauvrissement' without specifying the nature of the process not clearly known.

We did never find an E horizon above the B horizon. Therefore, while waiting for the results of the thin section examinations and taking in account the other properties , we will consider this B horizon without illuvial clay, as an oxyc B horizon. therefore this is why we call the soils of the uplands in Kalimantan ferralsols and not acrisols.

PHYSICAL PROPERTIES

The ferralsols are marked off from the other soils of this area because they always have very good physical properties : low bulk density, well developed structure very high porosity and permeability.

These properties are inversely proportional to the content and the size of the quartz in the parent material. They are therefore better in the very clayey soils on basalt (75% clay) than in the sandy clayey soils on granite (54% clay). This characteristic is due to the type of organisation between the constituents. It also depends on the quantity of metallic hydroxides in relation to the content of mafic minerals in the rock.

The aggregates of the A and B horizons resist mechanic pressures and are difficult to moisten because of the content of humic compounds, but they do not split in water. These properties give the horizons a strong resistance to the raindrops and erosion effects, favouring a fast water percolation through the soil. In the depth, as soon as the content of the organic matter drops below about 1,5% the stability and the resistance of the aggregates to water is reduced.

The bulk density varies between 0,90 an 1,30 g/cc3 with a porosity of 70 points in the topsoil and 50 points in the subsoil. The maximum porosity is reached onthe surface horizon of humic ferralsols on basalt. The available water, expressed in the equivalent sheet of water and obtained by calculation, varies from 90 mm to 130 mm per meter of soil. The 110 mm value can be considered as a mean average which corresponds to the usual data mentioned in many publications.

MOISTURE REGIME

This is a percolation regime. The rain water percolates through the soil over a depth of 200 cm at least without forming a perched water table.

The percolation speed varies according to the type of ferralsols and their physical properties. Water percolates through humic ferralsols on basalt with surprising rapidity. The percolation is slower in xanthic ferralsols because a saturated water level occurs near the transition between the AB and B horizon ; this saturation lasts for several hours after heavy rains. But we have never observed in ferralsols even a temporary watertable between 0 and 250 cm although the rainfall is very high.

We do not carry out on the field measures of the soil moisture. However, we estimate that the soil under forest has an almost constant level of humidity below 150 cm and that the mean annual variations of the water storage between 0 and 150 cm are always low, at around 100 mm. The soil moisture probably never falls below the permanent wilting point value (1) under the natural vegetation. In cleared and cultivated areas, the moisture regime is certainly more contrasted.

CHEMICAL PROPERTIES

These have the same above mentioned standards. Referring to the usual analysis results, the variations scale is narrow, whatever the type of ferralsols and parent materials. Here are some average values : pH 4,2 in the topsoil to pH 5,1 in the subsoil with a difference between the pH H20 and the pH KCL of 0,8 in the topsoil and 1,1 in the subsoil. The content of exchangeable based is less than 2 meq in the topsoil and less than 1,5 in the subsoil with a base saturation less than 10%. Some properties associated to the exchange complex differ slightly between typical ferralsols and 2/1 clays ferralsols. An exchange capacity higher than 10 meq in the topsoil is the result of a high organic matter content or 2/1 clay presence,sometimes the two characteristics being associated.

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(1) Water content to the pF 4,2.

A CEC higher than 8 meq/100 g of soil in the B horizon often means the presence of 2/1 clays. Exchangeable aluminium from 3,5 to 2,5 meq (1) in typical ferralsols reaches 7 and 5 meq in 2/1 clays ferralsols. Because of this they have a higher permanent charge and an aluminium saturation of 80% or more. The total bases extracted by concentrated nitric acid are significantly higher in 2/1 clays ferralsols because of the potassium content.

MINERALOGY

We cannot give strict rules, but we can say from a first approximation that the clay mineralogy seems to be related to the nature of the parent material. But complementary investigations would be necessary. The main mineral associations are as follows :

- On basalt : metahalloysite, kaolinite, gibbsite, goethite.

- On andesite : kaolinite, illite, a few interbedded illite-vermiculite, goethite.

- On granite and granodiorite : kaolinite, goethite, a little gibbsite, sometimes silica.

- On claystone : disordered kaolinite, illite, interbedded illite-vermiculite, goethite, gibbsite.

Hematite is rare whereas very fine quartz (less than 2 microns) is quite often found in the soils on grainy rocks. Some weathering horizons on andesite have a 2/1 clay content, others have none ; but in the reconnaissance survey the studies are not advanced enough to know the detail soil mineralogy.

In short, the ferralsols are homogeneous profile soils, clayey or sandy-clayey with good physical properties. They are rich in organic matter and sometimes contain 2/1 clays.

6.1.2. HUMIC FERRALSOLS.

They are humic because of the high organic matter content which penetrates in the B horizon and not because having an umbric A horizon. They all are ferralsols of low altitude areas with a well humidified organic matter having a C/N ratio of about 13. The content of organic matter varies from 5 to 10% in the topsoil and usually from 2,0 to 2,5 at 50 cm and 1% at 100 cm. In addition to their humic characteristic considered as a dominant feature, these ferralsols have also orthic and xanthic but rarely rhodic and acric characteristics.

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(1) When not otherwise stated, the first number refers to the topsoil and the second one to the subsoil.

They are mostly formed on basic rocks which have a high content of mafic minerals : basalt,andesite, metagabbro, amphibolite, and sometimes diorite. So, the soils have orthic, rhodic or acric characteristics. On rhyolites and shales with 2/1 clays, the ferralsols have xanthic characteristics, and rarely orthic characteristics.

The most beautiful forests grow on humic ferralsols which are very searched for traditional cultivation. The profile is very homogeneous ; it is difficult to discern the limits between the horizons and to estimate the content of organic matter on the field. The texture can be a clay texture to a heavy clay texture. Among all the ferralsols, the humic ones have the best physical properties : well developed structure, fine polyedric sub-angular to crumby structure in the topsoil, and fine polyedric in the subsoil. When dry, we notice that it breaks up into very small aggregates from 1 to 3 mm. The bulk density is less than 1,20 g/cc3 which gives a high porosity value.

They are the most permeable and the best drained soils. Hydromorphic features only appear around 150 cm depth on some rare sites when the topography is slightly undulating.

It seems that the exchangeable bases content in the topsoil is a little higher than in the other ferralsols. But these values are so that it could be at the limit of the systematic error of analysis or due to the heterogeneity of the sampling on the field. A statistic analysis of the data would be necessary in order to confirm this.

HUMIC FERRALSOLS WITH ACRIC CHARACTERISTICS

These always occur on dark basic rocks ; they have orthic or rhodic, but never xanthic characteristics. Their morphology is distinguished by a moderate biologic activity in the topsoil, the presence of gibbsitic or iron nodules at less than 100 cm depth and sometimes a iron hardpan.

Although covered by beautiful forest, they are not searched for cultivation though they form small areas of clayey soils amid sandy soils areas which have a very low fertility level. The physical and chemical properties of the absorption complex are special : the permanent charge is less than 1 meq/100 g of soil and the difference between the pH H2O and the pH KCl varies from 0,1 to 0,4 ; the exchangeable aluminium content is less than 1 meq in the B horizon and the total exchangeable bases less than 0,3 meq; these properties are among the acric characteristics.

6.1.3. XANTHIC FERRALSOLS.

By definition, these ferralsols have a rather pale colour, yellow to yellow brown or yellow reddish (1). They have a rather shallow dark brown A ochric horizon. The B horizon is a typical B oxyc with 2/1 clays. The dipterocarp forest has a lower productivity than the forest on humic ferralsols. After clearing and cultivation, the regrowth of weeds and of the secondary forest is quite slow. This seems to show that the natural fertility level is lower. Besides, large areas of xanthic ferralsols are still under primary forest. These soils are formed on granites, on granodiorites, on metamorphic rocks poor in mafic minerals and on clayey sedimentary rocks. The palest soils (10 yr of the Munsell code) are observed on akaline granites, orthogranites and leucocratic granites. The morphology is then characterized by organic matter penetrations in depth on the surface of the aggregates, by hydromorphic features in some volumes of the AB horizon, by the existence of clay skins on the aggregates in the B horizon between 30 and 80 cm, by the appearance of mottlings below 150 cm and by coarse sands.

Under a 3 to 4 cm litter, the organic matter content is very high, from 12% to 15% but it decreases rapidly in depth : 3,5% at 20cm, less than 1% at 50 cm, and 0,5% at 100 cm. The texture is from sandy clay to clay, sometimes clayey sandy in the topsoil on coarse grained rocks. The exchangeable bases content is, on average, less than 1 meq for all the horizons and the permanent charge less than 4 meq. The CEC does not reach 10 meq except in the soils containing 2/1 clays.

6.1.4 ORTHIC FERRALSOLS

These are ferralsols of which the B horizon is reddish yellow to reddish brown (2). Sometimes, they are associated in the same mapping unit to xanthic ferralsols. The ochric A horizon is shallow and it can be easily distinguished by its brown colour of the AB and B horizons.

The vegetation is a dipterocarp forest with many large-diameter trees. This forest looks like the humic ferralsols one. These soils are usually cleared when they are rather near the village.

They occur on medium acid rocks with mafic minerals content (granodiorites, diorites, gabbro), on metamorphic rocks (gneiss with amphibole) and on shales. They are also found on basic rocks when the organic matter content is not enough to classify them with the humic ferralsols.

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(1) From 7,5 yr to more yellow.

(2) More red than 7,5 yr on the Munsell code..

Uusually, the soil is deep and homogeneous. The soils on granodiorite and quartz diorite contain some iron nodules above 150 cm ; these nodules are 3 cm to 10 cm pieces of weathered rocks with an undisturbed lithologic structure. The residual constituents of the weathering in the nodules are cemented by iron hydroxides. The organic matter content is intermediary between that of the humic and xanthic ferralsols : from 4% to 6% in the topsoil with a C/N ratio of 14, from 0,8% to 1,2% at 50 cm and less than 1% at 100 cm. The texture varies from sandy clay in the topsoil to clay in the subsoil. The CEC, which is usually less than 10 meq in the topsoil, can reach 15 meq with a mineral fraction containing 2/1 clays and a high content of organic matter. The other properties are those of the ferralsols.

6.2 ACRISOLS

The most widespread after the ferralsols. Those soils cover about 25% of the map. They are often associated in the landscape with podzols. Acrisols occur on sandstone which the weathering produces a kind of sandy to clayey material, with mostly kaolinite in the fine fraction. Acrisols can also be observed on very siliceous igneous rocks or igneous rocks with a very high content of coarse quartz.

Those acrisols can be spotted on the southern part of the map, from the Western to the Eastern edge in the undulating to sightly rolling plain.

They are either of a pale colour or faintly coloured, sandy in the top soil, sandy-clayey to clayey-sandy in the subsoil. The soil is depth including 3 main horizons with gradual boundaries : an ochric A horizon - rarely umbric, an eluvial E horizon on an argilic B horizon. Hydromorphic features can be noticed at different levels of the sub-soil.

Three types of acrisols have actually been identified in the area : ferric, humic and gleyic acrisols.

ENVIRONMENT

The parent material of the acrisols is never very sandy or very clayey ; on very sandy parent material occur podzols whereas on very clayey parent material occur ferralsols.

The natural vegetation is the heath forest, or a kind of forest which is between the heath and the dipterocarp forest ; The topography of the southern part is slightly undulating but becomes more rolling towards the Northern part, and near the basement.

Generally, those soils are left rather uncleared ; but they can be cleared near the very cultivated alluvial lands along the rivers, especially where these lands are often flooded like in the Seruyan valley.

After the acrisols have been cultivated for some time without periods of fallows, the forest is then replaced by the Imperata cylindri savanna (alang-alang). This savanna is burned every year partially or in its whole part.

MORPHOLOGY

The ochric A horizon being of a dark brown colour can easily be noticed on the field. Its thickness varies between 10 to 15 cm.

Some acrisols with hydromorphic features have a very dark brown A horizon of which the thickness is enough to be considered as an umbric horizon. Then, the hydromorphic features appear from the base of the A horizon.

The colour of the E horizon is more pale than the A horizon one and often than the B horizon. The E horizon contains less clay and iron compounds than the B horizon. Examined through a magnifying glass, the structure of the soil components appears to be of the eluvial type : high interparticular porosity, the particle arrangement is intertextic or agglomeroplasmic but never porphyrosquelic ; very clean grains of quartz are not included in the aggregates.

The content of E horizon in organic matter is much lower than in the A horizon, even, in the E horizon of the humic acrisols. The argilic Bt horizon is often separated from the E horizon by a transitional horizon of variable thickness, with more B features than E.

On the field, the B horizon has been visually spotted because the presence of illuvial argilanes of a lighter colour than the matrix ; these pedological features can be located in the pores and the cavities, or at the top of coarse quartz grains.

However, the eye cannot always spot the argilanes, even with the help of a magnifying glass, especially when the horizons are pale ; then recourse to a soil thin section observation is needed.

The permeability and the porosity of this horizon are always lower than those of the upper horizons. Hydromorphic features appear on one part at least of the horizon, or sometime all over it.

Related to some of the E and B horizon properties, are two other characteristics that have been noticed on the field : the drainage water percolating through the soil, looks muddy with a clear-grey to greenish-grey colour. They contain (in relatively stable suspension) some fine clay and dispersed particles which can move in the soil to finally deposit where they find suitable physical and physico-chemical conditions. On the other hand, one has frequently observed accumulations of iron hydroxides which form cylindrical and rusty sheaths (of 2 to 3 cm in diameter), hardened by ferric compounds, around root channels.

These two phenomena prove a certain mobility of both iron and clay that is not being observed in the ferralsols, at a depth varying from 0 cm to 2oo cm.

PHYSICAL CHARACTERISTICS.

These soils have deficient physical properties with a tendency to deteriorate more after the clearing. In the topsoil, the aggregates are of a small size under the natural vegetation, but they are fragile, and can be easily crushed under weak mechanical pressure. The wettability of the aggregates is rather high ; they do not split in water when they have a high content of organic matter. Its resistance is reduced in the E and B horizons where the organic matter content is less than 1%.

The topsoil under the forest is porous, permeable and well structured due to a high biological activity, and a abundance of fine roots from 0 to 20 cm ; but in depth, these qualities disappear as the bulk density rises to 1,5 - 1,6 g/cc3 in the B horizon which resulted in an important reduction of the porosity and permeability. Some cultural cycles cause an important reduction of the surface porosity and on the other hand, increase the bulk density by the destruction of the aggregates in the topsoil where then the bulk density rises to 1.0 - 1.3 g/cc3.

THE MOISTURE REGIME

This regime is determined by 3 characteristics :

a) a low moisture holding capacity in the topsoil, and a low content in available water varying between 55 mm to 80 mm (1) of water per meter of soil. In the subsoil, this amount increases with the clay content to reach a maximum of about 125 mm.

b) a topsoil with contrasted moisture regime ; this

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(1) Calculated in water equivalent sheet.

is very wet to saturated during the rainy periods, but dry up quickly during the dry periods.

c) Heavy rains and a slackening of the water infiltration through the B horizon cause perched water tables. The bottom of these water tables lies at any level of this B horizon and its hydrostatic level fluctuates according to the volume and the frequency of the downpours. These water tables occur on the top of the hills as well as on the slopes. Along the roadtrenches opened for forestry works, the water of these water tables can be seen flowing laterally for several hours after a rain to a depth of 100 to 150 cm. These water tables are not permanent as they quickly disappear after a few dry days.

This moisture regime establishes an important difference between the acrisols and the ferralsols of this area.

THE ORGANIC MATTER

In spite of its dark colour, the topsoil contains a moderate quantity of organic matter, on an average 4%. This amount decreases rapidly in the subsoil : less than 1% at 50 cm and 0.5 % at 100 cm. Only humic acrisols have a higher content in the topsoil. The organic matter is slightly linked with the mineral fraction (1). Some grains of quartz are not integrated to the aggregates and their amount increases considerably in cleared soils.

THE CHEMICAL PROPERTIES

They are found on a lower level than those of the ferralsols ; only the pH of the topsoil which is about 4.5, is a little bit higher than that of the ferralsols. The pH of the subsoil is about 5.0. The amount of exchangeable rarely exceeds 0.5 meq and the base saturation nearly reaches 5%,the permanent charge is below 3 meq/100g; the exchange capacity is lower than 10 meq. in A and lower than 5 meq. in B ; only the topsoil of the humic acrisols has a higher C.E.C.. The aluminium saturation is equal or higher than 75%. Whichever the horizon may be, the mineral reserves are indeed very low : 4 to 5 meq of total bases extracted by nitric acid. The phosphorus and potassium content is also very low. That is related to the nature of the parent material which principally consists of quartz and kaolinite, with traces of muscovite.

About the general characteristics of the acrisols,

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(1) Ratio C/N : 19.

we can conclude that to the lower level of chemical properties than those of the ferralsols are added deficient physical properties which cause a particular moisture regime.

ACRISOLS ON IGNEOUS ROCK.

We had already said that they are formed on eruptive rocks, particularly rich in silica, with a medium texture like the aplites, or with a very coarse texture like the alkali granites and pegmatites. These acrisols are less typical than these issued from sandstones : they are always slightly widespread forming inclusions in the ferralsols. They are mostly found at the lower part of the slopes where sometime they are associated with podzols. Their texture is less sandy, with a pale colour changing from yellow to grey-yellow. The hydromorphic features mark the B horizon. The chemical properties are the same as those of the nearby ferralsols. But some of the acrisols on aplites contain 2/1 clays, which results in an exchange capacity of 18 to 24 meq and a reserve of total bases, from 12 to 16 meq, especially potassium.

6.2.1. FERRIC ACRISOLS.

They are the most commonly found. Their ferric character is marked by an exchange capacity value inferior to 24 meq./100 g of clay. They are neither humic nor gleyic. Their colour is never very pale, but yellow to reddish-yellow, without hydromorphic features between 0 cm to 120-150 cm; the transitions between the A, E and B horizons are very progressive. These soils are located on the top and on the slopes of the interfluves.

One has noticed some ferric acrisols associated with podzols; then they have a very sandy texture which give them the ferralic arenosols appearance. The succession of the horizon is the same as in the more clayey acrisols. A C.E.C. of 24 meq/1oo g is the highest value that is rarely reached in the ferric acrisols of this area ; the exchange capacity is most often inferior to 16 meq. for 100 g of clay.

The other properties are those commonly found in the acrisols.

6.2.2 GLEYIC ACRISOLS

As a whole, they are paler than the preceding ones, except for the A horizon which is darker ; this one is often ochric because of its weak thickness, but sometimes umbric.

The gleyic acrisols occur at the low part of the slopes between the ferric acrisols and the dystric gleysols in the valley bottoms ; but they can also be found on the top of the interfluves where they are then associated to some inclusions of podzols and humic acrisols.

Hydromorphic features appear in the E and B horizons and sometimes at the lower part of the A horizon. They are patterns of a rusty colour and ferranes in the root channels, hardened iron hydroxide concentration and very bleached volumes of a gley colour.

We have also described some gleyic acrisols where the organic matter penetrates in the form of tongues into the E horizon, above a compact and low permeability B horizon. The type of organic matter, the migration of organic substences in the subsoil indicates a pedogenesis with a tendency towards podzols to which those acrisols are of course associated.

6.2.3. HUMIC ACRISOLS.

They have an umbric A horizon with abundant organic matter (1) having a C/N ratio of 20 to 25, a very pale E horizon on a very compact, pale grey B horizon. The transition between the E and B horizon is very clear, and sometimes rather abrupt with a planic characteristic.

The high content in organic matter causes a C.E.C. of 15 to 20 meq. in the topsoil.

Hydromorphic features appear from the top of the E horizon, like in the gleyic acrisols to which they are associated.

The other properties are the characteristics common to the acrisols.

6.3 PODZOLS.

They are the 3th category of soils the most widespread which covers 15 % of the map. Due to their low agricultural interest, they are not subjected to detailed observations. Consequently, the description is limited to the principal types of podzols and their general characteristics.

The presence of a B spodic horizon (2) and a topsoil of raw humus renders a very easy diagnostic of these soils, without any possible confusion. The morphology is the same as that of the podzols from cold and temperate areas, with the exception of the E horizon which does not have an ashy but albic character.

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(1) 10% to 12% of total organic matter.
(2) Definition of spodic B. legend of the map of the world (P. 26).

ENVIRONMENT

The podzols occur in the sedimentary plain, on sandy or sandy-gravelly materials ; they are very rare on the basement where they only occur in the valley bottoms on the coarse and sandy colluvium produced by the weathering of the very siliceous rocks.

The type of forest is always the heath forest with concentrations more or less dense of Agathis according to the sites. The topography is almost flat, but can also become hilly near the border of the basement. The drainage waters are easily recognized as they get their very brown colour from the soluble organic products ; this indication has helped to locate the podzols on the field checked later during the survey.

TYPES OF PODZOLS

We have noticed several types of podzols. First of all, 2 great categories : podzols with perched water-table and podzols without perched water-table.

PODZOLS WITH PERCHED WATER-TABLE, they are subdivided into :

- Podzols with hardened spodic B horizon.

They are podzols with an O or H histic topsoil, often thick, over a very pale sandy E horizon, with an abrupt boundary over a thick B spodic horizon hardened and of low permeability. The perched water table is formed above the spodic B horizon which slows down or prevents the infiltration of rainwater in the subsoil. This water-table fluctuates in the A and B horizons laterally and slowly. The colour of this water is always brown, with reddish glints. The depth of the spodic B is situated between 50 cm and 150 cm.

In the lowest part of the landscape, the thickness of the topsoil increases progressively, and one notices the changing over to peat soils where the water saturation subsists longer than in the podzols.

- Podzols with unhardened spodic B horizon.

It is no longer the impermeability of the spodic B which causes the forming of the perched water-table, but the clayey B horizon, compact and slowly permeable, with hydromorphic features, under the spodic B horizon.

In the landscape, these soils are mostly associated to the acrisols rather to the peat soils and they are never as thick as the preceding ones. Under a 4 to 5 litter, their profile includes an O horizon and an umbric A horizon, but rarely a histic horizon : the E horizon is sandy, of a pale colour with black accumulations of organic matter, unhardened,with various orientations. The spodic B horizon is a little bit thick, between 10 to 30 cm, slightly hardened or unhardened; it gradually changes over a low permeability, compact horizon, sandy clay with a pale colour and mottlings. This horizon, looking like the clayey Bt of the acrisols, slows down the water infiltration in the subsoil and causes the formation of a perched water-table during the rainy season ; this water-table disappears after a few dry days.

PODZOLS WITHOUT PERCHED WATER-TABLE.

They are podzols where any horizon prevents the water infiltration in the subsoil ; they are consequently subject to water percolation conditions and they only reach saturation after the heavy downpours. We recognize 3 types of morphology :

- Podzols with spodic B horizon.

They are common podzols or othic podzols. The 10 cm E horizon contains accumulations of organic matter which do not wrap up the quartz grains. The spodic B horizon contains humic and ferric compounds. Under the spodic B horizon, we generally observe a slightly compact, sandy clay and pale colour horizon.

- Podzols with a very thick E horizon.

The profile is identical to the preceding one, but the E horizon is very pale, very sandy and thick, sometimes reaching a thickness of 5 meters. Under the E horizon a spodic B horizon locally slightly hardened.

In other areas, this type of podzols is called " giant podzol" because of the thickness of the E horizon.

- Podzol with humic and spodic B horizon.

Slightly to moderately thick, this profile includes a 10 cm to 50 cm E horizon, over a spodic B horizon containing organic matter, but only a little or any hydroxides. This horizon is friable and lies on a sandy to sandy clay permeable material.

PHYSICAL PROPERTIES

They are very deficient. The organic horizon of the topsoil has very high hydrophobic properties. The E horizon contains less than 10% or less than 5% of clay ; it has a particular structure and a very weak moisture holding capacity. The E and B horizons are not favourable for the rooting limited only in the topsoil.

The water holding capacity causes in the podzols without perched water-table a very contrasted moisture regime to which the vegetation has to adapt itself ; after heavy rains, a saturation period follows abruptly after a period when the sandy horizons were still dry.

THE ORGANIC MATTER.

The content of organic matter in the topsoil is very high in the podzols with water-table : from 35% to 60% in the podzols intergraded with peat soils. In the spodic B horizon the content of organic matter sometimes exceeds 15%.

The content of organic matter is lower in the podzols without water-table : from 10% to 15% in the topsoil of the orthic podzols, from 6% to 10% in the podzols with humic and spodic B horizon ; in the B horizon, the mean content is then 2.5% to 8% and sometimes reaches 12%. The C/N ratio of the organic matter varies from 20 to 35.

CHEMICAL PROPERTIES

The content in mineral elements available for the vegetation is very low and close to that of the acrisols. However, high organic matter content horizons have particular properties : the pH is very acid in the topsoil (between) 3.0 and 4.0) and acid in the subsoil (between 4.0 and 4.5). The total amount of the exchangeable bases reaches 2.5 meq in the very humic top horizon. Generally, the mean content changes from 0.5 to 1.5 meq.

The exchangeable aluminium rate is relatively low compared with this rate in the acrisols and ferralsols ; we may assume that the exchange complex is charged by some H^+ ions supplied by the organic matter. The exchange capacity isproportional to the organic matter content according to an approximate ratio of 2 meq. of CEC for 1% of organic matter.

The mineral reserves of the E horizon formed by 95% of quartz are of course very low. Cn the other hand, the reserves extracted by nitric acid are more importantin the humic topsoils,especially calcium and magnesium ; however, they are less important in regard to potassium. The phosphorous reserves are as usual : 22 PPM of 205 (HCl) in the topsoil 50 PPM of P_2O_5 ((HCl) in the subsoil.

CONCLUSION.

Therefore, they are soils with more deficient physical properties than those of the acrisols because of their very sandy texture, with almost identical chemical properties, but modulated by a high content of organic matter.

This area shows a wide range of tropical podzols. Though these soils present a low agricultural interest, they are at least scientifically interesting for detailed soil researchs.

6.4. GLEYSOLS

The gleysols, fluvisols, cambisols and histosols cover only 5%, or less 5% of the total surface. First of all, we shall examine the gleysols.

These soils present pronounced hydromorphic features at a depth less than 50 cm. They all have the dystric characteristic because the base saturation of the exchange complex is less than 50%. One have found 2 main categories of gleysols :

- The gleysols of the valley bottoms between the slopes, in the uplands ;

- The gleysols in the quaternary alluvial plains bordering the main rivers.

6.4.1. GLEYSOLS OF THE VALLEY BOTTOMS.

They occur in the flat valley bottoms between the slopes occupied by ferralsols or acrisols. Their extension varies according to the topography and the parent material. Generally, these valley bottoms are wider on the basic rocks and on the sandstones than on the granites and the metamorphic rocks. In the first case, their width can reach 100 to 150 m, but widths of 10 to 30 m are more frequent.

They are characterized by a permanent or semi-permanent water-table which fluctuates in the soil between the surface and a depth of about 100 cm. The natural vegetation is the dipterocarp forest, which presents a slightly different physiognomy with the forest on the slopes ; probably its floristic composition is different, which is not surprising because the moisture regime of the soils is also different. The secondary forest regrowth is slower than on the slopes after the clearing ; moreover, the valley bottoms are often used for rice cultivation which delays the forest regrowth.

MORPHOLOGY.

The morphological and physico-chemical characteristics vary only a little whatever the type of the other associated soils.

The 10 to 20 cm A horizon is ochric, grey brown to dark grey with or without hydromorphic features ; it gradually or abruptly changes to a B horizon paler with a few or many mottlings. The texture is heterogeneous ; the usual succession consists of a sandy-clay horizon over a more clayey horizon ; but the inverse disposition can also be observed.

These variations result from the parent material being a mixture of weathering products coming from the bed-rock and of colluvial products swept along the slopes and accumulated in the valley bottoms.

PHYSICAL AND HYDRIC PROPERTIES.

They depend on the texture. The sandy soils are porous permeable with a low moisture holding capacity. The clayey soils are compact with a low permeability. The difference with the clayey but permeable ferralsols, is due to the clay not linked to the iron hydroxides but associated to the quartzeous skeletal, thus forming a compact structure.

The soil is satured up to the topsoil during the heavy rainy months and it can be temporarily submerged by the rainwater flowing slowly on the soil towards the drainage streams. On periods of rain abatement, the water table drops to a level of 100 cm or 150 cm, or disappear if the subsoil is not enough porous or if the bed rock under the soil is cracked.

According to the observations, the gleysols on basic rocks seem to be more able to impound the saturation water than the gleysols on acid rocks ; the very clayey deep horizon probably forms a bottom for the water-table with rocky shelves in the subsoil, which prevent the water from flowing out laterally.

THE ORGANIC MATTER

The mean content is between 3% and 6% with a maximum of 10%. A very high content reaching 20% to 30%, which characterizes an umbric A horizon, is rare ; the C/N ratio of the organic matter is between 17 and 19.

CHEMICAL PROPERTIES.

They are nearly the same as those of the soils on the slopes . However, the gleysols can contain an amount of exchangeable bases relatively a little bit higher.

The pH varies between 4.5 in the topsoil to 5.0 in the subsoil. The average of the exchangeable bases is 1.0 to 2.0 meq. and the base saturation is between 10% and 30%. The exchangeable aluminium (less than 2 meq) represents 50% to 60% of the exchangeable cations. The exchange capacity is usually 12 meq. in the topsoil and 8 meq. in the subsoil.

In the gleysols sampled in the areas where the slopes have recently been cleared and burnt, the physico-chemical properties of the absorption complex suffer important changes. The pH reaches 5.5, the sum of the exchangeable bases reaches 10 to 12 meq. with a base saturation more than 35%. The exchangeable aluminium content drops considerably. This is due to the mineral elements contained in the ashes which the water has dragged down to the valley bottoms. This immediate action of the soluble ions absorbed on the exchange complex, is followed by the delayed effect of the progressive release of mineral elements from the fragments of charcoal also swept down to the valley bottoms by the water. It is therefore assumed that an artificial mineral reserve is formed, which supplies the low amount of the natural mineral reserves inferior to 10 meq. of total bases.

6.4.2. GLEYSOLS OF THE ALLUVIAL VALLEYS.

They are humic gleysols associated to fluvisols and histosols on quaternary alluvial deposits. They also offer a dystric character.

They differ from the preceding ones by a high content of organic matter, and by a fine homogeneous texture. Their whole profile is saturated during long periods by the soil water table and flooded by water during the swelling of the rivers because these soils are located in the lowest parts of the landscapes. The chemical properties are almost those of the preceding gleysols except for the higher exchange capacity in the topsoil due to the content in organic matter ; the pH of the topsoil is close to 5.0. The mineral reserves vary with the nature of the parent material. They are very low, 4 to 5 meq. of total bases in the soils on the clayey and kaolinitic alluviums, probably higher in the soils on silty-clay alluviums.

6.5. FLUVISOLS.

They are soils formed on recent alluvial deposits in the valley of the main rivers. They have an ochric A horizon on a silty-clay material more or less structurated by the pedogenesis, which still preserves the characteristics inherited from the sedimentation. We have noticed fluvisols with or without hydromorphic features, but all with dystric characteristics. The first ones are called gleyic fluvisols (the gleyic characteristic being considered as dominant) and the second dystric fluvisols.

The dystric fluvisols occur on the bank levee and in the well drained parts of the plains ; the gleysic fluvisols are found in the less drained areas, where they established the transition with the gleysols.

ENVIRONMENT AND PROPERTIES.

The natural vegetation of these soils is a riverine forest or a freshwater swamp forest, but it practically disappeared since these valleys have been occupied and cleared for a long time now. Therefore any soil could be sampled under the natural vegetation.The secondary forest with its bushy underwood alternates with hevea and rattan plantations, small coffee plantations and some rice fields.

The usual profile includes a brown topsoil, gradually changing to an homogeneous material brown yellow or red yellow, without coarse elements but with hydromorphic features at a variable depth depending on the topography. The structure is well marked on the topsoil, not so individualized in the subsoil where the porosity and the permeability slow down.The bulk density changes from 1.0 in the topsoil to 1.4. in the subsoil with a total porosity of 6o points to 45 points. The stratification of the parent material is often noticeable, but there is not abrupt variation of the texture, which always remains silty clay loam to silty clay.

In the subsoil under 200 cm, sometimes one can observe some sand beds and silty-sand beds, and under 300 cm a buried and brown A horizon 20 to 30 cm thick, containing 1 to 2% of organic matter.

The topsoil is well drained ; but in the depth the drainage is slowed down by the weak permeability and by the presence of the water table fluctuating during the year up to 50 cm in the gleyic fluvisols. During the floods of the rivers the water can submerge the fluvisols for a few hours to several days and then the water disappears at the end of the floods. The water holding capacity is rather high ; the reserves of available water range from 110 mm to 130 mm per soil meter like in the ferralsols.

The chemical properties can vary because they depend on the recent cultural utilization of the soil. However, according to the soils sampled in the fallows and in the old plantations, the characteristics of these fluvisols hardly differ from those of the other soils of the area.

The content or organic matter is 6 to 10 % in the topsoil with a C/N ratio 12 ; this content drops rapidly in the subsoil : 1% at 50 cm and 0,5% at 100 cm. The pH is around 5.0, the sum of exchangeable bases is less than 2 meq. for a base saturation of 10% to 15% ; the exchangeable aluminium content is twice at least higher than the exchangeable bases ; so, the aluminium saturation with regard to the permanent charge is more than 70%. The exchange capacity is proportional to the content of organic matter in the topsoil with a ratio of 2 meq. of CEC for 1% of organic matter. The content in mineral reserves depends on the mineralogy of the parent material. It is inferior to 5 meq. of total bases in the fluvisols on the kaolinitic clay, and can reach or exceed 20 meq. of total bases on the silty clay deposits, potassium being the main element.

6.6. CAMBISOLS.

They cover, as a whole, about 5% of the map occurring in inclusions in the ferralsols or in association with the fluvisols in the alluvial plains. All the cambisols have dystric characteristics because the base saturation is less than 50% ; many of them have the ferralic characteristics with a calculated CEC of clay less than 24 meq./100 g ; at last several are humic and non ferralic. These humic cambisols are found in inclusions in the ferralsols, on very basic rocks. The ferralic cambisols occur in inclusions in the orthic and xanthic ferralsols, on the granites and on the shales.

The cambisols are geographically distributed in 2 categories : the first one on the basement and the second one on the quaternary alluviums.

6.6.1. CAMBISOLS ON THE BASEMENT.

It is noted that the cambisols are associated to the ferralsols in the areas where the topography is hilly to very hilly ; often, they present the general aspect of the ferralsols, but thickness. It can be difficult for the surveyor on the field to distinguish between an eroded ferralsol and a cambisol . Therefore, the laboratory analysis are necessary to determine the level of activity of the exchange complex, and the content of mineral reserves.

These soils are covered by a beautiful forest and they are also very cleared within a perimeter extending far from the main villages.

Generally, these cambisols occur more often on the compact basic rocks than on the grained rocks like the granite.

MORPHOLOGY - PHYSICAL PROPERTIES.

The average depth varies from 50 cm to 200 cm ; the A horizon is ochric , not very thick, brown to yellow brown, with a gradual transition to a cambic B horizon, brown, yellow brown, or dark brown in the subsoil. The texture is sandy-clay to clayey ; the structure is very well developed , crumby to fine subangular blocky in the topsoil, and subangular blocky in the subsoil. Below the B horizon, one notices in some profiles some primary minerals with an undisturbed structure but very friable, and some blocks of unweathered rocks. There are any hydromorphic feature, because the permeability is very high in all the horizon on account of the very good structure.

The physical properties are like those of the ferralsols:a low bulk density of 0.85 in the topsoil to 1.15 or 1.20 g g/cc3 in the subsoil and a calculated total porosity varying between 65 and 55 points.

The mean content of organic matter is 5% in the top horizon, 1,5% at 50 cm and a little less than 1% at 100 cm.

CHEMICAL PROPERTIES.

On the one hand, they are characterized by a rather high CEC due to the organic matter and to the presence of a mixture of kaolinite with 2/1 minerals ; on the other hand, the mineral reserves increase towards the base of the B horizon where residual primary minerals can be found.

The humic cambisols can be distinguished from the other cambisols by the brown colour and the content in organic matter, the high CEC, and important reserves of bases, especially magnesium in the soils on basalt, like those of the upper part of the Kahayan river. Nevertheless one remarks (1) the very high desaturation of these soils and the very high content in exchangeable aluminium. Their aspect of well structured brown earth cannot therefore be associated to a high rate of chemical fertility like in other areas.

The cambisols on the basement have the qualities of the ferrasols and more higher CEC and mineral reserves. That places them among the soils having the highest cultural potential of the area ; potential which is only relatively high for this area,as it should be specified.

6.6.2. CAMBISOLS ON ALLUVIAL DEPOSITS.

They occur mainly on the alluvial deposits along the Katingan river. These soils have an ochric A horizon on a cambic B horizon without hydromorphic features (at least between 0 cm and 100 cm). The B horizon has cambic characteristics because the parent material has undergone a pedological evolution, such as the soil structure has taken the place of the no longer recognizable sedimentary structures.

Most of the time, these soils are cleared and used for food crops or perennial crops.

The topsoil is brown, homogeneous, porous, well structured ; the cambic B horizon is reddish-yellow, porous, with a medium blocky structure and with a diffuse boundary to the parent material.

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(1) Report to analytical data in appendix 6.

The physical properties are comparable with those of the associated dystric fluvisols ; the only difference is found in a better individualized structure which increases the permeability and makes easier the drainage in the subsoil. The content in organic matter is about 5% on the long-time cleared soils, but irregularly cultivated.

The organic matter penetrates deeper than in the fluvisols ; 1.5 % at 50 cm and 8.0 % at 100 cm ; this still concerns an organic matter which is well humidified and well linked to the mineral fraction, with a C/N 11.

These cambisols have a relatively higher content in exchangeable bases than the other soils : from 2.0 to 3.0 meq. in the topsoil and in the subsoil. The aluminium saturation is less than 50%, which rarely is observed in this area. The CEC is still related to the mineralogy of the parent material and to the content of organic matter. So, there are mineral reserves which are not negligible in the subsoil although, in general, these reserves are concentrated in the horizons with the highest content of organic matter. The reserves are included in potassic micas, micaceous clay, and in micro fragments of unweathered rocks deposited by the water. The CEC. calculated for 100 g of clay, often exceeds 24 meq./100 g ; that's why these cambisols are rarely ferralic and are thus called dystric cambisols.

6.7. <u>HISTOSOLS</u>.

These soils have a histic horizon formed by more or less decomposed organic residues.

They occur in 2 kinds of areas : the histosols of the <u>alluvial plains,</u> and the histosols of the <u>tertiary plain</u>.

<u>6.7.1. HISTOSOLS OF THE ALLUVIAL PLAINS</u>.

They are associated to the humic gleysols and, together, they can form intergrade soils. The content of organic matter exceeds 30%. Usually, it is a weathered peat (saprist) where the decomposed residues are mixed with a clay, or silty clay mineral fraction. The liquid flowing from the peat, when squeezed,, is turbid. The vegetation is a forest appearing different from the heath forest with some species having a characteristic aspect. The thickness of the peat is 50 to 100 cm on some sites it reaches 200 cm to 300 cm. The pH is 4.5 to 5.0 and the reserves of total bases extracted by nitric acid reach 20 meq./100 g.

6.7.2. <u>HISTOSOLS OF THE TERTIARY PLAIN</u>.

These histosols are associated to podzols which cover the lowest parts of the landscapes. In fact, they are soils, formed bv the podzol upper organic horizon which increases in thickness as it becomes more fibrous. The water flowing from the peat is not muddy but coloured in brown by soluble organic compounds. The histic horizon can sometimes be very deep : between 3 and 5 mm. The content of organic matter can exceed 75% ; the pH is very acid and less than 4.0.. The reserves of total bases extracted by nitric acid are 10 meq. of which 85% are calcium and magnesium.

The vegetation is an uncleared heath forest because these soils are never used for cultivation by the local inhabitants. Moreover, they are not more interesting than the podzols for land management.

6.8. RANKER, REGOSOL, LITHOSOL.

We mention for memory only the 3 types of soils which have been checked in small inclusions among the ferralsols and the cambisols on the inselbergs, on the high hills and in the mountainous areas. They occur on hard rocks and very steep slopes, 40% to 45% and more. The regosols and the lithosols are covered by a highland dense forest but the rankers sometimes are covered by a forest with low canopy.

6.8.1. RANKER.

This type of soil will become the subject of a more detailed description than the two others because we can consider it as unusual in the low altitude tropical areas.

It has a A reddish black horizon, 20 cm to 30 cm thick ; this horizon lies on the parent rock, an unweathered rhyolite.

In contact with the rock, one see discontinuous pockets filled with yellowish and silly-clayey material among hard blocks of rocks. The rankers are associated to the humic cambisols which appear when the discontinuous pockets meet to form a continuous cambic B horizon ; they are also associated to the lithosols when the organic A horizon, similar to that of the rankers, is only a few centimeters thick.

The A horizon of the ranker contains 60% of organic matter between 0 cm and 20 cm, with a 30 C/N ratio. It is saturated by water only during the drying out period, after the downpours. Its pH is very acid, between 3.0 and 4.0, the content of exchangeable aluminium varies from 4 to 6 meq. only ; and numerous exchange sites are probably occupied by H + ions. The mineral fraction has the characteristic to contain a very large proportion of talc associated to very fine quartz.

6.8.2. REGOSOL.

They have a weak thickness, with an ochric A horizon, on the more or less weathered rock with pockets of clayey material, yellow or reddish yellow between the rock fragments.

The forest succeeds in growing for its roots penetrate between the cracks of the rocks where they can find abundant mineral elements, and then very beautiful specimens of trees on these soils.

6.8.3. LITHOSOLS.

They are associated to the rocky outcrops on the mountainous areas. The soil is formed by a thin A horizon with a high content of organic matter in contact with the slightly weathered rock.

IV
M A P P I N G U N I T S

In this part, we are going to briefly describe the 20 mapping units. Firstly, we will give their extension on the map expressed in hectares and in %, their localization, the principal characteristics of the environment and the soils : distribution, proportions, particularities, land occupation. As a conclusion, we shall give some useful information in the event of a detailed or semi-detailed study of these soils. These are only general recommendations for the soil surveyor who will take it or not into account according to the purpose of the survey.

1. MAPPING UNITS 1 TO 4.

These units describe the soils of the alluvial plains which border the rivers. They cover 119.580 hectares, that is 5.3% of which 57.750 hectares (2.6%) are flooded plains and 61.930 hectares (2.7%) are unflooded or temporary floode plains.

MAPPING UNIT 1.

EXTENSION AND LOCATION

15.180 hectares ≃ 0.68%. Several outcrops in the alluvial valley of the following rivers : Seruyan, downstream Tb. Kalang, Seranau, Mentaya downstream Kualakuayan, Tualan downstream Sebungsu, Cempaga downstream Tb. Kuling, Kalanaman downstream Tb. Merah, the lower part of the Rungan River.

DESCRIPTION.

The histosols are fairly dominant with inclusions of humic gleysols and gleyic fluvisols. The principal outcrops of histosols are represented on the map in this unit 1, but the other small outcrops of histosols are associated in inclusions in the unit 2 and 4, but rarely in unit 3.

The thickness of the soil varies between 30 cm and 300 cm and more. Clay is generally the underlying alluvial material of the histic horizon ; but it can be replaced by a clay-sandy or sandy material near the border of the tertiary plain. Those alluvial valleys form a large depression the lower areas of which are covered by unit - 1. The soils are flooded and saturated by the overflowing waters and by the rainwaters during six months or more, although this evaluation still depends on the site.

Land occupation.

This unit is not cultivated except on its borders. Attempts were made to grow rice in the Seruyan Valley, but without success even when the peat is not thick. But we do not know if this failure is caused by the waterflowing or by edaphical conditions.

Recommendations for the survey.

Mapping the histosols by first measuring their thickness ; then, it is necessary to identify the underlying alluvial material if sand or clay especially whenever the thickness of the histosols is not very important. It is also necessary to establish a distinction between histosols on alluvions and those occurring on the near tertiary sediments, the latter having quite different characteristics (cf. Unit. 5-P). Cross-section topographic survey of the alluvial plain should be made in case detailed topographic maps are not available.

MAPPING UNIT 2.

EXTENSION AND LOCATION.

42.470 ha - 1,9 %.

The location is the same as the preceding unit 1. This Unit -2 covers the left-over surface which has not been mapped as histosols in the preceding alluvial plains.

Description.

The dominant soils are the gleyic fluvisols. Inclusions are histosols (1).humic gleysols, and dystric fluvisols. The histosols and the gleysols occur in the lowest areas of the plain, whereas the dystric fluvisols occur in the most upper areas which are of limited extension. Mostly kaolinitic, clay is the parent material. The hydrologic regime is characteristic on account of the topography. The river banks are low, without levee or with a low levee; this one is then dissected by defluent channels through which the river waters flow to the alluvial plain during the high water periods, and this flooding becomes even more important under the tidal effect in the lower part of the rivers. As a part of the plains is under the level of the river, their submersion lasts a long time. In addition to the overflowing waters, those plains receive the floods (during the high-water season) of the tributaries draining through the hinterland. There is also a water table in the sub-soil fluctuating all along the year between the surface and a depth of 50 to 100 cm. The parent material being kaolinitic clay, explains the very low chemical fertility of these soils.

Land occupation

Part of this unit has been cleared, but it is not very

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(1) Their extension is too small to be drawn on a 1/250.000 scale map.

much cultivated now. The villages are built on the slightly higher areas in the plain, or on the tertiary sediments of the hinterland which, by recrossing the alluvial valley, come thus in contact with the river.

Recommendations for the survey

Without topographic and hydrologic surveys, the detailed soil mapping should be carried out ; those surveys are indeed required because the soils cannot be used without a control of the water level. For that, it is necessary to get the knowledge of the ground configuration and of the river level fluctuations.

About the fluvisols, a distinction can be made between those with pronounced hydromorphic characteristics and those which are better drained;then, the inclusions of both histosols and gleysols.

MAPPING UNIT 3.

EXTENSION AND LOCATION.

23.590 ha - 1,0 %.

Upper part of the Seruyan, Mentaya, Tualan, Cempaga, rungan and Kahayan.

Description.

The dominant soils are the dystric fluvisols occuring on the levee, behind the levee and on the higher areas of the alluvial plain. The inclusions are gleyic fluvisols with hydromorphic features at 50 cm depth and dystric gleysols in the lowest areas. Few cambisols locally have been noticed in the Rungan Valley.

Soil and parent material can reach several meters in thickness. A water table always occurs at variable depths according to the site and the seasons. The alluvial valleys are relatively narrow and the levee is well pronounced ; behind this levee the topography is relatively flat with no large depressions. Valleys are flooded when the rivers in spate swell and flow over the levee. The submersion therefore fluctuates with the rainfall and this occurs several times a year, or not at all. As soon as the level of the rivers lowers, the overflooding waters leave the plain thus making the submersion rarely over a week.

Land occupation.

Nearly all the soils are already cleared and occupied by villages, some rice fields, rubber and rotan plantations fruit-trees as well as family home gardens.

Particularities.

The content of mineral reserves included in the primary and secondary minerals is relatively high. This content increases even more in the alluviums located in the upper part of the rivers, for example near the Kahayan, upstream of Tewah. The content in phosphorus is twice or three times higher than in the other soils : 600 ppm of P205 (HCl) in the topsoil, 200 ppm in the subsoil.

Recommendations for the survey.

Report to the indications given for the Unit 4.

MAPPING UNIT 4.

EXTENSION - LOCATION.

38.340 ha - 1,7 % ; in the Katingan River valley between Tb Samba and the Southern border of the map.

Description.

Two main types of soils are associated : dystric or ferralic cambisols, and dystric fluvisols upstream, rather gleyic fluvisols downstream. Fluvisols occur on the levee and in its surroundings while cambisols occur behind the levee. Varying in proportion from upstream to downstream, i.e. from Tb Samba to Kasongan, are the inclusions of histosols and humic gleysols.

The valley is about 5 km wide ; its hydrologic regime can easily be compared to that of unit 3, but the flooded periods increase downstream. Some outcrops of an old terrace (1) located at 6 to 10 m height above the actual deposits have been sighted. This terrace gradually changes into tertiary deposits with any important difference of the topographic level.

Particularities.

The nature of the parent material favours the soil chemical fertility which still remains low in absolute value ; however, this chemical fertility is slightly higher than in the other soils of the areas, ferralsols included.

Land occupation.

Practically the whole valley has been cleared. Fields, rubber and rotan plantations alternate with rice fields and recent or old fallows.

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(1) For instance on the right bank of the river, near Buntut Bali.

Recommendations for the survey.

First check over the boundary between the actual deposits and the old terrace, or the tertiary deposits. This can easily be done on the aerial photos. Then, it is necessary to make a distinction between the cambisols-fluvisols and the gleysols-histosols groups ; the criteria of identification, are to be found by the study of the soil surface. Should also be made clear the difference between the histosols with an altered histic horizon (saprist) and the histosols with a slightly altered histic horizon (lenist) which are found bordering the tertiary. Observations of the subsoil by boring will be necessary to survey the other groups of soils.

Note about the survey of the units 1 to 4.

Those units have been rather accurately located on this reconnaissance map owing to their preferential situation along the rivers. The management of those soils could be made by the drainage works ; this, of course, would ask for a very detailed study of the soils and of the site. We think that a semi-detailed study at a 1/50.000 scale is not necessary. The 1/20.000 scale could be selected. We even advise to carry out the detailed study directly at a scale of 1/10.000 using adequate aerial photos. Of course, the soil survey carried out in parallel with topographic and hydrologic studies is advised.

MAPPING UNITS 5 to 7.

These are the mapping units of the tertiary plain (units 5 to 6 A) and of its facies near the border with the basement (units 6 F and 7). The soils are mainly acrisols and podzols.

This wide area extends from the Seruyan right bank to the Katingan left bank, that means from one side to the other one of the map, starting from its Southern border up to the Tewah-Duriankait axis towards the North. These units cover 942.830 ha and 42,4% of the map.

The topography is the main feature which can help to make a distinction between the units 5,6 and 7. The parent material is always sandstone ; but it shows local variations of facies and it contains various inclusions.

MAPPING UNIT 5.

It covers the western and central parts of the map from the right bank of the Seruyan to the Katingan left bank. The soils are acrisols associated with podzols, together with inclusions of ferralsols, histosols, and gleysols. In unit 5, three sub-units (5P, 5A and 5F) are noticed. The limit between those sub-units is shown by a dotted line, on the map, meaning that the transition between two sub-units is very gradual, thus making the limit rather approximative. The dominant soils are the acrisols in the sub-unit 5A, podzols in the sub-unit 5-P and ferralsols in the sub-unit 5-F. We think that the sub-unit 5-A can still include some perimeters where the podzols or ferralsols dominate. But their identification was made impossible on the field without aerial photos. A semi-detailed survey would be necessary.

SUB-UNIT 5-A.

Extension-location.

380.480 ha - I7,1 % : a large outcrop, from the western part of Penbuang Hulu to the Eastern part of Pundu, crossed by alluvial valleys.

Description.

The weathering of the homogeneous parent material produces a clayey sand. The topography is slightly to moderately undulated with slopes of 2% to 8%.

Acrisols are the dominant soils and mainly the ferric acrisols. They cover the tops and the slopes, forming catena with dystric gleysols occurring in the lower parts of the valleys undissected by the rivers. At the foot of the slopes, the transition between the ferric acrisols and the gleysols is made by the gleyic acrisols. A petric phase appears to the nickpoint at less than 200 cm in the subsoil. The humic acrisols and the podzols are the inclusions often occuring on the tops of the slopes.

Particularities.

The mineral reserves are very low : from 4 to 5 meq. of total bases of which are 60 to 20 ppm of K20 (HCl) and 200 to 30 ppm of P205 (HCl) (1).

Land occupation.

Large areas are still covered by the forest. The cleared areas are found near the inhabited alluvial valleys where floods are an important limiting factor for the utilization of the alluvial soils. The areas of unit-5-A cultivated for many years now, are covered by Imperata or alang-alang.

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(1) The first number figure for the topsoil and the second one for the subsoil.

SUB-UNIT 5-P.

Extension - location.

332.900 ha - 15,0%.

The two main outcropsare located one on each side of the Katingan River (downstream of Tb Samba), and the other one on the right bank of the Mentaya (downstream of Kuala-kuayan). Other smaller crops have been spotted between the Mentaya and the Cempaga.

Description.

The weathering of the parent material produces a coarse sand, or a gravelly and quartzous sand. The topography is slightly less undulated than in the unit 5-A. Podzols are the dominant soils. They have hydromorphic features with a semi-permanent or temporary water table. Giant podzols have been observed with a very thick E horizon. Podzols are associated to very acid histosols with a slightly weathered histic horizon which differs from the histosols in the alluvial plains. Generally, the material found under the peat is sand but sometimes it is a pale and kaolinitic clay. Some inclusions of acrisols have been identified on the tops of these slopes ; their texture is slightly more clayey and then their colour more yellowish.

Land occupation.

This unit is neither cultivated nor cleared ; the small cultivated enclaves always correspond to different soils formed on some inclusions of the basement within the sedimentary. Recently, a project of coffee plantation in Tb Miwan widely encloses this unit 5-P. Probably, this project will not be a success.

SUB-UNIT 5-F.

Extension - location.

14.500 ha - 0,65 %.

The most important outcrops are shown on the map : between the Cempaga and the Tualan, in the West fo Sebabi on the Seranau, and in the South of Durain Kait ; other outcrops have been observed in the North of Pankalanbanteng in the sub-unit 5-A, but their extension is not important enough for being represented on this map. Other small outcrops still exist, probably, but we could not identify them during the reconnaissance phase.

Description

The parent material is a very fine clayey sandstone associated to some shale banks formed by a mixture of kaolinite and a low content of 2/1 minerals. The topography is more rolling than in the sub-units 5-A and 5-P. The slopes vary from 2% to 8% on the tops and from 10% to 15% on the sides.

The most widely spread soils are the orthic ferralsols sometimes xanthic, which cover the top of the interfluves and the slopes ; locally and towards the break of slope, at a depth varying between 50 and 100 cm, appear some hydromorphic features and a petric phase.

Particularities.

In the wide unit 5, this sub-unit 5 f is the only one to contain ferralsols inclusions over surfaces of 1000 ha to 10.000 ha. all in one block. Their chemical properties are close to those of the acrisols, except a mineral reserve slightly more important because of the presence of some 2/1 minerals. But their physical properties are quite better. This fact must be pointed about the unit 5 where the soils are indeed of poor quality.

Recommendations for the survey of the unit 5.

We would advise to start first with a semi-detailed survey of this unit 5 while excluding the sub-unit 5-P if the survey is carried out in view of an agricultural project. The most adequate scale seems to be the 1/50.000. The survey would consist first in delimiting (following a decreasing order of priority) the areas where the ferralsols, the gleysols, the ferric acrisols and the other kind of acrisols are dominating. The almost flat topography makes rather difficult the interpretation of the aerial photos ; however, the natural vegetation may help to interpret them. Easily spotted on the aerial photos is the health forest which corresponds to the podzol and locally to the acrisol (humic and gleysic) areas. Patterns of forests having the dipterocarp forest aspect correspond to the 5-F type ferralsols ; the intermediary vegetal formations cover the acrisols with variations corresponding to the edaphic conditions which have to be checked on the field.

MAPPING UNIT 6.

It differs from unit 5 by its rolling to hummocky topography, also by a less homogeneous parent material, often more clayey rarely sandy.

Two sub-units are to be considered : unit 6-A and unit 6-F.

SUB-UNIT 6-A

Extension - location.

125.340 ha - 5,6 %.

This unit extends from the western part of the Manuhing River up to the Kahayan border, and it is crossed by the alluvial valleys of the Rungan and Manuhing.

Description.

The parent material is a finer sandstone than that of unit 5 ; the weathering produces a sandy-clay material, rather compact with many mottlings of various colours. The more we come near the basement border, the more we find that the sandstone contains various inclusions : shale lignite or pebbles banks and very hardened iron hydroxydes plates, banks of coral limestone outcropping along the basement over a width of 200 m to 400 m and a few kilometers in length (1). At last, veins of basalt, metagabbro, amphibolite have been locally observed on the field.

The dominant soils are the acrisols forming catenas with the gleysols occurring in the valley bottoms ; the soils in inclusions are of varied kinds ; podzols occur either on the top of the interfluves associated to gleyic acrisols, or at the footslopes between the acrisols and the gleysols ; but they are never wide-spread. The humic ferralsols are exclusively associated to intrusions of basic rocks in the sedimentary. The cambisols are assumed to occur on the calcareous banks and may be associated to orthic ferralsols ; however, this fact should be controlled during the detailed surveys.

Particularities.

Acrisols are not very different from those of unit 5. The characteristic of this unit 6 is to contain widely dispersed ferralsols and coral calcareous banks.

Land occupation

This unit is only cleared along the Rungan and the Manuhing rivers, and also the near Tewah, which represents less than a quarter of its total surface.

SUB-UNIT 6-F.

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(1) Their thickness is unknown.

Extension-location.

12.800 ha- 0,55%.

The main outcrops occur near Tb. Jala, in the upper part of the Samba river, in the northern border of the sedimentary deposits recrossing the Katingan river basin. Another outcrop appears in the unit 6 on the east side of the Rungan River. Other small outcrops of the 6-F type may exist in the unit 6-A. They will certainly be spotted during the semi-detailed surveys.

Description.

The ferralsols are either dominant or associated to the ferric acrisols ; at the footslope, the ferric acrisols gradually change to gleysic acrisols, rarely to gleysols.

The Tb Jala outcrop is formed on a fringing facies of the sedimentary. Clayey sands alternate with both shales and conglomerates ; they contain lignite and pebbled banks, silicified woods, and rounded blocks of andesite and basalt. The top of the interfluves is sometimes covered by granit and the lower part by sedimentary deposits including conglomerates. Topography is rolling to slightly hummocky,with concave valley bottoms linked up gently with the slopes.

Land occupation.

This unit is only cleared along the Samba river ; the remaining part is covered by the forest.

Recommendations for the survey of unit 6.

We should advise to follow the same recommendations as for the unit 5.

MAPPING UNIT 7.

It differs from the units 5 and 6 by a very hilly topography. Two sub-units : 7-P with dominant podzols and 7-A with dominant acrisols.

SUB-UNIT 7-P.

Extension-location

28.590 ha - 1,3%.

Only one outcrop which looks like a wide strip of 3 to 5 km,recrossing the Katingan upstream of Tb Samba, and extending on the crest-line separating the river basins of both River Heran and River Samba. The unit 7 borders the unit 5 towards the south, but this limit is still approximative.

Description.

The parent material is a coarse sandstone with many banks of pebbles and both iron hydroxyde and manganese concentration, also with banks of lignite and fragments of silicified woods. The topography is hilly to very hilly and the relief is strongly dissected.

The dominant soils are orthic podzols with inclusions of acrisols. From the south to the north of the outcrop, the percentage of the acrisols increases while inclusions of ferralsols appear even on the banks of shale bordering the unit 6-F.

Particularities.

They are podzols without perched water table, which are saturated after downpours and which dry up during the short droughts giving a very contrasted moisture regime. The Agathis stations of this region are located on this outcrop. The river waters which spring from the crest line have a brown colour due to the soluble organic products.

Land occupation.

This unit is covered by the forest.

SUB-UNIT 7-A.

Extension-location.

48.220 ha - 2,2%

To the east and to the north of Kualakurun appears the main outcrop, while two small outcrops, isolated in the ferralsols on basalt are located to the north of this sub-unit.

Description.

The dominant soils are ferric acrisols with inclusions of orthic podzols, located on the top of the slopes. The sedimentary deposits have a facies formed by compact sandstone weathered into a clayey sand. This sandstone contains banks of greenish and purplish-blue shales, banks of lignites and pebbles, silicified wood ; coarse conglomerates of rounded blocks made of basic rock. The topography is very hilly and the relief very dissected to the north, less accidented as we approach the south. The valley bottoms are generally strongly incised.

Land occupation.

One part of this unit bordering the Kahayan and its le bank tributaries have been cleared ; but most of the patches of land are now covered with fallows because the cultivated areas have moved away towards the north on the ferralsols along the logging roads.

Recommendations for the survey.

The unit 7 has been classified unsuitable for the agricultural purpose.

MAPPING UNIT 8 TO 18.

They are grouping the units of the Uplands which are located between the plain extending to the seashore and the wide central mountainous area of the Borneo Island. The ferralsols are always the dominant soils occurring in catenas with gleysols. Inclusions are cambisols, regosols fluvisols, lithosols, and rankers.

This area covers 1.059.100 ha, i.e 47,6 % of the map and extends from the western border to the eastern border of the prospected areas, starting from the axis Tewah-Kurian Kait until the northern limit of the map.

MAPPING UNIT 8.

This unit covers 106.970 ha and 4,8 %. The soils are ferralsols on shales and siltites. It is sub-divided into three sub-units which differ by the topography and by minor differences in the parent material.

SUB-UNIT 8-F-G.

Extension -location.

6.250 ha. - 0,28 %.

Only one outcrop located between the Tualan River and the Cempaga River, to the north of the axis Sebungsu-Tb Sanak.

Description.

The parent material results from the weathering of siltites associated to shales and to fine sandstones. Banks of quartzites of 10 m to 100 m wide can still be spotted together with andesite inclusions irregularly distributed. Generally, the topography is strongly hummocky with slopes from 15% to 30% linked up abruptly with narrow valley bottoms. It is more hilly on the quartzites less accidented on the andesites associated to siltites where the slope gradient does not go over 15% and the valley bottoms are wider ; for example in the western part of the Tualan.

Ferralsols dominate occurring in catenas with gleysols in the valley bottoms. A petric phase formed by iron nodules, or by disjointed ironpan blocks, has been observed at a depth of 50 cm on the slopes, or even almost on the topsoil near the break of slope. Ferralsols are humic, or xanthic when the content in organic matter of the subsoil does not reach a high value ; we cannot give any precise rule about the distribution, but we can only assert that the ferralsols are always xanthic on the siltites, on the fine sandstones and on the quartzites ; they are humic sometime xanthic, rarely orthic on the shales and on the andesites.

Land occupation.

Are cleared the sections located to the west of the Tualan, the eastern part of the border of the same river, the border of the Cempaga, upstream of Tb Kuling. The remaining part of the soils area under forest, i.e. about 50% of the surface.

SUB-UNIT 8-F-O.

Extension-location

97.970 ha. - 4,4%.

The main outcrop occurs on the interfluve between the Mentaya and the Seruyan ; a second outcrop is found more to the north on the left bank of the Seruyan, at the same level of Rantaupulut ; some outcrops are found dispersed in the soils on andesite.

Description.

The parent material is formed by slightly compact shales splitting into plates of only a few centimeters thick. Locally the shales are slightly metamorphized, and sometimes they are crossed by thin veins of quartzite. The topography is hillocky and the relief is dissected. The average gradient of the slopes exceeds 20%, and the valley bottoms are narrow except near the rivers where the slopes are gently linked to some small alluvial flats. The slopes often exceed 30% on the watershed between the Seruyan and the Mentaya.

The dominant soils are orthic ferralsols rarely humic. They are very clayey and contain oval iron nodules of 1 to 3 cm diameter, from 40 cm to 200 cm. Hydromorphic features appear from 40 cm to 50 cm in the soils at the footslope in the areas the less dissected.

Dystric regosols cover the top of the highest hills with steep slopes ; they are associated to cambisols and some regosols.

Particularities.

Its particularity results from the 2/1 clay content coming from the parent material. The proportions in kaolinite and 2/1 clay vary according to an average ratio of 6 to 4. The reserves in total bases are twice to thrice higher than in the other ferralsols ; between 20 and 40 meq. of total bases extracted by HNO_3, 50% of which is potassium. The other chemical and physical properties are those common to the ferralsols.

Land occupation.

The border of the Seruyan is cleared, which represents less than the quarter of the surface ; the remaining part is covered with forest.

SUB-UNIT 8-Fp.

They are two outcrops of unimportant extension on the Seruyan right bank, to the south of Rantaupulut. They cover high hills with very steep slopes. The soils have the particularity to contain abundant iron nodules. Inclusions of regosols are associated to ferralsols on the steepest slopes.

Recommendations for the survey of unit 8.

First of all, we should make a general remark that can be applied to the mapping units nbr. 8 to 18. Considering the ground configuration and the distribution of the soils on the basement we think the 1/20.000 scale (1) is, in this area, more appropriate for the detailed studies than the 1/50.000 scale. For this purpose it is possible to select the approximate site to be surveyed in detail directly on the reconnaissance map at 1/250.000 scale. If the accuracy is considered insufficient, then a brief reconnaissance of about one week on the field in the preselected area, completed by a quick examination of the aerial photos, should help to delimitate with better accuracy the perimeter to be surveyed at 1/20.000 scale. The first advantage of a survey at this scale is the fact that it allows to represent on the map the gleysols of the valley bottoms very important for agricultural projects. The second advantage is the fact that this soil map at 1/20.000 scale, combined with a topographic map at the same scale showing all the talwegs as well as the main contour lines, can be immediately used by the land management

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(1) Or 1/25.000 scale, to be selected according to the standards of the Indonesian Topographical Map Service.

Offices.

About the unit 8 one could differentiate the ferralsols from the gleysols and from the regosols by analysing the topographic variations using the aerial photos ; the delimitation of the various types of humic, xanthic or orthic ferralsols probably calls for a systematic survey on the field. We should draw the attention that the units 8 and 9 are among the only units of ferralsols which contain abundant iron nodules at a depth inferior to 200 cm ; this is one of the means to identify them.

MAPPING UNIT 9.

This unit groups the ferralsols on metamorphic rocks. We have distinguished 3 sub-units, each one of them showing differences in topography and parent material. The unit 9 covers a total of 89.360 ha and 4,0%.

SUB-UNIT 9-F-G.

Extension-location.

5.307 ha. - 0,24%.

Only one outcrop located to the west and to the east of Kuala Kuayan.

Description.

The most usual facies of the parent material is a gneiss, with amphibole, the gneiss content in mafic minerals varies locally. The topography is hillocky and the relief is moderately dissected. The concave footslopes are linked to the valley bottoms of 10 to 30 m. wide.

Orthic ferralsols are associated in toposequences with gleysols ; petric phases are rarely observed.

Particularities.

These soils contain some 2/1 clay minerals, but in smaller quantity than in the unit 8. These minerals probably are the result of the weathering of micas abundant in the bedrock. As in unit 8, potassium mineral reserves are rather high.

Land occupation.

This unit has been cleared over all its surface. The limit of the clearing coincides with its eastern border on the Mentaya left bank.

SUB-UNIT 9-FO.

Extension - location.

14.680 ha - 0,66%.

Two outcrops are spotted. One to the eastern part of Kuala Kuhayan on the watershed between the river basins of the Tualan and the Mentaya ; the other one, to the west of Kuala Kuhayan, along the granite batholith. The western limit is still approximative on the map.

Description.

This unit is different from the precedent by 3 characteristics :

- the topography is more hillocky ; the relief is dissected without flat valley bottoms or with narrow valley bottoms.

- The parent material is formed by micaschists with banks of gneiss and locally phyllites.

- The petric phases are more frequent, especially on the phyllites occurring on the ridge in the east of Kuala-kuayan.

Land occupation.

The outcrop located to the east of Kualakuhayan is covered wiht forest ; one quarter at least of the outcrop located to the west is cleared.

SUB-UNIT 9-FX.

Extension - location

69.310 ha. - 3,1 %.

There are three widespread outcrops to the west of Tewah and in the upper basin of the Rungan river.

Description.

This unit occupies the high hills on the head of the Rungan river basin and its tributaries. The topography is very hilly and the slopes often reach 35% and locally 100%. The parent material is heterogeneous : a large preponderance of quartzites, phyllites, schists with some intrusions of gneiss and micaschists. Despite the steep slopes, the ferralsols are the dominant soils and they are covered with a rather beautiful forest. The xanthic ferralsols are more often observed than the orthic ferralsols.

Lithic phase of ferralsols is associated to regosols on the quartzites, to regosols mixed with ferralic cambisols on the other rocks. Lithosols are rare.

The relief is so dissected that the valley bottoms are very narrow and cut by the brooks. The borders of some secondary rivers are covered by thin alluvial and colluvial deposits where occur fluvisols and gleysols.

Land occupation.

Most of the soils are covered with forest. Some clearingshave been carried out along the rivers and the logging roads where we have noted rainfed rice-fields on slopes over 45%.

Recommendations for the survey.

The unit 9 -FX is not interesting for agricultural projects because of the very steep slopes. Indications given for the unit 8 can be applied to the units 9-FO and 9-F-G.

MAPPING UNIT 10.

Extension-location.

10.880 ha - 0,48%.

Two outcrops located the first one to the west of Tb Kalang, and the other one to the north of Tb Jutuh between the Kajuei river and the Rungan river.

Description.

The parent material is a very coarse alkaline granite with quartz and orthose. Its weathering produces a very thick material reaching a thickness of 15 to 20 meters ; rocks outcrop on the ridge and sometime on the slopes. The topography is hilly and very dissected. The hilly tops are slightly rounded but the sides are very steep, on an average more than 30%. Most of the valley bottoms are narrow and cut by the rivers. Some of them are wider and filled with coarse sand layer more or less thick deposed on a pale clayey sand. The dipterocarp forest has more the features and the structure of a forest forming the transition with the heath forest.

The dominant soils are deep xanthic ferralsols with inclusions of podzols and acrisols. The ferralsol profile is characterized by the presence of many hydromorphic features, very often appearing from the base of the A horizon. Podzols and acrisols are found at the footslope and in the colluvial valley bottoms. The association between the ferralsols and the podzols or the acrisols is not systematic ; it has been observed only in some sites. Very often the ferralsols cover all the landscapes, becoming more and more hydromorphic towards the footslope.

To the west of Tb Kalang, veins of pegmatite with orthose and muscovite cross the granite, where podzols can occur whatever the topographic position. There are always orthic podzols without water table.

Land occupation.

The Tb Kalang outcrop is under forest. The Tb Jutuh one is cleared along the rivers in some areas where abundant big rounded rocks often occur on the soil surface.

Recommendations for the survey.

This unit has been classified as inappropriate for agricultural purposes according to the norms we use.

MAPPING UNIT 11.

This unit groups the soils on granite ; it covers 194.520 ha - 8,6%.

It is sub-divided into 3 sub-units. The first two are differentiated by variations of the facies in the parent rock ; the third is differentiated by the parent rock and by the topography.

SUB-UNIT 11 FX.

Extension - location.

61.120. ha - 2,7 %.

There are about 15 outcrops of different size, varying from 500 ha to 28.000 ha. The main ones are located as follows : to the west of Kualakuayan, in the upper course of the Mentaya river and the Katingan river. On the Mentaya right bank, to the west of the Kualakuayan the outcrop covers 28.125 ha.

Description.

The rock is a common, homogeneous, and medium textured granite ; its colour is rather pale with black flakes of biotite. The topography described in the first part of this report is typical : the sides of the hill have a convex shape, the top is rounded and the steep slopes increase progressively to reach 45% towards the break of slope. The sides abruptly are linked up with flat and narrow valley bottoms.

The original vegetation is always the dipterocarp forest. This a thick and high canopy forest, but without a lot of big trees.

The xanthic ferralsols are associated in toposequences with gleysols, clayey sandy in the topsoil sandy clay in the subsoil sometimes sandy for a thickness of 100 cm. Generally the gleysols are dystric rarely humic.

Land occupation

Less than a quarter of this unit is cleared. The clearingsare carried out along the rivers, and the most recent ones along the logging roads in the surroundings of the Mentaya, of the upper-Mentaya upstream Tb Kalang. In the upper course of the Kalanaman and on the Katingan left bank, the clearing is more important ; probably because those outcrops are surrounded by wide areas of soils very poor and unsuitable.

SUB-UNIT 11 FX-0.

Extension-location.

66.100 ha - 2,9%.

Two main outcrops are found : the first one very extensive to the north of Tb Jutuh, from the Manuhing up to the Rungan left bank ; the other one extends at some forty kilometers to the north of Tb Samba.

Description.

The granite is heterogeneous. The common facies is mesocrate with biotite, and alternates with darker facies with biotite and amphibole, or it locally changes into a granodiorite. Diorite, gabbro and epidiorite veins are noted. Oddly shaped granite blocks outcrop locally. Ferralsols are xanthic on the granite, orthic on the facies with biotite and amphibole, sometimes humic on the basic rock veins. They are associated with gleysols located in the valley bottoms.

The relief is the same as the precedent sub-unit except for the valley bottoms which are sometimes wider downstream of the river basins.

Land occupation.

To the north of Tb Jutuh the outcrop is widely cleared (at least 50% of its surfaces) ; the Samba river outcrop is cleared along some affluents. Most of the soils occurring on the basic rocks veins are cleared and cultivated.

SUB-UNIT 11 F-R.

Extension-location.

67.300 ha - 3,0%.

Some twelve outcrops of variable size are dispersed over all the map.

Description.

This sub-unit is differentiated by the very hilly topography, and by the very dissected relief. The average slope gradient is equal or more than 30%. The convex hill-sides are linked up with narrow and cut valleys.

Most of the outcrops are located on the ridge in the upstream area of the river basins.

The granite is homogeneous; leucocratic, medium textured. The dipterocarp forest contains a lot of trees with a small diameter, and the underwood is rather scattered. The secondary regrowth seems very slow.

On the steepest slopes, the deep xanthic ferralsols are associated to ferralsols with lithic phase and to regosols among rocky outcrops.

Land occupation.

The largest part of this unit (at least 90%) is covered with forest.

Recommendation for the survey.

The sub-unit 11 F-R has been classified as inappropriate for agricultural purposes according to the topography. The recommendations will therefore apply to the two other sub-units. A detailed survey could first delimitate the ferralsols and the gleysols. This survey should be based on the topography and on the distribution of the valley bottoms in the landscape and in the drainage basins. In fact, it seems possible to locate the limit of the gleysols in the valley bottoms. The upstream limit at first where the valley bottoms become very narrow and then the downstream limit where the valley bottoms disappear cut by the rivers. Among the ferralsols it would be possible to delimitate the soils on the hilltops and the soils on the hillsides, upstream and downstream of the break of slope.

It is also necessary to note that almost all the outcrops of the unit 11 are found in the upstream of the large drainage basins and the upper parts of the landscape. The users will have to attend to a matter to the water supply which will be difficult because the phreatic waters are rare and not easily accessible. Therefore, the surveyors would have to carry out all possible observations in order to detect the ground water in the soils and also in the weathering horizons.

MAPPING UNIT 12.

This unit covers 245.730 ha and 11,1% of the map. It is subdivided in 2 sub-units according to the different proportions in the types of associated soils. This unit is the widest among the units with dominant ferralsols.

SUB-UNIT 12 F-G.

Extension-location.

79.440 ha. - 3,6%.

Three outcrops to the west, the north and to the north-east of Tb Samba ; two other outcrops to the south and to the south-east of Tb Kalang on the Mentaya right bank ; the widest of them extending to the north of Tb Samba covers 48.625 ha.

Description.

The parent material is a granodiorite ; locally, the facies can be either granitic or dioritic ; veins of gabbro and diorite can also be spotted.

The vegetation is the dipterocarp forest of which the structure appears slightly different from the forests on the common granite. One notices many big and high trees and a scattered underwood. The topography is hummocky to hillocky, rarely hilly. The interfluves are flattened with a rather wide and relatively flat top. The slope gradient is lower than 10% and the convexo-concave hillsides are gently linked up with rather wide valley bottoms, slightly concave rather than flat ; this description corresponds to the most common landscape. However, the latter can vary from upstream to downstream in the drainage basins.

The dominant soils are always the ferralsols associated in toposequences to gleysols of which the proportions can reach 20%. The orthic are more usual than the xanthic ferralsols. At the footslope hydromorphic features appear in the ferralsols bordering the gleysols of the valley bottoms.

SUB-UNIT 12 F-O.

Extension-location.

167.280 ha. 7,5%.

Three outcrops to the north and to the west of Tb Samba, to the east of Tb Heran, upstream of Tb Kuling on the Cempaga, to the south-west of Tb Kalang, in the upper course of the Rungan river.

Description.

The topography is hilly and the relief dissected. The hilltops are not so flattened ; the hillsides have a convex shape and they are abruptly linked up with flat and rather narrow valley bottoms ; the landscape is almost identical to the rounded hills on granite.

Ferralsols are widely the dominant soils and the proportions of gleysols are about 5% or less. On the diorite veins more frequent than in the precedent sub-unit occur orthic or humic ferralsols.

Particularities.

Upstream Tb Samba, in the area of the Katingan, the ferralsols show some particularity. The base saturation is higher compared to the usual rate of 10% since it reaches 20 to 40 %. This anomaly is due to the very low CEC of the B horizon which is less than 5 meq./100 g of soil. The permanent charge is less than 2 meq. These characteristics are marks of acric properties that are always unfavourable for the soil utilization.

Land occupation.

It is estimated that 85 to 90% of this unit 12 is under forest. Clearings have been carried out along the main rivers. But for a few years now the clearings seem to be carried out along the logging roads in the Katingan basin (1).

Recommendations for the survey.

Indications given for the unit 11 are available for this unit.

MAPPING UNIT 13.

Extension-location.

77.340 ha. 3,5%.

Ten outcrops ; the two main ones appear to the north of Kualakuayan, and in the upper basin of the Cempaga and the Tualan. ALl the others are dispersed in the Rungan and Katingan upper course. Small inclusions of the unit 13 have been identified in the unit 11 and 12 but they cannot be drawn on this small scale map (1/250.000).

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(1) Report to the geographic data.

Description.

The parent material is either a diorite or a gabbro undifferentiated on the map. The gabbro is dark, sometimes pale ; it happens also that its colour be greenish when the feldspars and the pyroxenes have been weathered. The rock texture is variable, coarse or fine.

The topography is hillocky to hilly. The top of the interfluves is narrow although relatively flat and the slope is less than 10% . The hillsides have a very convex profile and their slopes - as an average - are more than 20% ; according to the sites, the slope gradient can reach sometimes 45%. They are abruptly linked up with valley bottoms that are either narrow and cut by the rivers or not cut and then filled by gleysols.

The dipterocarp forest is often very beautiful and shows the aspect of the forest growing on the ferralsols from basalt or andesite. The vegetation regrowth after clearing is very thick.

The dominant soils are orthic ferralsols associated to humic ferralsols. No repartition rule has been found between the two kinds of soils. For that very detailed surveys would be necessary. The petric and petroferric phases of these soils appear on the hillsides ; one has even noted in the topsoil some volumes of hardened plinthite near the break of slope.

Sometime ferralsols are associated to valley bottoms gleysols, although few valley bottoms contain gleysols because they are narrow and cut. This is why gleysols do not appear on the map.

Land occupation.

The outcrops located in the Upper Kahayan and to the north of Kuhalakuhayan have been cleared up to more 75%, or in their whole part . The others are mostly under forest.

Recommendations for the survey.

The surveyor could delimitate at first the hilltops with gentle slope, the valley bottoms with gleysols, and then the hillsides without or with a petroferric phase at a shallow depth. Observations should also be useful regarding the indications of water storage in the soils, especially when the outcrops are located in the upper part of the drainage basins.

MAPPING UNIT 14.

Extension - location.

17.620 ha. - 0,80%.

Two main outcrops located in the area of Rantaupulut and a few others of 300 to 500 ha. dispersed in the unit 18. Another few of restricted extension probably occur in the unit 16 to 18.

Description.

The parent material is a rhyolite, or a rhyolitic tuff showing various facies. The topography is hilly to very hilly and the relief is strongly dissected. One observes a succession of hills with steep slopes, with linear or slightly convex sides and with narrow ridges ; generally, the hillsides are linked up to the narrow and cut valley bottoms ; but some of these ones are wide and flat, filled by sandy-clayey colluviums.

The dipterocarp forest does not show any particularity, except on the top of the highest hills where one finds a typical low canopy forest.

The soils are humic ferralsols with xanthic characteristics, associated to dystric or ferralic cambisols. Cambisols are more abundant when the slopes are steep. There are also intergrade soils between ferralic cambisols and ferralsols. The shallow dystric cambisols are associated with the regosols in a mosaic pattern. On the hilltops, rankers with a very dark surface horizon and a very abundant organic matter have been spotted. There are, at last, some small inclusions of lithosols associated to rocky outcrops and inclusions of fluvisols in the colluvial valley bottoms.

Particularity.

The content of organic matter is very high : from 8% to 12% in the topsoil, from 2,5% to 4% at 50 cm, and close to 1,5% at 100 cm. Those ferralsols contain some amount of 2/1 clay minerals (20% as an average), which increases in the cambisols. The reserves in total bases are rather high, especially in potassium.

Land occupation.

The areas located along the Seruyan and its tributaries are cleared. More than the half of the surface is under forest.

Recommendations for the survey.

The widest part of this unit, where the slopes are very steep, is not to be recommended for agriculture in a near future. If a survey has to be carried out, it would then be possible to delimitate in priority the foothills with gentle slope and the valley bottoms filled with colluvium.

MAPPING UNIT 15.

Extension-location.

7.680 ha. - 0,32%.

Two outcrops : one near Bejarau, the other one to the west of Kawanbatu. Some small inclusions, which have not been mapped, have nevertheless been observed in the units 16 and 18 FH. It is possible that there are still some outcrops of unit 15 in the unit 5 -A on the intrusions of basic rock in the sedimentary. Aerial photos will help to identify them easily.

Description.

They form well delimited outcrops on the intrusions of basic rock in the tertiary sediments, or in border of the tertiary. The soil characteristics show that the parent material is a basic rock ; but its exact nature is not always known : basalt, andesite or amphibolite.

The topography is hummocky to hillocky. The hilltops are wide and flattened with a slope gradient less than 10%. The hillsides are short with convex slopes linked up with valley bottoms often narrow and cut, but sometimes a little wider and occupied by gleysols.

The vegetation is a beautiful dipterocarp forest contrasting with the surrounding vegetation on the sedimentary like in the area of Bejarau.

The dominant soils are humic ferralsols, which also have rhodic (1) and acric characters. This corresponds to some particular properties of the exchange complex. The petroferric and petric phases are most frequently observed at the upper part of the sides.

Particularities.

The acric character is the main particularity of these soils. Their morphology and physical characters appear to be identical to those of the soils in the unit 16, but the state of the exchange complex is a supplementary constraint for the soil utilization.

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(1) Brown or reddish-brown in colour.

Land occupation.

More than the half of the Bejarau outcrop is cleared and about 10% of the Kawanbatu one.

Recommendation for the survey.

Drawing up the exact boundaries of this unit will be very easily done on the aerial photographs due to the topography, the form of the versants, and the vegetation. But a systematic field survey seems to be needed in order to outline the deep ferralsols and the ferralsols having petric or petroferric phases.

MAPPING UNIT 16.

Extension-location.

161.430 ha. - 7,2 % of the map.

This is a large unit made up of 4 main outcrops ; the upper Kahayan above Tb. Manangei, the upper Samba to the north and north-west of Tb. Baraoi (1), the upper Kuayan, and the upper Seruyan above Rantaupulut. Other outcrops of lesser importance are dispersed on the map.

Description.

Simply stated, the unit 16 is the equivalent of unit 18 but with more hilly relief and fewer valley bottoms.

The parent material is a basic rock. Andesite and basalt dominate a rather varied range : andesite to the west on the Seruyan and the Kuayan, basalt around the upper Samba, amphibolite along the upper Rungan, volcano-sedimentary and basalt combined with metamorphic rocks in the upper Kahayan area.

The landscape is rather complex. In general, the topography is hilly and the relief is dissected. The versants are short, with narrow ridges and rectilineous or slightly convex slopes ; they are linked together by narrow and sharply cut valley bottoms. But locally one can find versants with gentle and irregular slopes connected to wide valley bottoms along the small rivers. The landscape is also characterized by some high hills or inselbergs formed from basic or acid volcanic rocks. These reliefs are surrounded by a circular area which is slightly depressed, one or two kilometers in diameter, with gentle slopes.

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(1) Separated by the northern limit of the map, these two outcrops probably make up a single one only, which stretches to the north outside the mapped area.

This unit is covered by a beautiful dipterocarp forest including a lot of many large trees of the species "Eusideroxylon swageri", or "Ulin" among the emergent trees. The regrowth of the vegetation after clearing is particularly rapid. The logging roads and the areas along them are already overgrown with vines and bushy secondary vegetation while other roads that were opened at the same time on soils issued from granite are still clear of secondary vegetation.

The dominant soils are the humic ferralsols occurring in a mosaic pattern with cambisols. These one are always found in the areas with the steepest slopes. One also finds gleysols only covering a small part of the total surface area. But in certain sectors, they can occupy rather large portions of the landscape. The dominant soils have the typical properties of humic ferralsols and above all have excellent physical properties.

Land occupation.

On the Kahayan, at least half of the area is cleared Elsewhere, the clearing is limited along the rivers in the distant areas located in the upper river basins (Samba, Kuayan).

Recommendations for the survey.

The main variations in the forms of the landscape, previously described and the corresponding soils could be outlined on the aerial photographs. But the distinction between ferralsols and cambisols probably would depend on a systematic survey on the field.

MAPPING UNIT 17.

Extension-location.

12.500 ha. 0,61% of the map.

A few rather small outcrops are situated near the units 16 and 18 in the Mentaya River basin.

Description.

This unit has some common characters with unit 16. The parent rock is also an andesite but it is associated with a lot of intrusions of siliceous rocks, quartzites and aplites.

The topography is hilly to very hilly ; the zones where the relief is steeper than 35% correspond to the outcrops on siliceous rocks ; the flatter zones correspond to the outcrops on andesites locally associated with basalts.

The xanthic ferralsols are formed on siliceous rocks in a mosaic pattern with regosols ; the humic ferralsols occur on the andesites. We have also observed ferric acrisols on the aplites.

This unit includes many inselbergs and some high hills.

Land occupation.

A small part, less than 10% is cleared along the rivers and along the logging roads.

MAPPING UNIT 18.

138.790 ha. - 6,2 % of the map. It is divided into two sub-units : 18 F-G and 18 F-H, differentiated by the relief and the slope.

SUB-UNIT 18 F-G.

Extension-location.

80.700 ha. - 3,6% of the map.

Two outcrops along the Mentaya to the north of Kuala Kuhayan ; the largest one covers 78.250 ha.

Description.

The parent material is a basic rock ; andesite is the dominant facies, associated with basalt and perhaps with trachyandesite (1). Inclusions of acid rocks appear here and there : rhyolite, granodiorites,aplites. The aplites occur in rather large veins in the northern half of the Tb Sangei outcrop.

The topography is undulating to rolling and the relief is slightly to moderately dissected. Locally, the interfluves are very flattened with a large summit having a slope of less than 5%. The short versants are linked up to flat valley bottoms of which the width can reach 100 m to 200 meters. Elsewhere, the tops of the hills are more convex ; the versants with slopes of 8% to 15% are linked up to flat valley bottoms with a width of 30 to 50 meters. The relief is more hilly on the aplite and rhyolite inclusions. On the basalt, the relief can be slightly undulating but occasionally very hilly.

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(1) Determination in process.

The vegetation is a heathy dipterocarp forest,with many large trees. Regrowth of weeds and secondary vegetation are very dense. Plants indicating a good natural fertility, such as wild banana trees, grow abundantly. The secondary formations are very bushy and difficult to penetrate.

The dominant soils are humic ferralsols which have a xanthic character more often than orthic when the landscape is undulating. They are associated in toposequences with dystric gleysols, rarely humic, in the valley bottoms. The proportion of gleysols can locally reach 25% of the total surface. The xanthic ferralsols are formed on the aplites in association with acrisols. On the rhyolites, one observes a mosaic of ferralsols with inclusions of cambisols and regosols. The gleysols of the 18 FG seem to have a moisture regime more humid than the gleysols on granites. During the periods of rain abatement, the water table stays in the soil at a shallow depth.

Land occupation.

Around one third of this unit is cleared along the Mentaya and in the upstream part of the Tualan river and its tributaries. The rest is under forest exploited by the logging companies.

Recommendations for the survey.

We would recommend to survey firstly the less hilly areas, which also have the largest valley bottoms, on the basic rocks and then the soils on the intrusions of acid rocks. As usual the main thing would be to differentiate between the ferralsols and the gleysols.

SUB-UNIT 18 F-H.

Extension-location.

58.680 ha. - 2,6 % of the map.

3 outcrops : the first in the Kuayan river basin, the second to the north of Tewah (1), and the third near Pundu.

Description.

This sub-unit differs from the precedent one by the landscape. The slopes are steeper and the versants are linked up abruptly with valley bottoms flat and

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(1) This one extends to the east outside of the mapped area.

relatively narrow ; their width, on the average, varies from 20 to 30 meters, occasionally 50 meters but rarely more, except near the rivers, where colluviums are mixed with alluviums.

The relief is strongly rolling or hummoky and moderately dissected ; one part of the valley bottoms is sharply cut by the rivers, the other is filled by colluviums over a weathered clayey material.

The parent material is andesite near the Kuayan, basalt in the north of Tewah, andesite and basalt near Pundu. The dipterocarp forest is quite healthy with a high canopy, some large trees and a high productivity.

The dominant soils are again humic ferralsols which frequently have an orthic character. They are associated with gleysols in toposequences and with cambisols and regosols on the rock intrusions forming the high hills. A petric - but rarely petroferric - phase can be observed on the most convex part of the hillsides, generally near the break of slope.

Land occupation.

Seventy percent of the Kuayan outcrop is cleared, about the half of the outcrop north of Tewah, and the southern and western borders of the Pundu outcrop.

Recommendations for the survey.

We shall refer to the indications given for the precedent sub-unit. To the usual delimitation between ferralsols and gleysols, one can add that of the petric phase occurring in the ferralsols.

MAPPING UNITS 19 AND 20.

Mapping unit 19.

Extension-location.

8.230 ha. - 0,37 % of the map.

Very small outcrops mostly spread in the units 16, 17 and 18 in the western part of the map.

Description.

This unit is differentiated by the relief. All the outcrops are located on high hills or on rock domes, which dominate the landscape. The slopes are very steep and exceed 45%.

The parent material has not been differentiated on the map ; this would have necessitated a check of the parent rock on each hill without particular interest for the objectives of this project. The reliefs observed near the logging roads and the rivers are usually associated with basic rocks : basalt, andesite, trachyte and rhyolite; but there are also high hills on grained, acid rocks.

The forest has the physionomy and the structure of the dipterocarp forest. Even on very steep slopes sprinkled with boulders, we have noticed a lot of big trees.

The soils occur in a mosaic pattern with dominant ferralsols, often deep, but locally with a lithic phase. The inclusions are cambisols, regosols and lithosols on the very steep slopes among the rocky outcrops.

This unit is almost entirely under forest. But we found that the foot of some high hills had been cleared even located at a long distance from the villages. Such clearing is perhaps related to the depressed areas surrounding the hills and which have already been described in the unit 16. The forest is healthy and rich in Ulin, springs are plentiful, and the wild animals seem to like these places. It can be a possible explanation of the interest of the inhabitants for these areas.

MAPPING UNIT 20.

Extension-location

96.000 ha - 4,3 % of the map.

The main outcrops are located to the north and northwest of Rantaupulut.

Description.

This unit is distinguished by the relief, which corresponds to the mountainous areas, always very dissected.

The forest is a healhty dipterocarp forest with a high productivity especially on the soils near the eastern boundary occurring on the basic rocks.

The soils outcrop in a complex mosaic pattern with dominant humic or xanthic ferralsols ; their lithic phase is associated with regosols and lithosols, or with cambisols. The rankers are located on the summit zones with very steep slopes among lithosols, regosols and rocky outcrops. The fluvisols are found in the colluvial valley bottoms along the largest rivers.

The mountainous massif north of Rantau Pulut is under forest actually logged.

Unit 19 and 20 are classified unsuitable for agriculture due to the topography.

MAP OF LAND SUITABILITY FOR AGRICULTURE

Translated from the french Report

MAP OF LAND SUITABILITY.

1. DEFINITION.

This map was drawn up through the interpretation of the data shown on the soil map, with the main basis being the observations made on the field during the survey. It shows the distribution of 11 mappings units, classed with respect to the number and influence of edaphic or environmental constraints which could affect cultivated plants. The title of 'Map of Constraints' would therefore be more exact, but for the sake of convenience we shall keep the term "map of Land Suitability".

This is only a technical classification in view of agriculture in general ; uses for sylviculture and animal husbandry are not mentioned, nor a specific usage for any particular culture. This would imply the intervention of other parameters and others constraints, some of which are not within our competence . For example, a soil which is presently classified as "marginal" for any given culture might be considered more suitable a few years later if a technical innovation, a genetic amelioration of the plants, or a change in the economic conditions intervened. However, this does not mean that the edaphic constraints will have changed.

2. ACTUAL SUITABILITY -POTENTIAL SUITABILITY.

Here we consider the problem of the actual and potential suitability of lands. The level of potential suitability of a piece of land can be higher than its actual level. This supposes that the constraints that are the limiting factors at the level of actual suitability are removed. The problem is knowing which constraints can be removed and above all what technical and financial effort is planned for this. Such an effort can vary in strinking proportions. For example, if we use liming to temporarily eliminate the exchangeable aluminium of the soil or raise the pH of this same soil by 2 units, the cost of the operation can vary in proportions of 1 to 10.

Therefore, we shall limit ourselves to formulating the actual suitability. This include development by improvements brought about through local means ; for instance the construction of small dikes, manual land clearing, furrowing, farming with draft animals, the spreading of organic manure and occasional fertilizers. It excludes large improvements such as big dams or extensive irrigation works, mechanized labor, and the massive spreading of fertilizers. We are aware of the ambiguity of this enterpretation but we think, however, that it can suffice at the preliminary survey stage.

The potential suitability could be object of an analysis at the level of detailed studies by pedologists and agro-economists when the kind of project to use is specified.

3. BASES OF LAND CLASSIFICATION.

The general framework of this classification is that established by the FAO and summarized in the work "Transmigration Planning Manuel - Land Evaluation".

Within this framework, it was necessary to adopt guidelines in order to accomplish this classification. The latter was based, at the primary level, on the kind of agriculture to be used, on the previously acquired knowledge of the development of this kind of tropical forestry eco-system, and on the general characteristics of lands and the environment on the regional scale. Such are the general principles of this classification.

At the secondary level, we will integrate the general characteristics of the environment or the soil to the spatial scale outlined by the units on the soil map. These characteristics make up the limiting and discriminating factors of this classification.

The integration of these two levels gives, then, a land classification by descending order of suitability.

THE GENERAL PRINCIPLES OF THE CLASSIFICATION

At this primary level of analysis, 3 main questions come up :

- To what type of agriculture should priority be given ?

- What kind of soil improvement should be chosen to assure the success of the first choice without causing serious damage to the soil and to the environment in general ?

- Finally, upon what criteria should we base the judgement of the soil fertility and its consideration as suitable or unsuitable for this kind of improvement ?

We are going to try to give some elements of response to these three questions.

3.1. TYPE OF AGRICULTURAL PRODUCTION.

Two priority objectives of this project define the type of agricultural production :

- To research sites favourable to transmigration. The transmigrants will have to develop the land alloted to them by practicing rainfed farming, first assuring their alimentary self-sufficiency and later in selling their eventual surplus production.

- To research sites favourable to agricultural projects which could provide sufficient food crop production to assure the provisioning of the urban centers of the Province and Palangkaraya in particular.

One can therefore assume that at this stage of study, priority should be given to food crop production : the various tree crops and cash crops are the secondary objective to be met.

3.2 TYPE OF SOIL MANAGEMENT.

To define which type of soil management is most suited to the accomplishment of the preceding priority objective, we can base ourselves on 4 elements : the regional environmental constraints, those of the soils in general, the evaluation of the hazards of erosion and degradation, and the analysis of the result of the experience already acquired in the management of these types of soils.

3.2.1. The constraints.

There are constraints that are common to all the soils. Some come from the environment ; others are strictly edaphic. The followings are the most important ones.

The Environmental Constraint

The major constraint is the very high rainfall and its effect on the soil water balance. The considerable volume of water that percolates in the soil (20 to 25 million litres per hectare and per year) produces an intense leaching of the soluble mineral elements available for the plants. Those mineral elements which are artificially introduced by fertilizers will obviously be subjected to the same fate.

These constraint bears on all the soils, no matter what type or slope. There is practically no way to limit it, or at best, only methods which produce unfavourable secondary effects. For example, if the water infiltration is reduced, the runoff, and therefore the erosion, is increased.

The Edaphic Constraint

The main one is tied to the physico-chemical state of the absorption complex. We can summarize this state by saying that all the soils have an absorption complex with dystrophic and Al-dominated properties. Experience has shown that the soils which have this constraint are the most difficult to manage. We know that to the direct effects caused by the low nutritional level are joined indirect effects among which the abundance of weeds, for example, constitutes yet another secondary limiting factor.

The characteristics of the absorption complex have been described in the soil map report. To summarize briefly the pH is quite acid, the sum of exchangeable bases is inferior to 2 meq, the base saturation is less than 10% and often less than 5%, the exchangeable aluminium is 2 or 3 times greater than the sum of the bases, and the aluminium saturation with respect to the permanent change is between 60 and 90%. Several of these values are above the limits that are theoretically considered as critical, especially for the aluminium.

Thus, the low nutritional level and the intense leaching of mineral nutrients are constraints that will manifest themselves no matter what type of soil is chosen for management.

3.2.2 <u>Evaluation of the Hazards of Erosion and Degradation</u> (1).

In the first part of this report, we described their actual effects. It is now possible to evaluate them with respect to the type of management. For this, we will distinguish two possibilities of soil utilisation : that which is permanent for perennial crops. We will also differentiate between the two different groups of soils, the ferralsols and the acrisols. These soil do not have the same physical properties and we can therefore expect different behaviours if they are cultivated.

The main elements that control erosion in these soils are the intensity of the rains, the slope of the ground, and the characteristics of the topsoil. The very high level of rainfall and its intensity characterize an index of climatic agressivity (2); we can imagine that it is particularly high in this region if we base ourselves on the available results. This index is probably more than 2000 units.

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(1) We are basing ourselves mostly on the results recently obtained by ORSTOM from measurements and experiments done on the tropical forest soils (ferralsols) both under forest and cleared in particular the work done by E. ROOSE.

(2) Wischmeier and Smith index, 1960.

THE FERRALSOLS.

In these soils, the physical properties of the topsoil are very good ; the aggregates do not split in water ; the soil is very permeable on the surface and is capable of absorbing great quantities of rainwater under the protection of a forestry covering. But the unfavourable factor with ferralsols is the slope coefficient, which is usually more than 15% and which is frequently situated around 20 to 25%.

Probable Evolution Under permanent Food Crop Cultivation.

Once the soil is cleared, cultivated, and weeded, it will be exposed to the direct kinetic energy of the raindrops which will contribute, along with the loss of organic matter, to a degradation in the physical properties of the topsoil ; the quality of the soil structure decreases which immediately provokes a lowering of the permeability of the topsoil. Instead of spreading in thin streams that penetrates into the irregularities of the soil, the rainwater will be concentrated into a few axes, taking up speed as it runs downhill and causing considerable damage. This can be seen where the soil has been laid bare along the logging roads and the forestry working sites. The steeper and longer the slopes, the greater the damage.

To these spectacular effects caused by strongest rains is added a more discreet and insidious type of erosion from the runoff. It washes away the finest particles of clay and silt which, at best, are carried down to the valley-bottoms, or at worst, to the sea. Now, in these fine particles are concentrated many nutritive elements linked to the humus-clay complex (1). Measurements taken in the Ivory Coast have proved that "under an extensive corn culture which covers the soil badly, runoff is 50 times more abundant and erosion is 1000 times higher than under forest". (E. ROOSE, 1979.).

Below are, as an example, a few of the results of the measurements taken by Roose in the Ivory Coast in a forest environment under 2100 mm of rain per year and a slope of 7%. The soils are of the ferrallitic type, highly desaturated, and related to the dystrophic ferralsols.

	forest	cultivated	unprotected
total erosion tons/ha/year	0.11	32	138
runoff m3/ha/year	210	5250	6300

(1) These losses are added to the leaching of soluble elements by the drainage waters.

Probable Evolution Under perennial Crops

A tree crop associated with a cover plant (graminaceous or leguminous) partially reconstitutes the forest microclimate and the pedoclimate ; the soil is above all protected from the rain impact and the runoff remains very limited. In this case, erosion is very moderate and is situated at levels comparable to erosion under natural vegetation. However,when the slope is rather steep, some special precautions must be taken even though the erosion level is still much lower than for food crops under the same conditions. The main problem concerns the critical period between the time of land-clearing and the time when the cultivated vegetal covering is sufficient to protect the soil ; during this period serious damage can occur if a minimum of precaution is not taken.

The Acrisols.

The case of the acrisols is different because of their less favourable physical properties and their very low nutritional reserves. What has just been said about the risks of mechanical erosion in the ferralsols can be applied to the acrisols. Of course, the slopes are not as steep, but this asset it offset by the fragility of the physical properties at the surface. Besides, the climatic agressivity is such that the effets of erosion on slopes of 8% will also be very severe if it is allowed to exert itself, all the more so since these slopes are longer than in the ferralsols.

Another hazard, with less spectacular effects, but with more serious consequences, is the risk of degradation Some of this effects have been described in the first part of this report. Let us now briefly compare the ferralsols and the acrisols. The formers are formed on consolidated eruptive rocks : the rock is sometimes found at a great depth but it is an exhaustible reserve of mineral elements. Suppose that a ferralsol on andesite had undergone a major lowering of its fertility due to a long succession of cultivation cycles. With the exclusion of exceptional cases, the forest will ultimately grow back while ameliorating the potential fertility of the soil even if a longer fallow period than normal is needed. We are not well-acquainted with the ways in which the trees manage to extract new mineral elements from deep soils, but we must acknowledge the result even if we do not explain the process.

If we look now at the acrisols, we see that the parent material is only the residue of the weathering of old soils (ferralsols or their equivalents) that has been carried away by water and deposited in the sedimentary plain. This residue constitued of quartz and kaolinite in other words, of silica and alumine, is deposited on very great thickness. Even deep in the soil, the mineral reserves are very limited. If a long succession of cultivation cycles causes a serious decline in the soil fertility, we can fear that it could not reconstitute itself, at least if this had reached a critical stage. These acrisols, then, are going to enter a cycle of degradation which will accelerate : exhausion of the organic matter and the disappearance of the mineral elements linked to it, consecutive degradation of the physical properties beginning with the structure, change in the moisture regime, dessication of the soil, fires, leaching by the rains of the mineral elements contained in the ashes, acidification, infestation of specific weeds, etc... The moment arrives when this degradation must be irreversable and the fertility can no longer be reconstitued even if the land is under fallow for a very long time. The only thing left to do is to try artificial remedies which will certainly be extremely expensive without any guarantee of success.

These predictions might seem pessimistic, but many signs that were observed on the field authorize us to believe that such probably be the normal evolution of the acrisols if they are cultivated without caution. We also feel that these risks are much less likely under perennial crops with a covering grass.

Conclusion : in view of the climatic agressivity and the generally steep slopes, the permanent cultivation of the versants having ferralsols for weeded food crops can only lead rapidly to considerable damage by mechanical erosion. To limit the risk of erosion, it is absolutely essential to protect the soils on slopes from the direct impact of the rain and force the water to penetrate the soil instead of running off. Obviously, the more water which penetrates, the greater the leaching, but it is better to choose the lesser of the two evils.

Permanent cultivation of the acrisols for food crops, especially those whose recolt is exported, can only lead to their short-term degradation. This risk is limited under perennial crops.

3.2.3 Experience Acquired on these Tropical Soils

The problem of the management of these soils is summarized in this question : how to switch from the recurrent cultivation presently practiced by the local population (1) to the permanent agriculture that the transmigrants will have to practice on their allottments ?

Acquired experience will be our first reference. Up until the last decade, we can say that no method that could be widely popularized was perfected for the management of

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(1) Recurrent culture on an average ratio of 1 to 10 ; that is 1 year of cultivation for 10 years fallow.

tropical forest soils under rainfed farming in view of intensive food crop production. Tentatives employing massive doses of fertilizers did not have the expected results, not to mention the economic cost. Below is a schematic description of the results obtained on the different continents and the 4 main methods that were followed :

(1) Direct change from recurrent cultivation to permanent rainfed farming.This calls for very large amounts of fertilizers and it is very difficult to maintain the stock of organic matter. The needs are qualitatively the same as for temperate soils, but the necessary quantities were much larger. The experiments were deemed unprofitable.

(2) The natural fallow period is used to produce useful fallow plants. The effect on the soil evolution is favourable and almost the same as that of a natural fallow period. But the rotation periods are very long and this necessitates the use of vast areas. If the area is limited, this type of land utilisation is not considered satisfactory.

(3) Exclusive use for perennial crops. The change is thus rather simple and does not modify the environment much. But this system does not include food crop production.

(4) Concentration of food crops in developed valleys.

3.2.4. Conclusion and choice of the type of management.

From the preceding considerations, we can conclude that it is necessary to adopt a kind of management that both assures food crop production and limits the erosion of the soil and its degradation, while taking into account the low nutritional level and the difficulties in the use of fertilizers because of the climatic agressivity.

We have therefore retained the following type of development, used as one of the bases of estimation for land classification.

1st Priority.

Management of the fluvisols and other associated soils in the alluvial valleys. Erosion risks are practically non-existent, chances of degradation are slim, and irrigation is possible. The fertility level is at least equal, or a little superior, to that of the upland soils.

2nd Priority.

Management of the system constitued by the association of ferralsols and gleysols, which is schematically represented on the plan below.

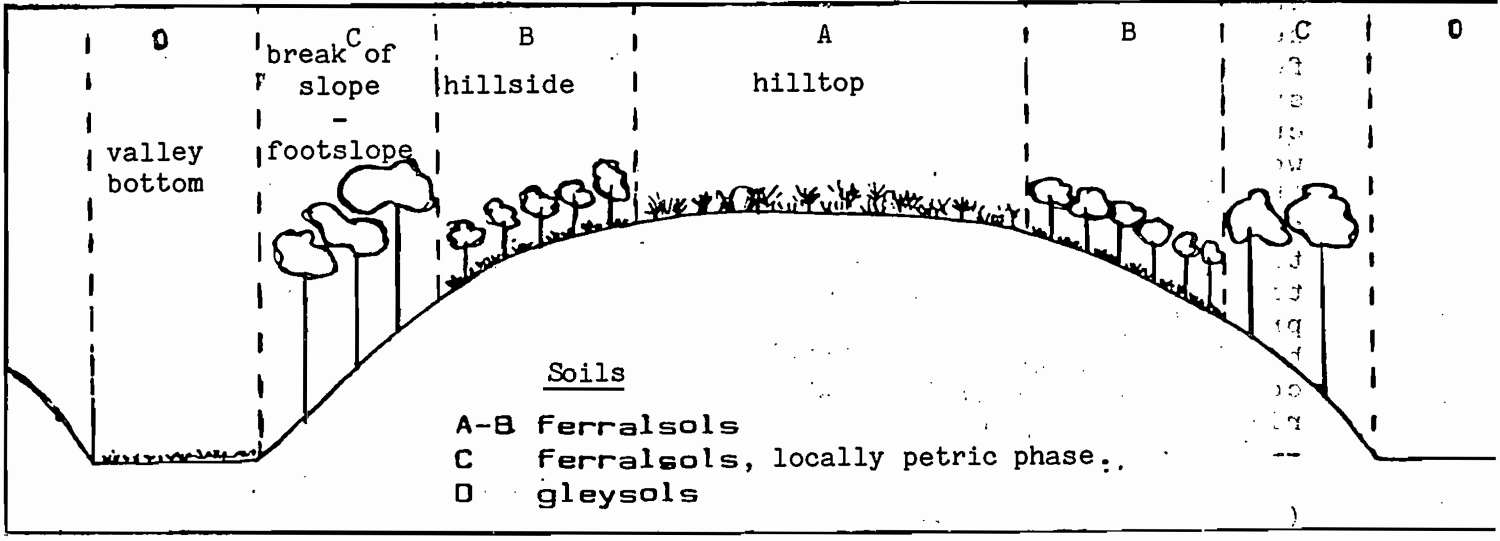
The base unit for such management could be the toposequence that is the association in the landscape of the ferralsol on the versant and the gleysol in the valley bottom. It would be possible to manage this landscape in the following way :

- Reserve the gleysols of the valley bottoms exclusively for permanent food crops by developing them through local means. It is first of all necessary to assure the control of water for the crops and the needs of the population and livestock (cf zone D of the plan).

- Manage the tops of the hills with gentle slopes for short and long cycle associated food crops and if necessary intercalate strip contours planted with a grass cover. A single imperative : favourize the soil covering to the utmost all year in order to reduce runoff and erosion. There are some risks of erosion but they can still be controlled (cf zone A of the plan).

-Develop the slopes exclusively for the tree crops with a cover plant, graminaceous or leguminous, which completely covers the ground. This plant could possibly be used for the pasture. Such vegetal covering is the best method of controlling and limiting erosion (cf zone B of the plan).

- Leave the steepest slopes under natural vegetation or under artificial fallow, especially the zones located towards the break of slope. The risks of erosion in these zones are very high and the best way to prevent it is to leave the tree covering, which could, for instance, supply the daily needs for workable timber and firewood (cf zone C of the plan).



Example of the ferralsols-gleysols system on granite

The agronomists can define the best formulas for rotation and fertility transfer from one zone to another.

3rd Priority.

Management of the acrisol plain according to the above model, but with some variations :

- Concentrate food crops in the valley-bottoms,

- Restrict, as far as possible, the food crops picking up and exporting a lot of mineral elements from the soil because of the very low soil reserves and the high risk of degradation,

- The possible spreading of tree crops with grass cover to those versants whose slope is slight to moderate.

We believe that the proposed type of management can furnish this region with a certain amount of permanently cultivated food crops without causing any major damage to the soil and the environment in general. It is a management for rainfed farming that requires not large investments but manual workers and local methods.

The choice of such a management brings with it two practical consequences concerning the method of clearing the land and the repartition of land allottments in the projects.

Methods of land-clearing

Careful clearing of forest or old fallow is an essential condition for the future success of the projects. The expeditive method which consists of clearing with heavy machinery, pulling up stumps and pushing some of the felled trees into the valley bottoms (1) is not what we would suggest. It would be better to proceed with manual clearing, cutting up the timbers on the field transforming the strong wood into charcoal, etc. Such methods demand more time but they have the considerable advantage of preserving the two qualities of ferralsols : their good physical properties and their content in organic material where the nutritive elements are concentrated. If these qualities are preserved, their beneficial effects on production will be seen at medium term and at long term and will largely compensate for the time apparently 'lost' during the clearing.

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(1) Report on land clearing in the outer islands of Indonesia. L.J. Clarke, January, 1980. Working paper.

Repartition of land allottments.

Such management also implys that the repartition of the plots of land allotted to the future occupants first of all take into account the spatial distribution of the soils. The combination of ferralsol -gleysol or acrisol -gleysol always has the same disposition : ferralsol and acrisol on the versants, gleysol in the valley bottoms. The demarcation of the allottments should therefore be perpendicular to the contour lines, and not parallel to them.

3.3. FERTILITY ESTIMATION.

It is now necessary to determine the criteria which allow an estimation of the fertility of the different soils and, then, a classification of the lands according to their suitability for the type of management defined above.

The usual method of estimating the fertility of the soils is to base oneself on the chemical and physico-chemical properties, perhaps because this is the usual method for the soils of temperate climate areas.

The specialist who examines the result of the chemical analysis of the soils of this region would find that the fertility level is extremely low. The content in certain mineral elements (1) is often those limits considered as mineral deficiency or even as lack. The content in exchangeable aluminium is very high. The specialist would therefore be able to assume that cultivated plants do not grow normally in this region.

Now, we have found on the field that the plants do not appear to suffer, in general, from the very low nutritional level defined by the analysis and such toxic levels as are theoretically possible. Furthermore, we find that the fertility of certain soils is clearly superior to others (2) without showing any significant differences at the level of analytic results.

The content in mineral elements usually shown by the analysis is so low that it reaches the limit of systematic errors of analysis and errors due to the heterogenity of the sampling.

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(1) Exchangeable calcium and aluminium, for example.

(2) The proof being the selection of these lands by the local population through empirical knowledge.

The minor variations that were noticed cannot be considered significant. One might therefore believe that the range of the value determined by analytic methods is not wide enough for the particular properties of these soils or that the usual types of analysis are not pertinent.

This being the case, it is still possible to estimate the fertility by observing the plant's reactions.

The forest's aspect shows natural fertility ; but the forest sometimes lives on its own nutriment reserves which are recycled by the turnover so that the soil's reserves do not come into bearing. If there are no soil reserves, the fertility will be low the land is cleared.

The aspect of fallow and of forest regrowth give better information on the potential fertility under natural conditions. The many observations that have been made confirm that there is truly a relationship between the level of potential fertility and certain properties of the soils; this could be due, for instance, to the influence of a factor in the soil formation, such as the parent rock ; but this relationship is not always expressed at the fertility level determined by usual chemical analysis.

Finally, in order to better understand the potential agricultural fertility, the best method in this case is to proceed to experiments in a test farm. We believe that a favourable bioclimatic environment could partially compensate for a low level of chemical fertility. Let us not forget that the soil is deep, water abundant, and the temperature is constant, all conditions which are favourable to plant growth. In our opinion it is difficult to estimate a prioriti the behaviour of any particular plant in this environment. Thus it is the tests in the field which can determine the real level of fertility which is the best for optimal plant growth in this bioclimatic environment and under such edaphic conditions.

In conclusion, in order to establish a land fertility classification, we cannot base ourselves on certain chemical properties of the soil (1), nor on empiric observations that cannot be quantified, nor on the unavalaible results of agronomic tests. The chemical properties of

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(1) Water pH, KCl pH, exchangeable bases, saturation rate, exchangeable aluminium, permanent charge.

these soils are certainly a limiting factor with respect to their management ; but as they are nearly the same for all the soils, they do not constitute a discriminating factor necessary for the achievement of this classification. Therefore, other factors must be sought.

4. LAND CLASSIFICATION.

We have chosen 12 limiting and discriminating factors which are either edaphic or environmental in origin. They are either permanent constraints which man cannot eliminate or constraints which are difficult to overcome; if this be the case, the cost is usually very high.

The former are : slope, width of the valley bottoms, type of parent material, and available water. The latter : amount of organic matter, physical properties, exchange capacity, soil drainage, moisture regime, erosion and degradation hazards, and reserves of mineral nutriments.

4.1 SLOPE

It is this factor which, in connection with the intensity of the rains, determines the erosion. Slope and length of slope do not necessarily augment erosion ; everything depends on the state of the topsoil. If it is impermeable, the slope favourizes erosion by accelarating the runoff. The terracing done to limit this constraint is quite spectacular and very costly. But the method of protecting the soil with vegetation and mulch has been found to me more effective in the long term and above all the less expensive (1).

For a first estimation, we could establish for this region a slope classification in the following range : 0 - 2% 2 - 5%, 5 - 15%, 15 - 30%, more than 30%. Above 5%, the risks of erosion are very high under crops which cover the soil badly, especially if they are weeded ; the risks are moderate if the crop rotations assure the permanent protection of the soil. Above 15%, it seems that the combination of perennial crops and grass cover is the most advisable method. If the slope is steeper than 25 - 30 %, it would be better to leave the soil under its natural vegetal covering for the time being.

4.2 EXTENSION OF THE VALLEY BOTTOMS

Narrowness of the valley bottoms is a major constraint as this limits the possibilities of permanent crops which must assure food production. The larger and

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(1) Experiments and measurements made by ORSTOM in the Ivory Coast between 1970 and 1980. (E. ROOSE et All).

flatter the valley bottoms, the more favourable the land. Their use has 4 advantages :

- low to nonexistent risks of erosion ;

- limited loss of mineral through leaching;

- possibility of water control through minimal land management works ;

- the valley bottoms receive all the products from the erosion of the versants : ashes, charcoal, clay, and humic compounds.

As we have shown before, those valley bottoms having gleysols combined with soils on the versants could serve as base units for management. The planners could choose from the detail maps those zones where the proportion of valley bottoms is compatible with their projects.

The figure shown in the legend of the map is an average percentage of the valley bottoms with respect to the total area of the mapping units. This percentage varies, even among the different mapping units, according to the situation in the river basin and the outline of hydrographic network. One of the priority objectives of detailed studies would be to outline them precisely, show them on an appropriately scaled map, and calculate their extension.

The figure "100 " shown in the legend has been assigned by convention to riverine alluvial floodplains.

4.3 EROSION AND DEGRADATION HAZARDS

These have been discussed in detail in 3.2.2, and we shall not speak of them again. Briefly summarized, this is a major constraint for this region ; mam can do nothing to halt the causes; he can only look for ways to limit the effects.

4.4 MOISTURE REGIME

We have distinguished 3 constraints of the moisture regime :

the flooding hazard, the soil drainage and the water available for the plants.

The flooding hazard : this is quite high in the lower alluvial valleys where the water spreads from overflow points into the plain, which is situated lower than the level of the river waters. Overcoming this constraint necessitates a great amount of work : preventing the overflow, controlling the water that arrives from the back country via the tributaries, and evacuating the overflow through drainage.

This hazard is moderate in the upper alluvial valleys and is limited to the flood periods. Controlling it in this area is relatively easy.

Lastly, it is low in the valley bottoms between the versants where it is easy to control the water.

<u>The soil drainage</u> is shown by the rapidity which the rainwater drains through the soil. If no direct measurements are available, it can be evaluated by examining the soil profile while looking for the various hydromorphic features. We have observed 4 categories :

- very rapid drainage : the rainwater percolates through the soil without forming even a temporary watertable. There is no hydromorphic features in the profile.

- rapid drainage : the rainwater percolates down the base of the profile observed (200 cm) but it can temporarily slowed at a less porous level (AB horizon, for example) and form a perched watertable which remains for several hours. Some hydromorphic features show up in a few soil volumes.

- medium drainage : the rainwater percolates slowly and can saturate a layer of soil for several consecutive days. Hydromorphic features appear at the soil base and in part of the B horizon.

- Slow drainage : the water saturates the soil for a very long time. All, or almost all, of the profile shows hydromorphic features.

<u>Available water</u>, is represented in the legend as a water-holding equivalent for two soil layers. 0-50 cm corresponds to the depth accessible to the roots of annual plants and 0-150 cm to the depth normally reached by perennial plants.

An available water quantity of 70 mm means that an annual plant, for example, can develop normally during a dry period as long as it does not use that amount of water equivalent to 70 mm of rain. It can be estimated that the evapotranspiration under a crop which covers the soil well should be at about a maximum value of 3.5 mm per day in this region. The growth of the plant will slow and will stop when the permanent wilting point has been reached, after about 20 days, upon the exhaustion of all available water.

If one examines the values of available water, one can calculate that they are sufficient to assure normal alimentation lasting for 9 to 18 days for the annual plants and 32 to 50 days for the perennial plants. This limit is naturally prolonged if the evapotranspiration is fed from a watertable accessible to the roots.

But the water quantities indicated are theoretical and there are possible variations. As a matter of fact, the theoretic value of available water is obtained by calculations made from the laboratory measures. It is the difference between the water content at 15 bars (permanent wilting point) and the water content at 1/3 atmosphere that is generally considered to be the value of the retention capacity. Now, it is probable that for the ferralsols of very humid regions, the water content at effective retention capacity corresponds to values fo 2.2 bars or lower (F.X. HUMBEL),1976 (1) We can therefore consider that the theoritic values of available water underestimate the effective available quantities by at least 25%.

Available water is defined for optimal rooting ; but the latter can be reduced for various reasons, the most frequent of which come from unfavourable cultivation methods. In this case, the water that is theoritically available is no longer so in practice and the theoretical value therefore overestimates the quantities that can actually be used.

Observations made on the field confirm this. As the value of monthly rainfall is always higher than that of the monthly PET, the period of plant growth lasts, in theory, the year round.

In reality, we find that the rice crops depending on the rains are greatly damaged if a dry period of relatively short duration sets in. This risk could also happen to perennial plants that are badly rooted during those exceptional dry spells whose recurrence is decennial.

The best way to understand precisely the constraint represented by the available water is to take measurements in the field in cultivated plots of land during 2 or 3 yearly cycles. There are techniques that are simple and inexpensive for carrying out this type of measurement.

4.5 QUALITY OF PHYSICAL PROPERTIES

Five physical properties have been selected. Their combination defines 5 levels of quality : very high, high, medium, low, and very low. These properties are : the porosity calculated from the bulk density, the structure, the resistance of the aggregates to mechanical pressure,

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(1) Determinations in situ during annual cycles.

the resistance of the aggregates to immersion in water, and the ability to absorb water, estimated by tests on air dried aggregates.

We will cite the two extremes as examples :

Very high level : porosity equal or higher than 60 points ; fine crumb structure to subangular blocky ; very high resistance of aggregates to mechanical pressure ; holds very well when immersed water ; low absorption ability for water.

Very low level : porosity below 40 points, massive structure, very weak resistance to mechanical pressure, high absorption ability, rapid breaking up of the aggregates immersed in water.

4.6 PROPERTIES OF THE PARENT MATERIAL

Two characteristics of the parent material could indirectly be limiting factors : a very high content of coarse quartz and a very low content of black minerals.

The content of quartz and their dimensions.

The mechanical effect of granular quartz occurs more than its chemical and mineralogical composition. The quartz combines with argillaceous products issued either from the weathering of other minerals or already existing in the parent material to form various kinds of organisations. We find that the more abundant and coarse the quartz, the less structured the organization and the less porous and permeable the soil. The only exception to the rule is that of the pale clay without quartz and without metallic hydroxides. This material is arranged in compact and slightly porous structure. The size of the quartz grains also plays a part. If they are small dimension, they are integrated into the aggregates, and as the properties of aggregation dominate the rigid skeletal effect, the soil remains rather porous.

We have defined several categories of material : at one end of the scale is a material having abundant and coarse quartz ; at the other is a material without quartz (1) formed from clays and hydroxides issuing from the weathering of feldpars and mafic minerals.

The content in black minerals

This is related to two soils properties :

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(1) Or else with a very small quantity ; even the basalt soils of this region always have a little quartz.

a. The physical properties

The weathering of black minerals produces iron hydroxides which mix with clay minerals, giving a colloidal complex that is stable in water and which is made up of aggregates, forming a porous structure. It is, in a way, the inverse effect of quartz. This is why we find that the soils on black rocks abounding in black minerals (i.e. basalt) have a very good structure and an excellent porosity. These qualities change in the soils if the amount of black minerals dimishes in the rock.

b. The fertility.

The second property is related to empiric observations. The soils on rocks either with or without black minerals have about the same potential in chemical fertility according to the usual analyses. But while observing the growth of the plants we find that the fertility potential is always higher on the soils occurring on the dark rock and that these have above all an ability to recover quickly this potential after a fallow period.

4.7 CONTENT OF ORGANIC MATTER

The organic matter can be a limiting factor due to its effects on the physical properties, the mineral reserves, and the rooting.

Physical properties.

In these desaturated soils, the organic matter plays a capital role in assuring the cohesion of the aggregates. The diminution of the organic matter in the acrisols is probably the starting point in the degradation cycle.

According to some tests that were made, a 1.5% content in organic matter in a material having 50% clay seems to be the limit ; below that, the cohesion of aggregates diminishes significantly.

The soil reserves

The mineral reserves originating from primary and secondary minerals are very low even in ferralsols on basic rock because the mineral hydrolysis and the leaching are very intense. The soils containing micas that are resistant to weathering or micaceous clays have reserves which are a bit higher but which remain low in relative value. Also, the main source of mineral elements is the organic matter, which is the veritable "safety box" of these soils. The following example shows the importance of the stock of elements contained and recycled by the biomass. One hectare of equatorial sempervirent forest contains about 2000 kg of calcium ; this quantity corresponds to the total amount of calcium contained in the 0-35 cm surface horizon of a ferralsols on granite in this region.

Rooting

We have noticed that rooting is often related to the depth of penetration of the organic matter. This is not surprising as the nutritive elements are concentrated there. Rooting is very dense on the surface, still abundant up to 40 cm (1) and spread according to whether the organic material is diffused or concentrated on the face of the aggregates and in the pores. In the humic ferralsols, rooting can go down quite deep, more than one meter.

The figures of organic matter indicated in the legend correspond to the content in organic matter in the soils under forest, at the surface, at 50 cm, and at 100 cm. We do not know the equilibrium content when the soils are cultivated for a long, continuous period. A great number of selected samples would be needed to obtain any significant figures. The quantity of organic matter in the forest soils is probably going to decrease progressively under cultivation, to reach an equilibrium which will depend on the pedoclimatic and bioclimatic conditions in the cleared areas. It would be very important for the soil management to know what this equilibrium value will be and the effect it will have on the physical properties of the surface horizon. This could be one of the objectives of the experimentation (1).

We know through experience that is very difficult if not impossible, to permanently raise the value of the equilibrium rate of organic matter in these tropical soils, even by bringing in great doses of organic manure. On the other hand, the amount of organic matter at equilibrium remains stable in the case of normal soil utilisation.

4.8. EXCHANGE CAPACITY OF CATIONS

A low exchange capacity is a major constraint for management as it is difficult to overcome if one wishes to obtain long-term effects. It is possible to obtain short term results by raising the pH of the soil through liming. In fact, the CEC of ferralsols depends on the pH to a certain extent, but calculations show that the doses of lime needed would be considerable, in view of the leaching.

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(1) except in certain soils like the podzols having an E albic horizon.
(2) combined with a study of the new microbiological equilibrium.

On the other hand, we direct the attention of the users to the hazards of liming in certain ferralsols. Experience has proved that it can provoke very destructive secondary effects : peptization of the colloids and unavailability of certain mineral elements. It is strongly recommended to make preliminary tests, especially in the case of ferralsols with acric characteristics like those of Bejarau.

4.9. THE LEVEL OF MINERAL RESERVES

The range varies from 4 to 40 meq, but it only has a relative value ; a content of 20 meq of total bases, considered in these soils as a high mineral reserve can be considered low in other regions.

The figure shown in the legend corresponds to the sum of the total base (Ca+Mg+K+Na) extracted by heated nitric acid 13N and expressed in meq/100 g of fine earth.

4.10. PROPERTIES OF THE ABSORPTION COMPLEX

This is an important constraint as it is relatively easy to dispose of through technical means. However, operational costs can be very high.

The pH is always more acid at the surface than at a depth even though the amount of exchangeable bases is slightly higher there, as is also the base saturation rate. This apparent anomaly would be cause by the acid groups of the organic matter. The pH of the acrisols of sandy texture can sometimes be abnormally high, that is, around 5.0 or slightly higher even though the content in exchangeable bases is extremely low ; in this case, the soil buffer capacity no longer plays its part due to the sandy texture.

The exchangeable magnesium and calcium in the topsoil are a bit higher than the limit considered as being deficient in tropical soils (1) ; in the subsoil, it is often below this limit. But it is better not to trust the analytic results which are difficult to intrepret due to very low contents. Experimentation in the field is again the best method of verifying the level of deficiency and lack in the bases.

The exchangeable aluminium deserves special attention. If we refer to the norms that are usually acceptable, this would be a very great constraint in these soils. Its content is quite high, 2 to 3 times that of the exchangeable bases ; its saturation rate with respect to the

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(1) J. Boyer. ORSTOM; Paris, 1978. Calcium and magnesium in the soils of tropical and sub-humid regions.

exchangeable cations surpasses the critical rate of 60% ; moreover, the pH is often less than 5.2, which would be the value at which the aluminium begins to play a part in the exchange reactions.

But if one observes some plants, such as rubber, coffee, oil palm , and rice, one finds that they seem to be perfectly adapted to the high content of exchangeable aluminium. This is why we think that the toxic levels attributed to aluminium must come from a combination of several processes. According to our observations made on the cultivated acrisols of the southern area, it would seem that the combination of the 3 following factors provokes unfavourable conditions for the plant, which result in problems of growth : a high content in exchangeable aluminium and manganese, the presence of abundant organic matter, and above all a water saturation that creates reductive conditions in the soil. These troubles have not been seen in the ferralsols which also contain exchangeable aluminium, manganese, and a large amount of organic matter, but which are always well-drained.

If necessary, the aluminium can be neutralized through liming by raising the pH to 5.5, but it is quite probable that the effect would be slight under such rainfall.

4.11 THE MICROELEMENTS

The user will find in annex 6 several indications on the content in microelements. Without any value of reference or result of experimentation, we cannot know if microelements are a limiting factor.

In the ferralsols area, the mineralizations linked to sulphides are very abundant in the rocks ; this is why we believe that these soils are adequately provided in sulfur and metallic microelements.

4.12 TEXTURE - DEPTH

Texture is not among the limiting factors. Usually, it is the extremes of the range that are considered as constraints : very clayey texture and very sandy texture. However, a very clayey texture is here a favourable factor a very sandy texture is associated with soils that also have other more constraining factors.

Depth is rarely a limiting factor. If it is, it is always in mountain soils whose topography remains the major limitation.

5. THE MAPPING UNITS

The 11 mapping units are divided into 2 orders at the highest level of classification : the suitable lands and the unsuitable lands (1). The suitable lands are sub-divided into 3 classes : the highly suitable, the moderately suitable, and the marginally suitable. The unsuitable lands are divided into 2 classes : the currently unsuitable and the permanently unsuitable.

Each class is then subdivided into sub-classes with respect to the discriminating and limiting factors described in the preceeding chapters.

Each sub-class is represented by a letter indicating the suitability (S) or the unsuitability (N), followed by a figure identifying the class and symbols showing the major limiting factors (S) . Below is the key to the symbols used.

f = flooding hazard
n = low chemical fertility level
l = landform,especially low percentage of valley-bottom,
t = topography, steep slopes
e = erosion hazard
d = degradation hazard

Now we would like to summarily describe the mapping units while indicating their extension and localization, the correspondence of the units to the soil map, the major limiting factors, and the particulars (2).

5.1. ORDER OF SUITABLE LANDS

5.1.1. Class of highly suitable lands

No land has constraints low enough to be placed in this class.

5.1.2. Class of moderately suitable lands

The limiting factors are such that the soils are still suitable for agriculture without necessitating important improvements and without serious risks of damage caused by erosion and degradation in the event of management as defined in paragraph 3.2.

This class consists of 4 sub-classes in which the constraints progressively limit the suitability of the lands for food production.

This class covers 306,290 hectares, or 13.8% of the

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(1) Definition of the classification system in 'Transmigration Planning Manual n° 3".

(2) The surface of each unit is shown in the legend to the map.

map.

Sub-class S2f

Extension-localization

59,185 ha - 2.6 %. Katingan River valley, upper course of the Rungan, Manuhing, Mentaya, Cempaga, and Tualan rivers (1).

Correspondence to soil map

Units 3 and 4. Fluvisols, cambisols, and gleysols of the temporarily flooded alluvial valleys on silty-clay parent material.

Major limiting factor

Flooding hazards during the river swellings due to the waters overfloowing the banks. A management of these valleys necessitates prior water control.

Particulars

The risk of erosion is negligeable since the land is flat or almost flat. The flood risk is moderate ; this can only happen during the river swellings of the rainy season. Water control should not pose any major problems as long as some hydrological information and a minimum to topographic data are available.

Controlling the floods would probably be more desirable than stopping them altogether, since every year the flood waters bring fine elements in suspension in which are concentrated nutritive elements for the plants. This yearly alluvial deposit is important for the soils whose potential in chemical fertility is relatively low.

Soil drainage should be possible since the surface of the alluvial plain is higher than the average level of the water in the rivers. Construction of small dams on the tributaries would be an eventual possibility in order to irrigate the alluvial soils of the valleys.

The presence of a water table in the soil can slow or stop the unfavourable effects of a climatic accident. Finally the presence of weatherable minerals in the parent material, even in small quantities, is favourable to chemical fertility.

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(1) For more precise localization, see soil map.

This S2f unit is therefore considered the most suitable of the all mapped area for agricultural use with priority on food crops ; almost all the surface, except for a few inclusions of histosols, is susceptible to be managed.

Sub-class S2n

Extension-localization

80,000 ha - 3.6 % North of Kualakuhayan in two outcrops, the largest of which covers 78,250 ha in the Tb. Sangai area.

Correspondence to soil map

Unit 18 F-G. These are humic ferralsols, sometimes xanthic, associated with dystric gleysols in toposequences in an undulating to rolling topography. The inclusions of regosols, acrisols, and cambisols are not widespread.

Major limitation

The major limiting factor is the low level of chemical fertility. The other factors are less restrictive.

Particulars

This is the only unit on the basement rock where the topography is not too hilly and the valley-bottoms are relatively large. These latter can be managed for food crops along with the versants having slight slope, with limited risks of erosion.

Sub-class S21

Extension-localization.

56,935 ha - 2.5%. 3 outcrops : one to the north of Tewah (22,125 ha) (1), another in the Kuhayan river basin (28,850 ha) and the third near Pundu on the Cempaga River (6,560 ha).

Correspondence -soil map.

18 FH. This is the same association as in the preceding unit with several additional sections having soils with petric or petroferric phase.

Major limitation.

The relief is such that the valley-bottoms are

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(1) Spreading towards the east outside of the map's boundaries.

narrower than those in the S2n unit and the slopes are steeper on the average. The tops of the hills are still fairly flat but the slope of the versants at their lower half is more than 10%- 15% and reaches 25-30% at the break of slope.

Particulars

Much of this unit is formed on very basic rocks. Despite this, the chemical fertility level is still low, excep for the cambisols of limited range.

As the preceding unit, the gleysols in the valley-bottoms and the tops of the hills having a slope of less than 5% can be used for food crops without any great risk of erosion. It is better to leave the versants for tree crops and to leave the sectors along the break of slope under natural vegetation. The total area useable for food crops is thus smaller than in the preceding unit.

Sub-class S_2l,n

Extension -localization.

110,170 ha - 4.9%. About ten outcrops distributed on the map ; the largest is found to the north of Tb. Samba (48,625 ha) ; the others have areas ranging from 3,000 to 18,000 ha.

Correspondence soil map.

9 F-G, 12 F-G, 15. This unit is heterogenous. It includes orthic and xanthic ferralsols on grained, slightly acid rock and humic ferralsols with slightly acric characteristics on basic rocks. The pedologic landscape still relates ferralsols and a certain proportion of gleysols in the valley-bottoms. The topography is rolling to hummocky.

Major limitations

First of all are the narrowness of the valley-bottoms and the steep slope on the lower third or the lower half of the versants. Another factor is the low level of fertility due to acric characteristics of some soils.

Particulars.

This sub-class is considered the least suitable of class 2. The valley-bottoms are occasionally narrow, shorpl cut, and without gleysols, especially in the upstream sector of the river basins. Elsewhere, the soil having acric characteristics are difficult to fertilize with usual methods. The landscape is rather varied ; zones with slight slopes are followed by zones with steep slopes, and very narrow valley-bottoms are followed by broader ones. A semi-detailed study is needed to outline them more precisely.

The area that can be used for food crops varies from one site to another, but on the whole it is much smaller than in the preceding units.

5.1.3. Class of marginally suitable lands.

These lands are classed as marginally suitable because their use for a permanent agriculture in view of food crops can bring with a serious risks of erosion and a resulting loss of fertility. A great deal of management work would be necessary where this is possible.

This class covers 1,1175,700 hectares, or 52.8% of the map,

Sub-class S_3,l,t

Extension-localization.

159,990 ha - 7.2%. Many outcrops spread out on the map ; the largest are located around Tb Miri (62,500 ha) (1), Tb Jala (27,750), upper Kuhayan River basin (24,680) and west of Rantaupulut (19,800).

Correspondence - soil map.

Unit 16. These are humic ferralsols on basic rocks in a hillocky and dissected relief.

Major limitations.

They are the very low proportion of valley-bottoms and the steep slopes.

Particulars

The area of valley-bottoms with gleysols does not exceed 5% on the average. But small sectors, each covering a few thousand hectares, have a topography that is less hillocky and valley-bottoms that are larger ; for instance, the surroundings of some rock domes. The largest rivers are also locally bordered with alluvial banks from 100 to 200 meters in width. A detailed study would allow useful valley-bottoms and alluvial flats to be outlined.

This unit seems, in general, to be well-adapted for tree-crops with a grass cover. In this case, we can assume that the erosion hazards would be low to moderate.

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(1) Spreading to the north outside the map's boundaries.

Sub-class S3,t,e

Extension-distribution:

592,920 ha - 23.8%. This mapping unit is the most widely spread. It is divided into many outcrops dispersed throughout the map. The largest outcrops are localized in the basins of the Mentaya, the Katingan,and its tributary the Samba.

Correspondence -soil map

8 F-G,8 F-G,9 F-o,11 Fx11 Fx-o, 12 Fo, 13. These are xanthic, sometimes orthic, ferralsols on grained rocks which are acid to moderately acid, and on shales in a hummocky to hillocky area having narrow valley-bottoms with gleysols.

Major limitation.

The topography is the major limiting factor as the average slope is from 15 to 30% ; the another one is the erosion hazards due to the steep slopes.

Particulars.

This unit groups 2 types of land that are somewhat different even though the slopes are still steep and the valley-bottoms narrow. The one presents rectilineous or only slightly convex versants, narrow hill-tops and very few valley-bottoms with gleysols ;this is the usual landscape on shales and metamorphic rocks. The other presents convex versants with rounded summits and valley-bottoms that are narrow but more numerous and with flat bottoms : such is the case of the zones located on granites, granodorites, and diorites.

Any agriculture that favourizes a permanent vegetal cover is recommended in order to avoid the serious risks of erosion.

We shall also direct the attention of the users to the critical period between the clearing of the natural vegetation and the start of the soil covering by the plantations. If the soil remains uncovered or is badly protected during a seasonal cycle, extremely extensive damage could result from erosion on such steep slopes in several months. This risk will be even higher if the clearing was accomplished with the use of heavy machinery.

Sub-class S3n

Extension-location.

25,750 ha - 1.1%. Several outcrops of 1000 to 10,000 ha dispersed in the tertiary plain.

Correspondence - soil map

Units 5 F, 6 F. These are ferralsols on clayed or clayed-sand deposits in a rolling to undunlating landscape.

Major limitations.

The very low level of chemical fertility due to the quality of the parent material, and, locally, the steep slope in the lower half of the versants.

Particulars.

The loss of organic matter after clearing can lead to a degradation of the physical properties of the surface. In this case, erosion hazards will he high even on relatively slight slopes. A land management using trees crops and a grass cover would probably be the best way to manage these soils. But no matter use is considered, fertilization is the first priority.

Sub-class S_3,n,d.

Extension-localization.

460,700 ha - 20.7 %. Several large outcrops in the tertiary plain : near Bejarau, Sebadi, and Palankalanbanteng, in the west ; sectors of the Manuhing, the Rungan, and the Kahayan, in the east.

Correspondence - soil map.

5 A and 6 A. These are dominant acrisols on sandstone in an undulating, slightly dissected landscape.

Major limitations.

The very low level of chemical fertility and degradation hazards are the main constraints. Deficient drainage and its secondary effects are also limiting factors.

Particulars.

The valley-bottoms with gleysols are locally rather wide ; the erosion risks are there low to negligeable and the risks of degradation are limited due to the clayed to clayed-sand texture of the topsoil. They would be suitable for food crops under the same conditions as for the other gleysols. For the reasons given in the preceding chapters, it is preferable to keep the acrisols on the versants for perennial plantations. It would be desirable to perform field experimentations to determine the types of plants that would best adapt to these soils and the types of fertilization to adopt.

5.2. ORDER OF UNSUITABLE LANDS.

5.2.1. Class of currently unsuitable lands.

These lands are classified as "currently unsuitable" for 2 reasons which distinguish the two sub-classes.

Sub-class N.1.f

This class is unsuitable at present because the amount of work to be carried out in the near future for its management is very important and is not compatible with type of improvements adapted to the objective of the project whose priority is rainfed crops cultivation.

Extension-localization.

53,500 ha - 2.40 %. Lower alluvial valleys of the Seruyan, Seranau, Mentaya, Tualan and Cempaga rivers.

Correspondence-soil map.

Units 1 and 2. These are the gleysols and the histosols of the alluvial valleys that are flooded for long periods.

Major limitation.

The submersion of the soils by the river overflows.

Particulars

Controlling the water necessitates a great deal of work because the level of one part of the alluvial plains is lower than that of the high waters in the rivers that cross these plains. Improvements cannot be limited to any particular site but must be carried out on a larger scale, for instance, in the upper valley or on all the plain on one of the river banks. The major improvements to be planned would be :

- control the submersion caused by the overflow ;
- regulate the arrival of water from the tributaries that spreads out on to the plain at certain times of the years ;
- and to evacuate the excess water through drainage.

The fertility potential of these soils is without a doubt lower than that of the other alluvial soils in unit S2f. Tests crops of rice on unflooded gleysols, locally, produced very mediocre results. It would be helpful to know if the causes of this were edaphic.

Sub-class N1,t

This class is presently unsuitable because its management without very important improvements would cause excessively high risks of erosion that would be incompatible with the profit could be hoped for.

Extension-localization.

209,500 ha - 9.4% Numerous outcrops widely dispersed on the map.

Correspondence-soil map.

Units 7 A, 8Fp, 10, 11 Fx-R, 14,17.

Major limitation.

The very hilly and very dissected topography.

Particulars.

This unit groups together all the soil units whose average slopesis superior to 30%. These soils are sucepti-ble to a very severe risk of erosion if they are permanently cultivated. Their developement would require an enormous amount of work to limit the erosion as far as this is possible.

5.2.2 Class of permanently unsuitable lands.

These are lands considered as unsuitable for agriculture in this region.

Sub-class N2n, N2t

Extension-localization.

479,490 ha - 27.6%

Correspondence - soil map.

5 P, 7 P, 19, and 20.

Particulars.

This unit regroups two categories of soils ; the first (N2n) has a great number of physical, hydric, and chemical constraints ; these soils are above all podzols. The major limiting factor of the second (N2t) is the topography since the soils are located in mountainous areas or isolated rock domes whose average slopes are steeper than 45%.

LIST OF APPENDICES.

APPENDIX - 1 -.

DRAWING OF THE BASIC MAP_METHODOLOGY

Here is the methodology used to draw up the basic map used to report the agronomical, geographical and pedological data. To carry out the survey, we had available among the basic maps, topographic maps of the AMS, T503 and PIT series. The first field work has proved their inaccuracy enough to cause difficulties to survey and to report the data. The inaccuracy of these maps is only due to the lack of aerial photographs needed by the specialists to draw the topographic maps.

To make up for this lack of photos, we have decided to use the satellite imagery. These are images at 1/250.000 obtained by photographic enlargements from documents at 1/1.000.000 provided by NASA. These enlargements were made at ORSTOM Remote Sensing Laboratory in Paris.

Two types of landmarks are visible on these images : the hydrographical network, very clear in the channel 7 and the network of logging roads in the channel 5. This road network is often only temporary ; this is why we have chosen the hydrological network às the permanent landmark. The làtter is therefore to be considered as the frame of the basic map, on which all the data acquired on the field or interpreted from the imagery have been reported.

Outline the hydrological network (c.f. plan).

The surveyed area is circumscribed in a perimeter covered by 2 images located in the row 061, and the path 127 for the western part and in the row 061, the path 128 for the eastern part. Among all the images available from NASA, two of them were selected according to their low cloud covering: image n° E 81 048 02 073 of september 9 th 1972 and image n° E 81 355 133 of July 13 th 1973.

These two images present, on their eastern and western boundaries respectively, a common section where one can see the course of the Mentaya river running N - S and that of the Katingan river running E - W. These 2 rivers have been chosen as landmarks in order to put the two images into perspective with each other. The two adjusted images constitute the reference pattern of the basic map.

From this pattern, the hydrographic network which is visible to the naked eye or with the use of a magnifying glass have been reproduced according to the best possible conformity as to its outline and hierarchy. So, one can see on the map 5 rivers with their main tributaries. These rivers are : the Seruyan, the Mentaya, the Katingan, the Rungan and the Kahayan.

Thus, the main landmark network has been outlinedon the reference pattern.

Complementary outline of the hydrologic network.

Some parts of the network do not appear on the reference pattern due to the cloudiness. We have had therefore to complete, locally the outline of the waterways. For that, we used complementary satellite images positioned with respect to the landmarks on the reference pattern. These complementary images are :

- for the eastern, northeastern and southeastern parts :

E 81 102 02 081, 2 Nov. 1972,
E 81 138 02 082 8 Déc. 1972,
E 83 0589 01 544,15 oct. 1979.

- for the southern part :

E 81 372 02 080,30 July 1973,
E 81 444 02 061, 10 Oct. 1973,

- for the west and southwest part :

E 81 409 02 131,5 Sept. 1973,
E 83 0176 02 031,28 Aug. 1978,
E 83 0590 02 002,16 Oct. 1979.

A few supplementary images were examined to clarify particular points.

Outline of the hydrographic network when it is not well visible or invisible on the imagery.

It happens that the course of some tributaries is difficult or impossible to discern on the imagery.

Occasionally, one sees the general orientation of the river without being able to distinguish the exact outline of the meanders. In this case, the river is located with respect to the main hydrologic network outlined on the reference pattern, but the outline of the meanders is made up according to the data get on the field with a compass and a survey-tape.

It also happens that the river orientation itself is invisible. In such cases the river is located with more or less incertitude according to the topographic maps and the field data. This is the case of the upper Tualan, the upper Cempaga, and some sections of the Rungan basin.

Finally, when the river is invisible and without data got on the field, the river is drawn with dotted line.

Location of Topographic Positions.

It was not possible to report the outline of the latitudes and longitudes based on the available topographic maps due to distorsions between these maps and our basic map. We only reported one geographic point that could serve as a landmark : the intersection of 1°, 30' south latitude and 112°, 30' east longitude. This point is located around 16 kilometers west of Tb Kalang on the right bank of the Mentaya. It is shown on the map by a cross circumscribed inside a circle.

Conclusion .

We are aware of the relative precision of this basic map. It should be only considered as a temporary document, until accurate topographic maps become available. Until that time, it has the advantage to be conform with the most valid basic data we have, to be operational, and be sufficient to reach the objective of the stage 1 of the agreement.

We have described the methodology used to compile this map ; a permanent landmark (the hydrologic network) has been chosen and a geographic landmark drawn on the map. This should permit all our data to be reported on the future topographic maps when they will be available.

Remarks for use.

For a user having the satellite imagery, the hydrologic network on our basic map could present some apparent anomalies, especially in the lower course of the rivers with a lot of meanders. These anomalies can have several explanations.

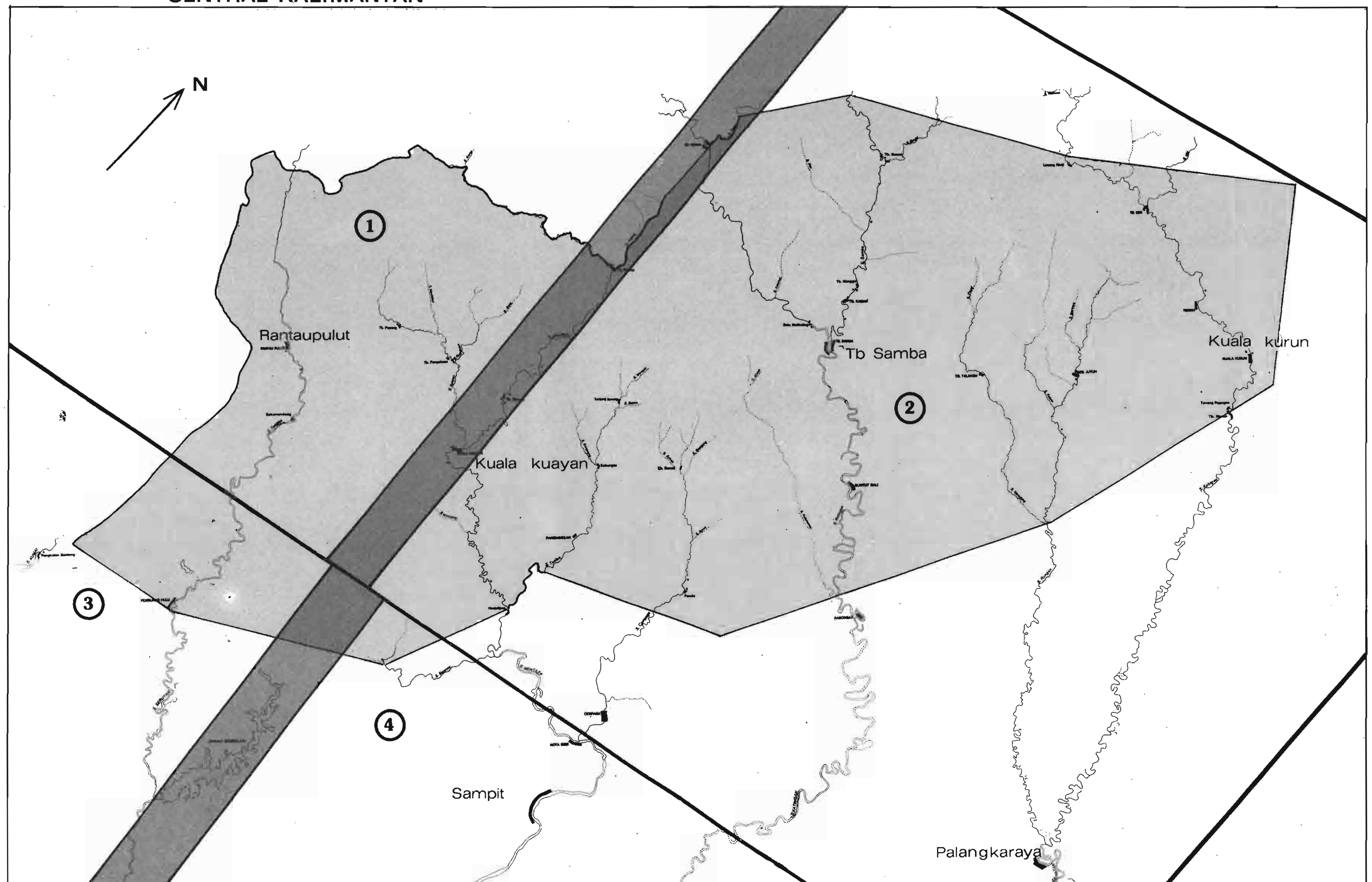
The outline of a meander might have changed over time ; the outline of a river and its width appears more or less clearly according to the level of water and the season or according to the tidal effect towards the downstream areas. Furthermore, the examination of an image in the channel 5 shows a nonfunctional meander in place of the real outline visible in the channel 7 of the same image.

The user should therefore refer precisely to the used channel and to the image used to outline our basic map.

D.J.T. - ORSTOM TRANSMIGRATION PROJECT DATA FOR THE BASIC MAP Reconnaissance soil map

P.T.A. - 44 REPORT

CENTRAL KALIMANTAN



SCALE 1:1 000 000

MOSAIC OF REFERENCE

1 satellite image n° E 81 355 02 133 13 july 1973 - NASA

2 satellite image n° E 81 048 02 073 09 september 1972 - NASA

COMPLEMENT

3 satellite image n° E 81 409 02 131 du 5 septembre 1973 - NASA

4 satellite image n° E 83 0229 01 575 du 28 octobre 1978 - NASA

OVERLAP of images

survey boundary

satellite image boundary

D.J.T. - ORSTOM TRANSMIGRATION PROJECT

P.T.A. - 44

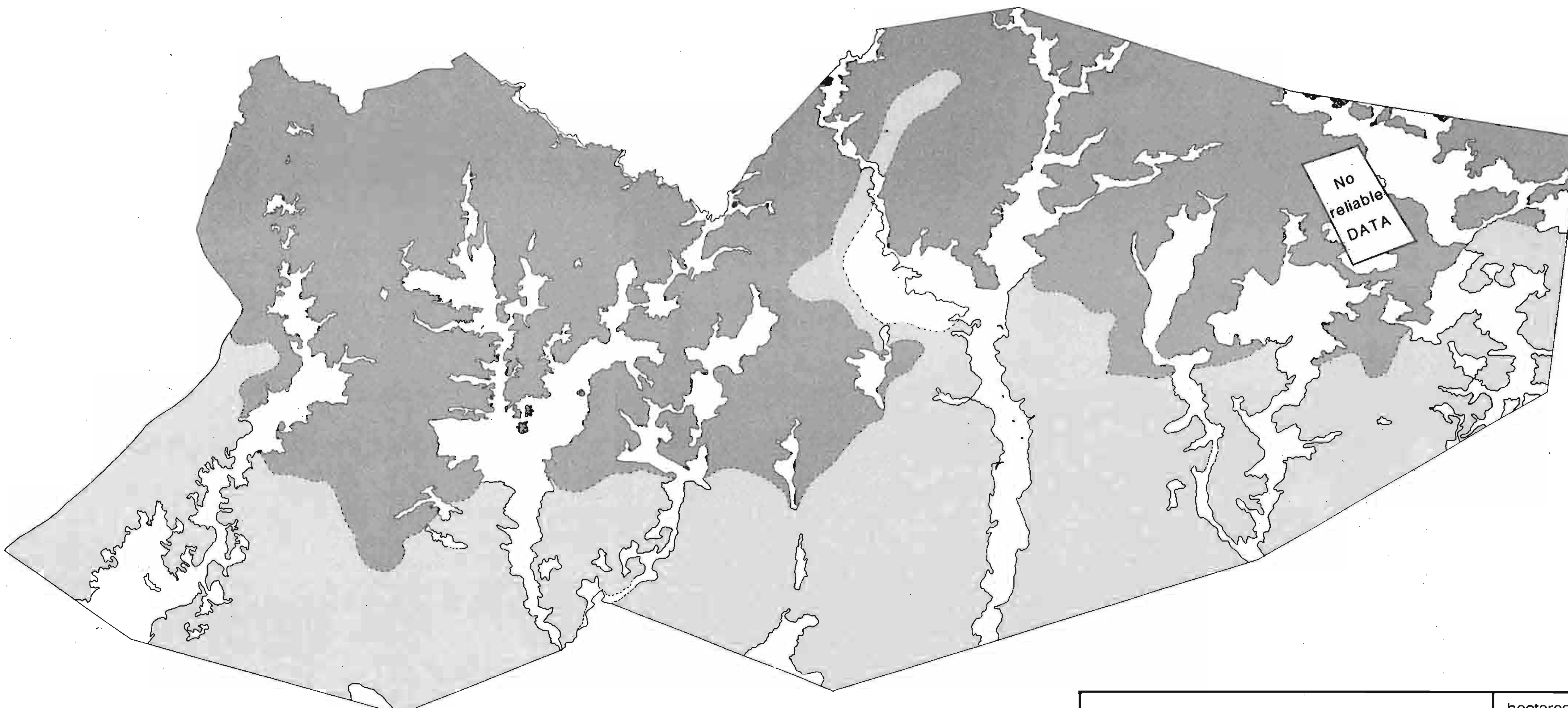
CENTRAL KALIMANTAN

VEGETATION TYPES AND REPARTITION

Reconnaissance soil map

REPORT

APPENDIX 2



SOURCE : visual interpretation of NASA satellite imagery and field work.

SCALE 1 : 750 000

drawn by : **P. BRABANT - T. BUDIANTO**

		hectares	%
PRIMARY FOREST	DIPTEROCARP FOREST	920.000	41
	HEATH FOREST	820.000	37
CLEARED FOREST	under shifting cultivation plantation, fallow brushwood secondary regrowth	462.500	21
NO RELIABLE DATA		22.500	1

D.J.T. - ORSTOM TRANSMIGRATION PROJECT

P.T.A. - 44

CENTRAL KALIMANTAN

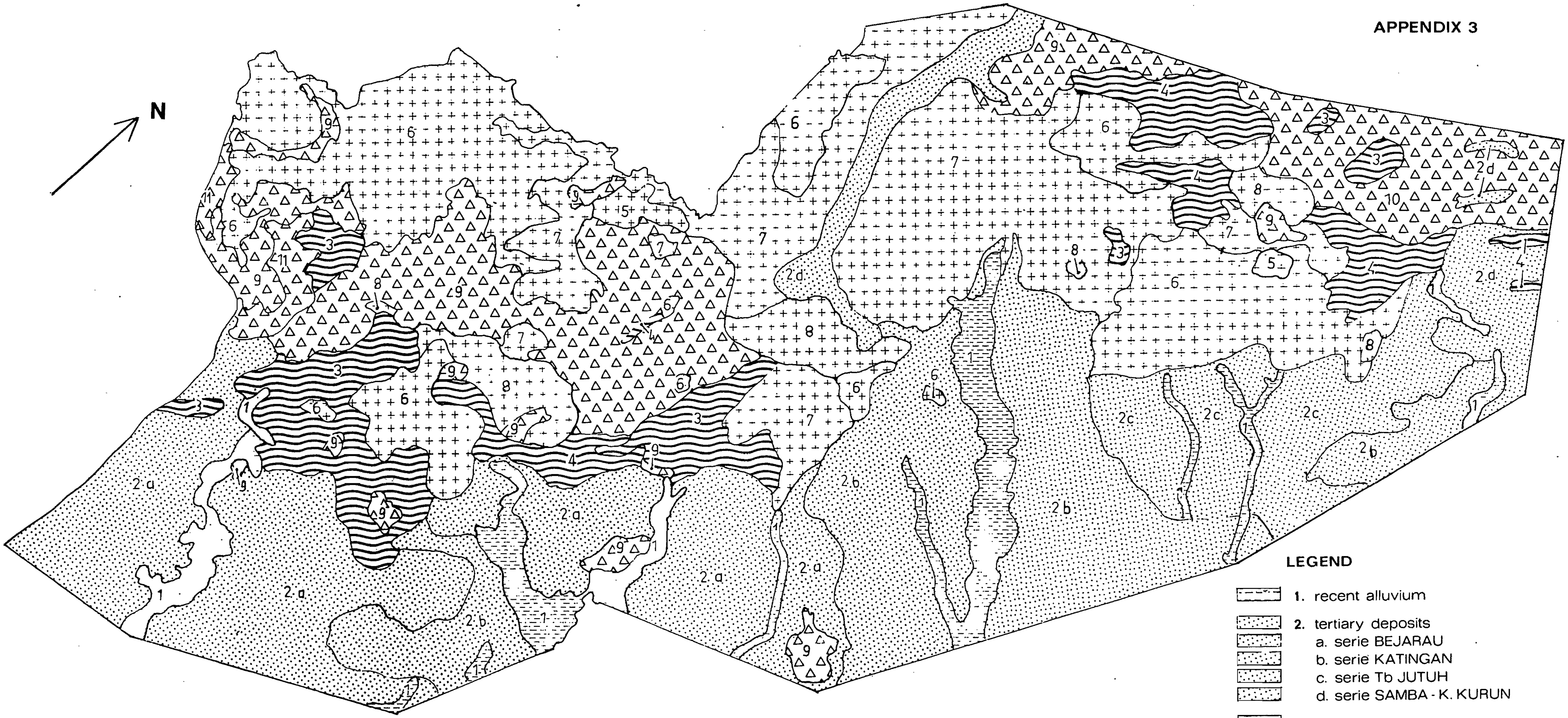
SKETCH MAP OF GEOLOGY AND PARENT MATERIALS

SCALE 1 : 750 000

Reconnaissance soil map

REPORT

APPENDIX 3



LEGEND

1. recent alluvium
2. tertiary deposits
   a. serie BEJARAU
   b. serie KATINGAN
   c. serie Tb JUTUH
   d. serie SAMBA - K. KURUN
3. shales
4. indifferenciated metamorphic rocks
5. alkali granite
6. orthogranite
7. granite with biotite and amphibole
8. diorite and gabbro
9. basalt, andesite
10. basalt, andesite mixed with volcano-sedimentary
11. rhyolite, tuff rhyolitic

Drawn by : **P. BRABANT**

compilation and field survey :

S. BACHRI *, P. BRABANT **, T. BUDIANTO *, K. JUANDA *, D. MULLER **, SAMBAS *, G. SIEFFERMAN **, HJ. SUMULJADI *, E. SUPARMA *.

Mission ORSTOM INDONESIA
CENTRE FOR SOIL RESEARCH BOGOR

Sources : - field survey
- geologic map of west and southwest Kalimantan quadrangle-scale 1 : 500 000 Directorat Geologi - 1970
- Tewah quadrangle, Central Kalimantan A. SUDRADJAT, 1976, scale 1 : 250 000

D.J.T. - ORSTOM TRANSMIGRATION PROJECT

P.T.A. - 44

CENTRAL KALIMANTAN

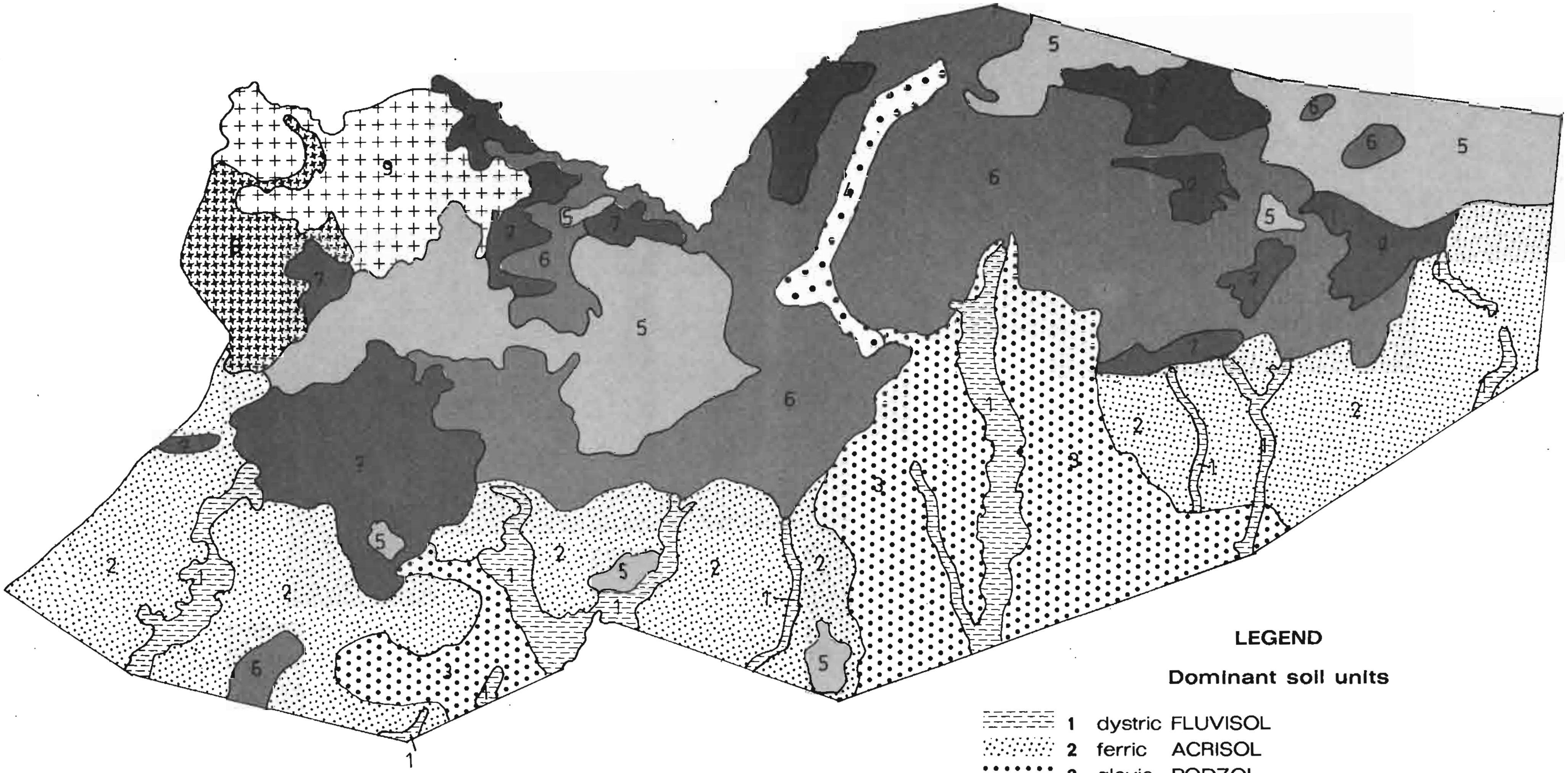
GENERAL REPARTITION OF THE SOILS

SCALE 1:1 000 000

Reconnaissance soil map

REPORT

APPENDIX 4



LEGEND

Dominant soil units

1 dystric FLUVISOL
2 ferric ACRISOL
3 gleyic PODZOL
4 orthic PODZOL
5 humic FERRALSOL
6 orthic-xanthic FERRALSOL
7 xanthic FERRALSOL
8 humic FERRALSOL - dystric REGOSOL
9 xanthic FERRALSOL - dystric REGOSOL

Source : Reconnaissance soil map 1: 250 000
DJT-ORSTOM-1981

A P P E N D I X 5

METHODS

1. - CHEMICAL ANALYSIS.

TOTAL ORGANIC CARBON.

Method ; acid potassium bichromate digestion ; colour is measured by colorimetry.

TOTAL NITROGEN.

KJELDAHL method ; sulfuric acid digestion with selenium as catalyser and distillation of ammonia.

EXCHANGE CAPACITY.

Leaching by 1N ammonium acetate at pH 7.0. displacement and distillation of absorbed ammonium.

EXCHANGEABLE BASES.

Leaching by 1 N ammonium acetate at pH 7,0 ; Ca and Mg measured with AAS, and Na by flame photometer.

pH DETERMINATION.

pH measured by a glass electrode using a RADIOMETER pH meter.

pH H 20 : ratio soil/water 1/1.

pH Kcl : ratio soil/Kcl 1/1.

P_2O_5 Hcl.

Extraction by Hcl 25% at room temperature ; P determined by molybdenum method and measured by colorimetry.

K_2O Hcl.

Extraction by Hcl 25% ; K measured by flame photometer.

TOTAL BASES.

Extraction by HNO_3 13 N ; Ca and Mg measured by AAS, K and Na by flame photometer.

2. - PHYSICAL ANALYSIS.

MECHANICAL ANALYSIS.

According to the pipette method ; digestion of organic matter by H_2O_2 ; dispersion using sodium pyrophosphate.

BULK DENSITY.

Sampling on the field using cylinder method ; capacity cylinder : 125 CC3.

PARTICLE DENSITY.

Using pycnometer method.

WATER CAPACITY.

at pF 2,5 : pressure plate extractor. ;

at pF 4,2 : pressure place extractor .

3.- MINERALOGICAL ANALYSIS.

C.G.R. diffractometer using Co anti-cathode ; rotation speed 10°/minute ; pretreatments : orientated powder, desorientated powder, heating, glycerol.

MICROELEMENTS.

By spectrography of the sample dry extract.

4. - METHODS FOR FIELD DESCRIPTION.

Soil profiles are described according to the "Glossaire de Pédologie" ORSTOM PARIS 1967.

Coloursare described according to MUNSELL color charts.

For horizon designations, we use the symbols defined by FAO.

D.J.T. -- ORSTOM TRANSMIGRATION PROJECT
PTA – 44
CENTRAL KALIMANTAN

ANALYTICAL DATA (1)

Reconnaissance soil map
REPORT
APPENDIX 6

Soil type	(2) depth	(3) texture	(4) clay %	pH H2O	pH KCL	C ‰	N ‰	C/N	(5) CEC meq	exch. bases meq	exch. AL meq	(6) P.C. meq	Base satur. %	(7) Al satur. %	mineral reserves: P2O5 Hcl ppm	mineral reserves: P2O5 HNO3 ppm	mineral reserves: K2O Hcl ppm	mineral reserves: K2O HNO3 ppm	total bases meq	microelements: Cu ppm	microelements: Mn ppm	microelements: Mo ppm	microelements: Zn ppm	bulk density	Clay mineralogy
humic FERRALSOL	T S	C	56	4.3	3.5	39	3.0	13	18	1.4	3.5	4.9	<10	71	320	950	100 (9) 260(10)	400 (9) 1700(10)	7.5	15	230	<10	60	0.85	metahalloysite, kaolinite locally
	S S	C	65	5.2	4.2	5.7	0.60	–	8	0.6	2.0	2.6	<10	77	60	350	20 (9) 100(10)	250 (9) 1200(10)	11	10	190	< 5	75	1.15	gibbsite inter.2/1, goethite (35%)(12)
humic FERRALSOL acric type	T S	H C	75	3.9	3.8	31.6	2.1	15	14.5	0.4	2.6	3.0	< 5	86	130	670	90	300	7	–	–	–	–	0.90	kaolinite
	S S	H C	80	4.7	4.4	6.3	0.60	–	4.5	0.2	0.3	0.5	< 5	60	60	360	20	250	7					1.15	gibbsite, goethite
orthic FERRALSOL gran. (8)	T S	SaCL	80	4.3	3.5	25.8	1.8	14	8	1.1	1.3	2.4	<15	54	200	250	100	2000	10-15	<10	80	< 2	70	0.9-1.0	fire-clay, inter. 2/1 (10-20 %), goethite, quartz — on granodiorite
orthic FERRALSOL shale	T S	C	46						13		6.0	7.1	<10	85				10000	15-35						
orthic FERRALSOL gran. (8)	S S	SaC to C	50	5.1	4.0	4.6	0.40	–	7	0.6	2.3	2.9	<10	80	50	150	30	3000	8-12	<10	80	< 2	70	1.30	kaolinite, inter. 2/1 (50 %), illite, goethite, quartz — on shale
orthic FERRALSOL shale	S S	SiC	46						9		4.7	5.3	10	88				7000							
xanthic FERRALSOL	T S	SaCL	32	4.3	3.5	20.0	1.3	15	8	0.8	2.5	3.3	10	75	150	200	150	1500	8	15	40	< 2	15-30	1.10	fire-clay goethite, inter. 2/1 (10-15 %)
	S S	SC to C	45	5.1	4.1	2.9	0.30		5	0.4	1.9	2.3	<10	82	50	80	20	2000	9					1.35	quartz
FERRALSOL on claystone	T S	C	58	4.0	3.4	29	1.9	15	12	1.0	6.0	7.0	<10	86	150	350	200	1000	4	2	50	< 5	< 60	–	fire clay goethite, inter. 2/1 (5-10 %)
	S S	C	62	5.2	4.0	4.0	0.45		8	0.5	4.0	4.5	<10	88	30	60	20	700	5	3	90	< 5	<60	–	quartz, gibbsite
Ferric ACRISOL on sandstone	T S	SaL to Lsa	18	4.5	3.5	23	1.2	19	7	0.5	2.0	2.5	<10	80	–	100	60	300	var.(11) 5-40	5	40 to 180	4	11	1.0	kaolinite, gibbsite, quartz
	S S	SaCL	30	5.0	4.0	2.9	0.20		3.5	0.2	2.0	2.2	<10	90	–	10	20	400						1.6	goethite
orthic PODZOL	T S	Sa	<10	3.6	2.6	60 to 90	2.5 to 4.5	20 to 35	20 to 70	1.3	0.2	1.5	<10	13	150	600	60	100	6	–	–	–	–	–	–
	S S	Sa	<10	4.4	3.8	34 to 86	0.70		var.(11)	0.6	3.0	3.6	<10	83	30	80	20	20							
dystric GLEYSOL	T S	SaCL to CL	20-45	4.7	4.0	34.5	2.0	17	12	1.5	1.7	3.2	<15	53	200	800	120	500	–	–	–	–	–	–	fire clay, inter. 2/1 (15 %)
	S S	SaCl to C	25-50	4.9	3.9	2.9	0.30		8	1.0	2.0	3.0	<15	86	30	800	30	–	–	–	–	–	–	–	quartz
humic GLEYSOL	T S	C	50	5.0	4.1	74.5	4.6	16	30	1.5	2.5	4.0	5	62	600	–	300	–	–	–	–	–	–	–	–
	S S	C	50	5.2	3.9	–	0.30		10	1.0	2.0	3.0	10	66	200	–	150	–	–	–	–	–	–	–	–
dystric FLUVISOL	T S	CL to SiC	35-55	4.8	3.8	34 to 57	2.8 to 5.0	12	10 to 20	1.5	4.0	5.5	10-15	72	600	–	350	–	5 to 20	–	–	–	–	1.0	fire-clay, inter. 2/1, chlorite, illite (50 %)
	S S	CL to SiC	35-55	5.0	3.8	2.9	0.30		8	0.9	3.0	3.9	10	77	130	–	50	–	5 to 20	–	–	–	–	1.4	quartz
dystric CAMBISOL	T S	SiC	41	4.8	3.8	29	2.6	11	20	2.6	2.5	5.1	13	49	350	–	700	–	20						illite, inter. 2/1 (60 %)
	S S	SiCL	30	5.6	4.1	4.6	0.40		8	2.7	1.2	3.9	34	30	700	–	1000	–	20	–	–	–	–	–	kaolinite, quartz, goethite
Ferralic CAMBISOL	T S	SaC	42	4.9	4.1	46	4.2	11	24	2.3	3.0	5.3	10	56	200	–	200	–	–	–	–	–	–	–	–
	S S	C	45	5.3	4.1	2.9	0.30		10	1.2	3.0	4.2	12	71	60	–	50	–	–	–	–	–	–	–	–
humic CAMBISOL	T S	H C	72	4.9	3.7	54.5	3.9	14	37	0.8	17	17.8	< 5	95	–	330	–	500	20	–	–	–	–	0.88	–
	S S	H C	80	5.2	3.9	14.5	1.3		32	0.3	19	19.3	< 5	98	–	145	–	400	22	–	–	–	–	1.12	–
RANKER	T S	–	47	3.0	1.6	344	11.5	30	82	1.6	4.4	6.0	< 5	73	–	480	–	500	7	15	11	< 2	14	–	–

(1) others analytical data are given in the legend of map of land suitability
(2) TS : topsoil, SS : subsoil
(3) using USDA modified CER DIAGRAM
(4) clay content in 100 g of fine earth without organic matter and water
(5) meq : meq for 100 g of fine earth
(6) P.C. : permanent charge : exch. bases+exch. Al.
(7) Al sat. : exch. Al/PC in %
(8) granodiorite and diorite
(9) Ferralsol on basalt, andesite
(10) Ferralsol on rhyolite
(11) variable with organic matter content
(12) interstratified 2/1 minerals : illite-vermiculite and chlorite-vermiculite with vermiculite dominant

Key for texture :

HC heavy clay
C clay
CL clay loam
SiC silty clay
SiCL silty clay loam
SaCL sandy clay loam
SaC sandy clay
SaL sandy loam
LSa loamy sand
Sa sandy

RECONNAISSANCE SOIL MAP

SOIL MAPPING UNITS - ACREAGE AND PERCENTAGE

MAPPING UNIT	SUB UNIT	ACREAGE hectares	ACREAGE percent	
1		15.180	0.68	histosols and alluvial soils 5.3 %
2		42.470	1.9	
3		23.590	1.0	
4		38.340	1.7	
5	5 P 5 A 5 F	332.900 380.480 14.500	15.0 17.1 0.65	area with acrisols and podzols dominant 42.4 %
6	6 A 6 F	125.430 12.800	5.6 0.55	
7	7 P 7 A	28.590 48.220	1.3 2.2	
8	F-G F O F P	6.250 97.970 2.750	0.28 4.4 0.12	area with ferralsols dominant 47.6 %
9	F-G F O F X	5.370 14.680 69.310	0.24 0.66 3.1	
10		10.880	0.48	
11	F X FX-O FX-R	61.120 66.100 67.300	2.7 2.9 3.0	
12	F-G F O	79.440 167.290	3.6 7.5	
13		77.340	3.5	
14		17.620	0.80	
15		7.680	0.32	
16		161.430	7.2	
17		12.500	0.61	
18	F-G F h	80.100 58.690	3.6 2.6	
19		8.230	0.37	soils of mountainous areas 4.7 %
20		96.480	4.3	

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