DIREKTORAT JENDERAL TRANSMIGRASI
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SCIENTIFIQUE ET TECHNIQUE OUTRE-MER
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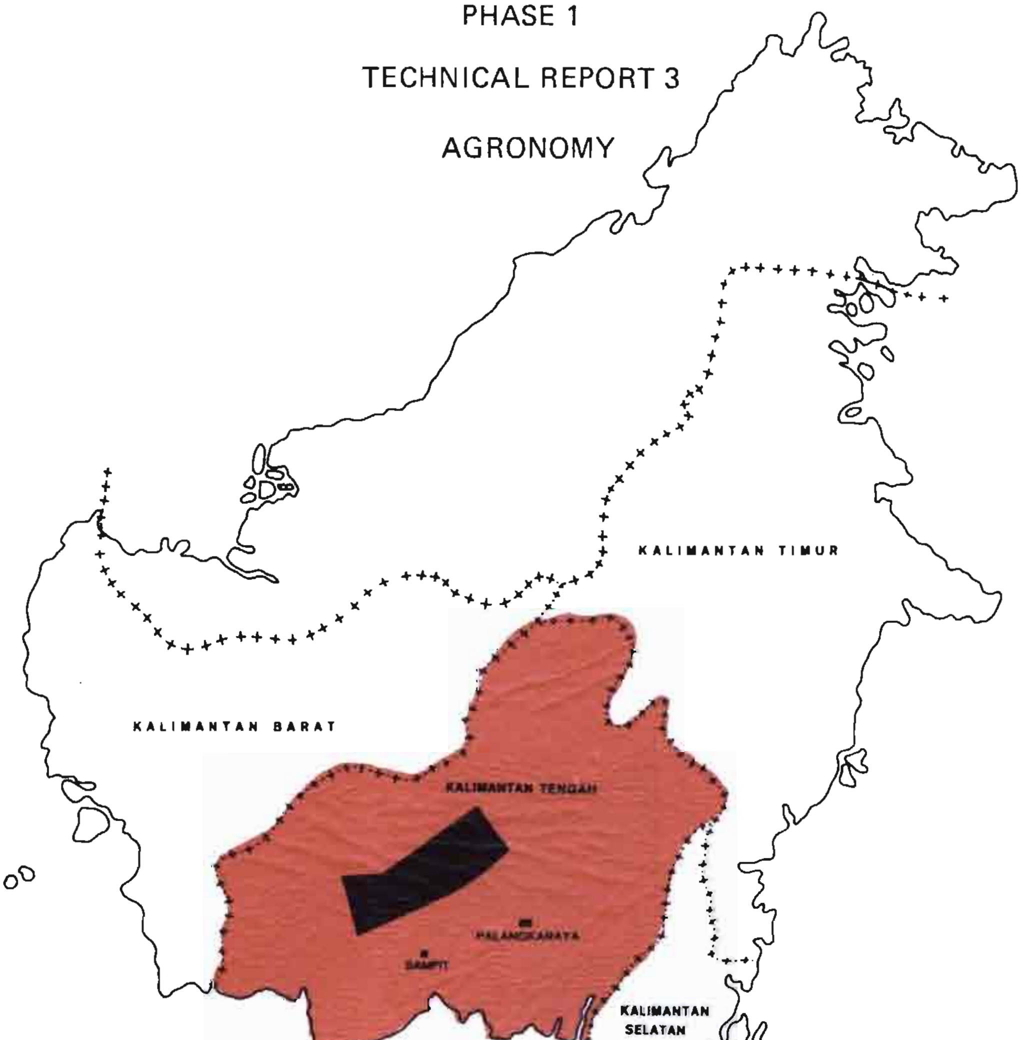
- SURVAI TINJAU DI PROPINSI KALIMANTAN TENGAH
- ETUDES DE RECONNAISSANCE DANS KALIMANTAN CENTRE
- RECONNAISSANCE SURVEY IN CENTRAL KALIMANTAN

PHASE 1

TECHNICAL REPORT 3

AGRONOMY



INDONESIA - ORSTOM TRANSMIGRATION PROJECT (PTA-44)

JAKARTA - 1981

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(Republique Francaise)

SURVAI TINJAU DI PROPINSI KALIMANTAN TENGAH

RECONNAISSANCE SURVEY IN CENTRAL KALIMANTAN

PHASE 1

TECHNICAL REPORT 3

AGRONOMY

P. LEVANG
Ir. SUDIRMAN.S
Ir. R. MARTEN

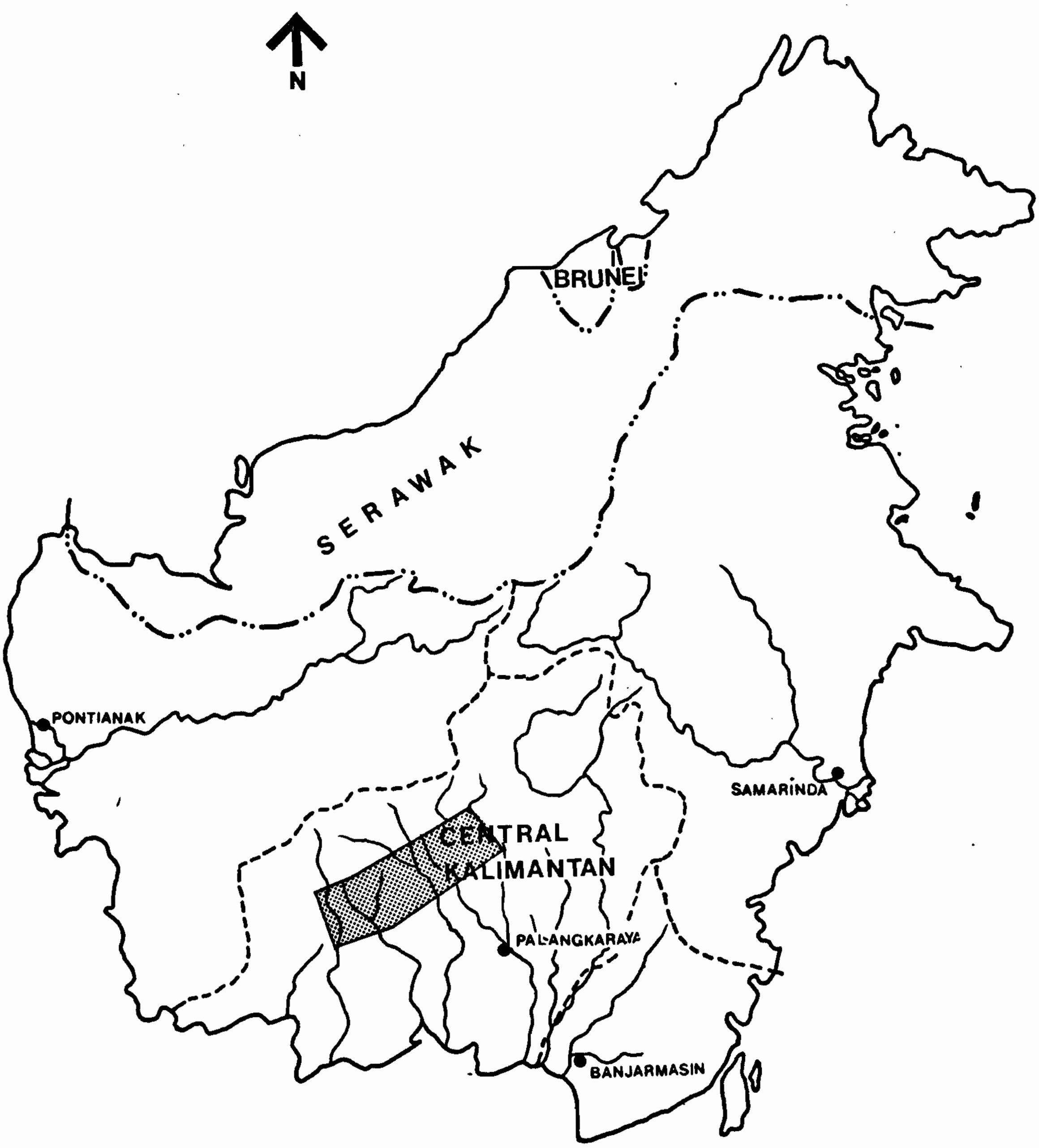
INDONESIA - ORSTOM TRANSMIGRATION PROJECT PTA-44

JAKARTA, DECEMBER 1981

SUMMARY

LOCALIZATION OF THE STUDY AREA

Project ORSTOM - TRANSMIGRATION PTA - 44



Study area

Scale : 1 / 7.460.000

INTRODUCTION

This report is the agronomist's contribution to a reconnaissance study made by a multidisciplinary research team from ORSTOM, in Kalimantan Tengah (Indonesia) from 1979 - 1981.

This study was carried out in the framework of an agreement signed by the Indonesian Ministry of Transmigration and ORSTOM. The aim of the research undertaken was the delimitation of sites suitable for agricultural settlements, in the framework of Transmigration.

In order to achieve this, a preliminary survey (phase I) had to be undertaken over a part of the province of Kalimantan Tengah covering more than 2 million hectares (cf. map introducing the area). The results acquired have given rise to specific reports (pedological, geographical, agronomical) and have led to a final report of phase I.

In another connection, all the cartographical documents that have been drawn up (soil map, land suitability map, areas under shifting cultivation, ethnical and religious groups, etc.) have been put together in an atlas.

In this preliminary phase, we have limited ourselves to making a census of the main agronomical problems linked to the climate, to the soils and requirements of various tropical crops.

Later more detailled studies will be undertaken on the sites under consideration by the transmigration authorities.

CHAPTER 1

CLIMATE

AGRONOMICAL PROBLEMS LINKED TO CLIMATIC CHARACTERISTICS

The general description of the climate is presented in the final report of the end of Phase I as well as on a sheet of the Atlas. In this chapter we mainly discuss the agronomic problems linked to the various climatic characteristics.

It should be remembered that there are very few meteorological stations in Central Kalimantan. The only available data concern the rainfall and its reliability is more often than not doubtful. The years of observation are rarely complete, the readings not always daily, the equipment often defective and the locations sometimes surprising.

This is why we rely mainly on the readings carried out by the Agricultural School of Tumbang Lahang (PLPP - GKE, Tumbang Lahang) and kindly given to us by the authorities. These reliable data unfortunately only cover fifteen complete years. In addition, the Tumbang Lahang station is situated in the centre of the study area, which makes it representative of a mean value according to the orography.

1. Temperatures

The temperatures are remarkably stable throughout the year. The average mean temperature is 27 $^{\circ}$C, and the difference between the monthly average of the "coldest" and "hottest" months is about 1 $^{\circ}$C. The highest daily temperature registered has been 35 $^{\circ}$C and the lowest 22 $^{\circ}$C.

The daily variations are about 6 $^{\circ}$C. There is consequently no problem of temperature for the tropical crops. The temperatures are always well above the temperatures of zero growth and below the maximum temperatures tolerated.

2. Sunshine

No correct measurement of sunshine is available at present in Kalimantan Tengah. According to the agronomists of Tumbang Lahang, however, it does not appear that sunshine is a limiting factor. Our own experience brings us to the same conclusion: the days are generally very sunny and 78% of the rains are nocturnal.

There should not, therefore, be a problem of sunshine even for demanding crops such as oil palm and coconut. We should exceed the 2000 annual sunshine hours (5 to 6 hours/day on average).

3. Hygrometry

No measurement of the hygrometric state of the air is available but the relative humidity remains high and clearly will not go down below 80% (estimate).

This is consequently very favourable not only to the growth of tropical plants but also to the development of parasites and cryptogamic diseases. In this climate phyto-sanitary problems are particularly acute for crops such as cocoa for example.

4. Winds

No measurement is available regarding the strength or dominant direction of the winds. However, following enquiries amongst the inhabitants, we have established that strong winds are very infrequent, storms and cyclones non-existant. It is rare that an isolated tree is uprooted, the limbs of the banana tree leaves are rarely torn contrary to what can be seen in areas where there are violent winds.

5. Evaporation

To our knowledge there is no measuring tank for evaporation in Kalimantan Tengah, neither evaporometers. Without data on wind speed, insolation or evaporation it is impossible for us to calculate the monthly PET. In relatively similar climates, the values normally used in Indonesia are 1300 to 1400 mm of PET annually; that is 110 to 120 mm PET monthly, given the stability of the temperature.

6. Rainfall

The rainfall is the only climatic factor for which we have sufficient information.

6.1. An always high annual rainfall

The annual average over the 15 last years is 3.527 mm with extremes of 2.366 mm and 4.793 mm. The variation coefficient ($\frac{\text{standard deviation}}{\text{average}}$) is of about 19%. The number of rainy days is between 80 and 236 with an average of 198 days a year.

Let us now consider the terms of the water balance P = R + D + RET + DS (where P represents the rainfall, R the run-off, D the drainage, RET the real evapo transpiration and DS the variation of the water stock in the soils).

In spite of the heavy rainfall the run-off is very low, around 100 to 200 mm annually, the vegetal cover ensuring a good protection. For the RET we have taken, as a first approximation the PET value : 1300 mm and for DS 100 mm. The result is that the drainage value D is around 2000 mm.

The consequences on the importance of leaching are evident on these soils formed on very ancient parent material. In fact (cf soils) the nutritional level of all the soils in Kalimantan is very low. The saturation rates of exchangeable bases rarely reach 10%.

But if the water run-off is very low in the forest or even on the ladangs (fields under shifting cultivation) of the autochtons it will not be the same on the plots of transmigrants dedicated to a more intensive cultivation involving soil work. Erosion hazard is very high as the rains are abundant and very heavy.

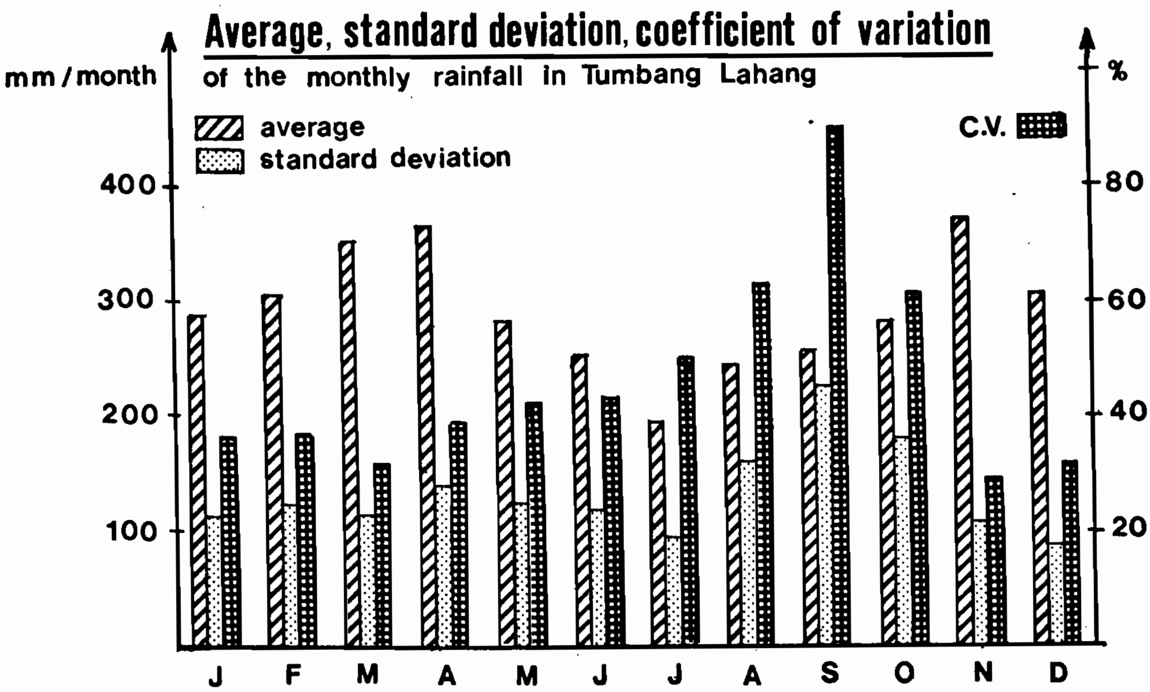
6.2. High inter annual variations of the monthly rainfall

The annual rainfall is very stable as extreme years are very rare. The variation coefficient of the annual rainfall is only 19%.

The average monthly rainfall varies from 197 mm in July to 371 mm in November.

Under these conditions it is difficult to understand that a drought period of 30 consecutive days can occur, as in January 1981, and destroy 80% of the upland rice harvest. The monthly averages do not in any way take into account a large inter annual variation of the monthly rainfall.

In the last line of table No. 1 we have calculated the variation coefficients (C.V.) for each month. We show them on the diagram below :



MONTHLY RAINFALL IN TUMBANG LAHANG

In mm of rain per month from 1966 to 1980

Table 1.

Year	Month: J	F	M	A	M	J	J	A	S	O	N	D	Total of the year
1966	160	277	242	463	190	358	246	606	94	321	227	354	3538
1967	316	298	287	448	529	290	222	67	28	115	290	251	3141
1968	202	42	589	324	219	272	212	277	129	256	417	518	3457
1969	308	285	442	309	512	171	146	183	83	318	478	179	3416
1970	342	337	477	337	352	406	282	247	607	519	414	248	4568
1971	350	248	251	184	242	135	126	563	513	330	252	217	3411
1972	382	481	272	498	224	130	18	146	2	53	518	256	3000
1973	431	452	410	507	290	488	434	342	610	212	270	347	4793
1974	53	537	463	510	368	167	218	290	609	199	378	283	4075
1975	424	329	308	690	441	378	289	174	336	589	347	212	4517
1976	179	174	285	292	159	110	239	90	23	679	513	293	3036
1977	266	355	177	282	129	190	64	144	89	159	210	291	2356
1978	268	278	327	198	196	150	168	199	272	234	332	495	3117
1979	475	236	463	300	240	359	163	55	375	81	546	292	3585
1980	266	290	293	165	183	211	122	314	31	269	376	374	2894
Average	295	308	352	367	286	254	197	247	253	289	371	307	3527
Standard - deviation	110	117	110	142	122	115	97	157	228	176	106	94	664
Coefficient of variation in %	37	38	31	39	43	45	50	64	90	61	28	31	19

FREQUENTIAL ANALYSIS OF THE RAINFALL

TABLE : 2

Over 15 years of observation in Tumbang Lahang

J	F	M	A	M	J	J	A	S	O	N	D
475	537	589	690	529	488	434	606	610	679	546	518
431	481	477	510	512	406	289	563	609	589	518	495
424	452	463	507	441	378	282	342	607	519	531	374
382	355	463	498	368	359	246	314	513	330	478	354
350	337	442	463	352	358	239	290	375	321	417	347
342	329	410	448	290	290	222	277	336	318	414	297
316	298	327	337	244	272	218	247	272	269	378	292
308	290	308	324	242	211	212	199	129	256	376	291
268	285	293	309	240	190	168	185	94	234	347	283
266	278	287	300	219	171	162	174	89	212	332	256
266	277	285	292	196	167	146	146	83	199	290	251
202	248	272	282	190	150	126	144	31	159	270	248
179	236	251	198	183	135	122	90	28	115	252	217
160	174	242	184	159	130	64	67	23	81	227	212
53	42	177	165	129	110	18	55	2	53	210	179

$\bar{x}$	295	308	352	367	286	254	197	247	253	289	371	307
s	110	117	110	142	122	115	97	157	228	176	106	94
CV	37	38	31	39	43	45	50	64	90	61	28	31

Source : PLPP - GKE Tumbang Lahang Kalimantan Tengah

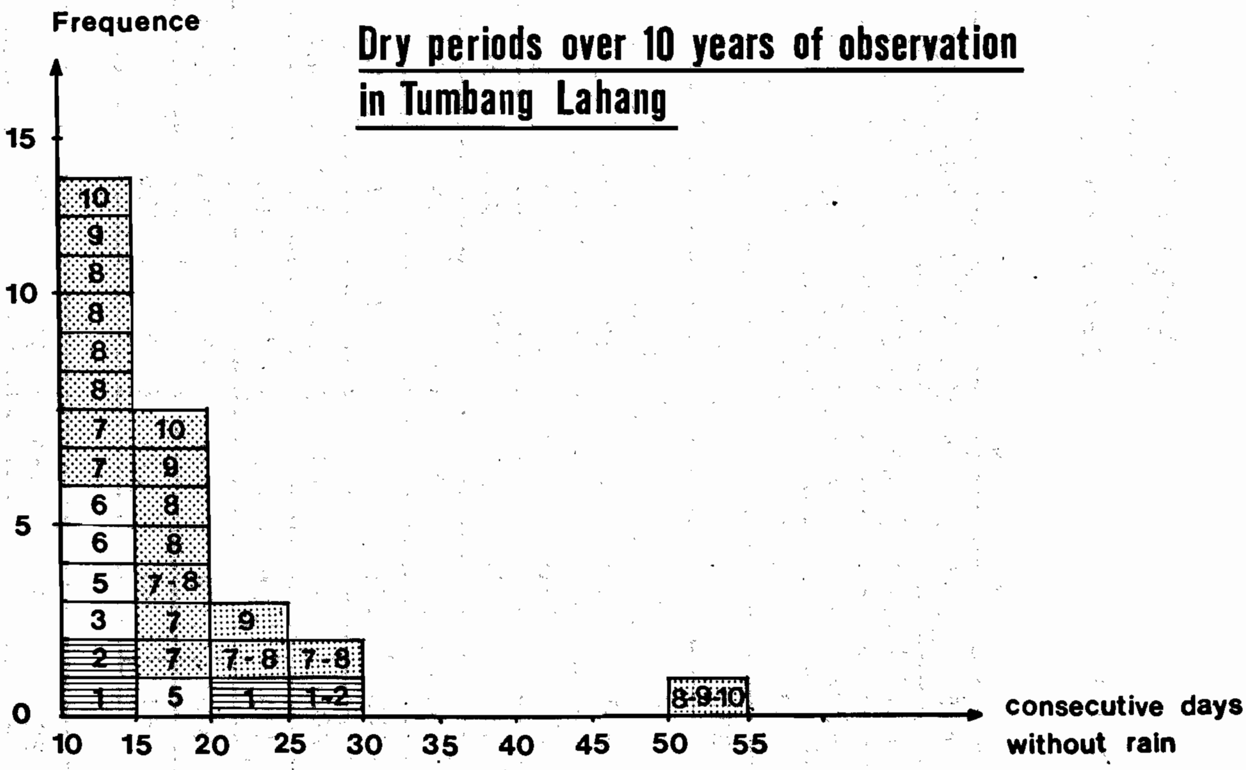
The months from November to June have a slight inter annual variability, they are well watered (300 to 350 mm on average) and extreme values are rare.

From July to October the variabilities are high with a summit of 90% for the month of September. The averages vary from 200 to 300 mm, but the extreme values are numerous. The month of September is either very wet (more than 300 mm, 6 years out of 15) either lacking rain (less than 100 mm, 7 years out of 15).

On table No. 2 the monthly rainfall of the last 15 years have been ranked. The deficient months occur between July and October with a higher frequence in September. However, once in 15 times January or February can also be deficient. Two consecutive deficient months have only appeared 3 times (1967, 1972, 1976) in the last 15 years. Under these conditions there is no real dry season but a seasonal dry period hazard.

6.3. Reduced risks of drought

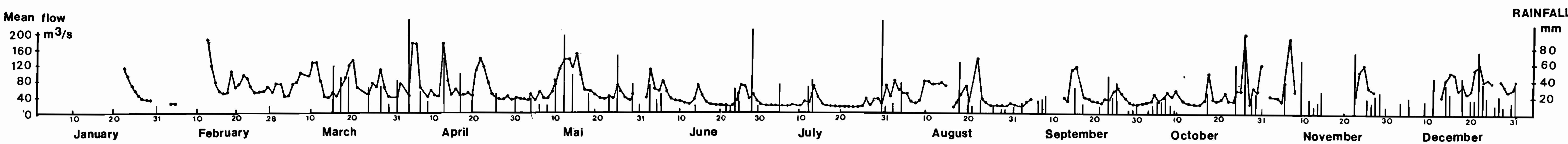
If it is clear that for the perennial crops we would never have problems of water deficiency, it is not the same in the case of the annual crops. Using the daily rainfall data of the last 10 years, we have been able to note the frequency of periods of over 10 days without rain. They are shown in the diagram below. The figures inside the squares correspond to the date (month's number) of the period in question.



Dry periods over 10 years of observation in Tumbang Lahang

Graphic : 3

TUMBANG JUTUH (RUNGAN RIVER) - DAILY MEAN FLOW AND DAILY RAINFALL



SOURCE : DPMA BANDUNG - LEMBAGA METEOROLOGI DAN GEOFISIKA - JAKARTA

(data collected by D. MULLER and R. MARTEN)

P. LEVANG - O. SEVIN - SUDARMADJI

ORSTOM - TRANSMIGRASI June 1981

In 10 years, 28 periods of drought of over 10 days occured. Certain years such as 1972 or 1976 had respectively 5 and 6 dry periods, others such as 1970 had none.

The implications on the adjustment of cultural cycles are immediate. In the Dayak's shifting cultivation system, the most crucial moment is that of the drying of the felled trees and the burning. The better the quality of the burning, the higher the quantity of ashes - thus of fertilizer - the better the harvest. It is not surprising under these conditions that the traditional period of burning is around end of September. Every other time the burning will be of a bad quality and the following harvest mediocre. From this angle the crop system would be rather badly adapted..

We have already pointed out that September is either deficient (7 times out of 15) or frankly excessive (6 times out of 15), the average amounts being rare. For the annual crops of the transmigrants, it is important to determine the optimal sowing dates in order to avoid that a sensitive period for the crops falls between the months of July to October.

6.4. Generally heavy rains

From the daily data (one reading in the morning and another in the evening) we have classified the rains in order of importance :

small rains from 1 to 5 mm
medium rains from 5 to 20 mm
heavy rains more than 20 mm

- 6.6% of the annual average rainfall is of rains less than 5 mm
- 27.4% is due to medium rains
- 66% is due to heavy rains

On the other hand 46% of the rains (in number) are inferior to 5 mm, 30.6% of the rains are medium and 23.4% are heavy.

On diagram 3 we have shown the daily rainfall and the daily mean flow of the river Rungan in Tumbang Jutuh. Because the rainfall data is not representative of the rainfall of the whole river basin, this diagram has no quantitative value. However, it is a good illustration of the phenomenum. The rains less than 20 mm replenish the reserves in the soil and do not drain away except if repeated.

The heavy rains drain very quickly and the same day (or the next day as we have only daily measures) the flow rapidly increases in the river and falls again the next day (or the day after) to its original level.

Some rains, one to three a year, reach 150 mm, sometimes more. The level of the water in the river can rise, from 4 m or more in a few hours and fall to its original level in one or two days. The floods, 2 to 3 a year, are all the longer if one is downstream of the river basin, but rarely exceed 7 consecutive days.

6.5. Mostly nocturnal rains

Having 2 daily readings at our disposal we are able to separate the diurnal and nocturnal rains.

6.5.1. In quantity

During 10 years of observation 70 to 87% of the annual rainfall has fallen at night. The average is 78.2% of nocturnal rain against 21.8% of diurnal rain.

6.5.2. In frequency

For an average of 198 rainy days per year it rains an average 171 times during the night and 95 times during the day. It thus rains 68 times the day and night of a 24 hours day.

6.5.3. In intensity

Values in % of the annual rainfall

	Small rain	Medium rain	Heavy rain	Total
Day	2.8 %	10.3%	8.7 %	21.8 %
Night	3.8 %	17.1 %	57.3 %	78.2 %
Total	6.6 %	27.4 %	66.0 %	100.0 %

The heavy rains are mainly at night : 57.3% of the annual rainfall falls at night against 8.7% during the day.

The consequences at the level of organisation of the agricultural work are serious :

- The nuisance caused by the rains during the day is minimal. It only rains on average 95 times per year during the day and very rarely heavy rains. There are very few workless days because of rain.
- On the other hand it is not possible to tapp the rubber trees, which has to be done in the early morning, if there have been heavy nocturnal rains. Medium and heavy rains fall from 70 to 123 times a year at night, with an average of 100 times a year. The tapping work is thus hampered 1 day in 5 to 1 day in 3, with an average of more than 1 day in 4. This data should be integrated when an optimum tapping system is chosen.

7. Conclusion

Agronomical problems linked to climatic characteristics are in the main due to an excessive rainfall throughout almost the whole year.

To be noted :

- High erosion hazard which will imply anti erosive measures, even on relatively shallow slopes.
- A very intense leaching of soils which will reduce the efficiency of the manuring and will require appropriate fertilizers and techniques.
- Flooding hazard in the valleys of the main rivers.
- Phyto-sanitary problems for certain crops (cocoa tree) which will require expensive means of combat.
- The problems of fecundation and/or the grouping of flowering and harvesting periods of certain crops (coffee, pepper, clove).
- Decided difficulties for the rubber tree tapping.

On the other hand the very small risks of hydric deficiencies should permit two to three harvests of short cycle food-crops per year.

CHAPTER 2

THE SOILS

AGRONOMICAL PROBLEMS LINKED TO THE EDAPHIC CHARACTERISTICS

The soils present in the study area have been described by the pedologists, regrouped in "land units", then mapped. The study of various characteristics of these soils has enabled a census to be taken of the main agronomical problems which will arise at the time of development.

The cartographic units judged inapt for an agricultural use (slopes over 30%, podzols) will not be taken into consideration below. The valley bottoms, the soils on sedimentary formations and the soils on granite or granodiorite, presenting particular problems, will be dealt with separately.

1. Ferralsols (except xanthic ferralsols on granite or granodiorite)

1.1. High erosion hazard

The topography of the study area is of a relatively broken up appearance. It is not surprising as the research was voluntarily limited to the hilly areas between the coastal sedimentary formations and the Schwaner mountain range. The landforms are hilly to hillocky with generally very narrow valley bottoms.

The almost complete absence of accelerated erosion phenomena can be surprising. Under 3,000 to 4,000 mm of rainfall a year, with a very high frequence of heavy rains, the erosion remains moderate, even on steep slopes. This is explained by the protecting effect of the vegetation, mainly made up of primary or secondary forest.

But even on the "ladangs", upland rice fields under shifting cultivation, of the local people the erosion is not above normal. This is due to the shifting cultivation techniques which imply neither stumping nor soil work, even light. In addition the ladangs are left fallow after one to two years of cultivation and then the regrowth of the secondary forest protects the soil.

Independantly of this, and in spite of the clayey textures, the very good soil structure (very porous, rapid percolation) enables the violent tropical rains to infiltrate rapidly and considerably reduces the water run-off.

But if the present erosion is of a normal level, the risks of accelerated erosion are particularly high after clearing. The crop systems or techniques implying stumping and soil work could have catastrophic consequences.

1.1.1. Annual crops

The problem is particularly acute for annual crops which frequently leave the soil without protection for long periods. Small protection dikes should be provided, even on very gradual slopes. The construction of terrasses or anti-erosive banks will be necessary for slopes of 4 to 8%. Above 8% the soils should be reserved for perennial crops.

The creation of a discontinuity in the soil profile (for example a plough pan) by the soil work, can create a prejudice. Mechanical ploughing should be limited to slopes of less than 3%.

The cultivation systems proposed by the CRIA-LP3*are well adapted to limiting erosion. The multiple cropping systems (intercropping and relay-planting) very rarely leave the soil without protection. Certain plants such as maize, which gives a bad soil covering, should never be sown alone as a single crop but always as an interpolated crop.

1.1.2. Perennial crops

The perennial plants generally assure a soil protection equivalent to that of the forest. In any event during the first years the protection is insufficient. It is easy to remedy by planting leguminous covering plants (Pueraria, Crotalaria, Centrosema, etc.).

For plants requiring a small amount of shade for the first years, as the coffee shrub or cocoa tree, one can keep some trees at the time of grubbing. Unless it is absolutely necessary the stumping and the removing of trunks and branches should be avoided.

In the case of mechanical grubbing, the swathing of the residues following contour lines, limits the erosion and keeps the ashes left from the burning in place. On slopes of over 15% the traditional clearing techniques used by the Dayaks are the best adapted.

The absence of stumping causes additional maintenance work because of the numerous regrowths. On the other hand if the plantation fails and is abandonned by the transmigrant the soil will be rapidly protected by the forest regrowth.

The accelerated erosion phenomenum, frequent along the tracks of the forestry concession, entails high maintenance costs. One year after the end of the exploitation, these tracks become impassable. The same problem will arise in an increasing fashion in plantations requiring a dense network of tracks as in oil palm plantations.

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* Central Research Institute for Agriculture. Bogor, Indonesia.

Whatever use is envisaged one must be very carefull at the time of clearing. The Dayaks' system of shifting cultivation, primitive as it is, is remarkably adapted to the environmental conditions. For several centuries it has not reduced their soil capital. Great care must be taken to ensure that irreparable damage is not caused in the future, on the pretext of using modern techniques.

1.2. Favourable physical characteristics

The physical characteristics of the soils - considered in this paragraph, are generally good, even excellent. Their depth is usually more than 1.50 m. Horizons which are hard, impermeable or impenetrable are absent in shallow depths. The underground waters are generally deep, and there are no perched water-tables. The coarse elements, gravel, stones, pebbles or rocks do not impede an agricultural use as they are rare.

There is consequently no major obstacle for the penetration of roots. The muddy clay to clayey textures, the high rate of organic matter and an intense biological activity in the top soil contribute to the good structure of these soils. Their porousness is over 50%, the aeration is good, the retention capacities are of around 120 mm per meter and the drainage good to rapid. Certain soils are even humic the rates of organic matter being over 1% to a depth of more than 1 meter.

We have no field study at the moment of the evolution of these physical characteristics of these soils under permanent cultivation.

The planting of perennial crops should only cause minor modifications. On the other hand, for annual crops certain techniques of soil work should be tested before being generally used. A mechanical ploughing carried out under humid conditions could create ploughing pans in these heavy textured soils. The discontinuity thus introduced in the section could have very disastrous consequences taking into account the risks of erosion. Independant of this erosion hazard the creation of a perched water-table will provoke asphyxiation of the roots. This phenomenon has been observed in Tumbang Lahang in the slightly hollow parts of the plots ploughed by tractor.

The consequences of soil work even light and manual, on the physical characteristics of these soils are still little known under the climatic conditions in Kalimantan. Great care should be exercised in the choice of techniques for soil work.

1.3. An extremely low nutritional level

If the physical characteristics are often excellent it is not the same as regards the chemical characteristics.

Due to a dense vegetal covering and a structure ensuring a good drainage, the surface run-off is always very reduced. The PET being a maximum of 1,400 mm per year, even if the run-off reaches 200 mm and the variation of water stock in the soils 100 mm, the drainage will be around 2,000 mm per year.

This particularly intensive leaching affects most of the chemical characteristics of the soils.

1.3.1. Very poor soils

The pH are very low, around 4 in the top soil and 5 in depth. At best the amount of exchangeable bases is around 1 meq/100 g of soil and more often around 0.5 meq/100 g. The levels of exchangeable calcium, magnesium and sodium are very low and the levels of exchangeable potassium around 0.1 meq/100 g. The amounts of exchangeable aluminium are always higher than the amounts of exchangeable bases, from 2 to 6 meq/100 g on average and in one case 18 meq/100 g.

The desaturation of the absorbant complex is very elaborate. The saturation rates rarely reach 10%. The total reserves of phosphorous (nitric acid extraction) are generally below 500 ppm and never exceed 800 ppm. The total potassium is between 200 and 500 ppm on average but can reach 1,000 to 2,000 ppm in certain cases.

The cationic exchange capacities vary between 10 to 20 meq in the top soil and from 5 to 10 meq in depth. The fertility of the soils is linked to the organic matter. The levels of the O.M. are between 3.5 and 7% (2 to 4% of carbon and 0.08 to 0.25% of nitrogen). The C/N ratio oscillates between 10 and 15 on average but is more than 20 in certain cases.

1.3.2. Modifications after clearing and burning

Numerous authors have studied the modifications of the chemical characteristics of the soils after grubbing and burning. Their conclusions are often contradictory. The heterogeneities in the same plot are such that great care must be taken with sampling techniques (NYE and GREENLAND 1964, ANDRIESSE, 1977).

All the authors are in agreement about the spectacular increase in the nutritional level of the soils after burning. On the other hand they do not agree on the persistance of this increase. Certain limit it at 1 year, others 2 to 3 years and others even 5 to 7 years. As all these surveys were not carried out in the same climates nor on the same soils, we will opt for that of ANDRIESSE which took place in Sarawak on Ferralsols.

The value obtained before burning and after the harvest for the various elements analysed are not significantly different. The increase in the nutritional level is thus very short-lived as it lasts than a year.

The following table gives the values obtained after burning and after harvesting with the exports of a rice crop (1 ton/ha of panicles). The values are given in kg/ha.

Assimilable element	After burning	After harvesting	Removed panicle
N	264	132	10
P	23	0.7	2.7
Ca	792	66	2.6
Mg	127	12.7	1.9
K	106	12	2.3

The efficiency of this type of fertilization is particularly poor. More than 90% of the materials brought in were not used and have disappeared by erosion and leaching. The role of erosion seems predominant. The ashes not being buried, they are carried along by the running-off waters and accumulate at the bottom of the slope.

The large amount of exchangeable bases brought in by the burning has the effect of considerably increasing the pH. The increase is generally of 1 to 2 units but can reach 3 units. The original levels are always so low that deficiencies in micro-elements cannot be induced.

The effect of the burning on the level of organic matter is much smaller. According to NYE and GREENLAND (op. cit.) the bringing in of C only represents 8% of the quantity of carbon contained in the burnt vegetation. A small decrease appears in the first 5 cm, but it is compensated by an enrichment of the horizon of 5 to 15 cm. The quality of the O.M. varies more than the quantities. The proportion of fulvic acids increase after burning and the mineralization of the O.M. accelerates. But a new balance is quickly reached.

1.3.3. Effect of the bush fallow

The role usually given to the bush fallow is the restoration of the soil's fertility. The nutritional level of soils under primary forest is very low in Kalimantan. Immediately after burning this level rises very considerably. After one or two years of cultivation this level falls to its original level. Then, for 20 years of bush fallow, no important increase in the rates of easily assimilated elements appears (ANDRIESSE, op. cit.).

The fallow does not improve the structure of the soil either as the former physical characteristics are changed very little by a single year's use. On the contrary, the effect of the crop (upland rice) is often benefic.

Under these conditions it is erroneous to talk of restoring the soil's fertility.

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The role of the bush fallow is in fact more complex :

- In the first instance it assures a rapid covering of the soil and a particularly efficient protection against erosion hazards.

- It enables an important biomasse to be reconstituted in 10 to 20 years, a veritable stock of natural fertilizers. It is not the fertility of the soil that is reconstituted, but the possibility of fertilizing it by burning.

- Above all it permits the reduction of the stock of weeds. The first year after burning the weeds are rare. From the second year the infestation is such that as there is generally no weeding the yields are reduced by half. The third year the rice is choked by the weeds.

The Dayaks are particularily aware of this precise role of the bush fallow. In fact according to them ten years of fallow is enough to reconstitute the biomass necessary for the fertilization by the burning. But 15 to 20 years are indispensable in order to efficiently reduce the stock of weeds.

- The fallow also breaks the cycle of parasites of the cultivated plants.

1.3.4. Practical consequences

The fertility level of the Kalimantan soils is too low to think of using them for permanent cultivation without using fertilizers.

The beneficial effect of the burning is of short duration due to leaching and erosion. The waste of fertilizers is very great and it will probably be the same for chemical manure.

In the first instance the effects of the burning should be prolonged. The running-off water carries with it considerable quantities of ashes towards the bottom of the slopes. The rapid burying in the ground of these ashes, the construction of anti-erosive banks, a light ridging of the earth, etc. would keep them in place. Some of these techniques, however, could well increase the erosion and we would achieve the inverse effect of the one required. The light ridging for example is only recommended on gradual slopes.

*

When perennial crops are planted the swathing of the remains of the burning following the contour lines should be enough to keep the ashes in place. The fertilization of the young plants will thus be assured during approximately 5 years for very little cost.

For the annual crops it will be difficult to keep up the effect of the burning for very long. The losses by erosion and leaching will be higher without mentioning the removings due to the harvests. The desaturation of the absorbing complex will cause a rapid drop in the pH generally aggravated by the use of chemical manure.

This drop may well cause a decrease in the microbic life of the soil. The activity of the rhizobiums will be reduced, from which arises a considerable drop in the output of leguminous plants such as the groundnut and soya.

The low pH could cause the inassimilability of certain oligo-elements such as molybdenum, the reduction of iron composites and a possible retrogression of phosphates (CHARREAU & FAUCK 1969). FORESTIER (1960) reports on the coffee shrub that the more the pH drops, the more the insolubility of the phosphates. The low pH can also lead to serious toxicity such as that caused by manganese (FRANQUIN & MARTIN, 1962).

In principle the pH can be increased by liming. FRANQUIN (1958) reports that for the clayey desaturated ferralsols of Congo-Brazzaville, the pH of 4.3 and 5.3 are easily increased by at least a half unit, by bringing in 2 tons a hectare of agricultural lime (62% CaO, 3.3% MgO). But at the end of a year's cultivation the pH falls to its initial level or lower. In Kalimantan the cost of lime would be prohibitive and probably inefficient. Rather than trying to raise the pH, one must ensure that it does not drop further. The spreading of natural tricalcic phosphate for example would not only bring in phosphore but avoid a drop in the pH (TOURTE et al 1964).

In a more general manner the fertilizers used should comply with two imperatives :

- Not acidify the soil
- Not be leached too quickly

The acidifying role of the nitrogenous manures is well known. Amonia sulfate is the most acidifying but urea and cyanamide have the same effect. On the other hand, calcium nitrate and calcic cyanamide bringing lime and calcium at the same time do not acidify the soil (VERLIERE 1967 cited by BOYER 1970).

In order to avoid a too rapid leaching of the fertilizers the bringing in should be considerably divided up. One will, of course, exclude liquid fertilizers and one will avoid the use of manures easily rendered soluble. Better results should be obtained with a packaging in granulated form.

Parallel to this the rates of organic matter should be maintained at high levels by the burying in the ground of the crop residues, the bringing in of manure, etc. for the fact that the exchange capacities of the soils in Kalimantan are essentially linked to the organic matter of the soils, the clays (generally Kaolinite) having low CEC.

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Toxicity due to exchangeable aluminium

Numerous authors, cited by BOYER (1976) report toxicity caused by exchangeable aluminium when the pH are low. In Brazil for example, when the ratio

$$\frac{\text{Exch. Al}}{\text{Exch. Al + Exch. bases}}$$

is more than 50%, some authors consider the soils unsuitable for many crops.

In Kalimantan this ratio is never less than 65 - 70% and it frequently reaches 98%. It is even in the most fertile soils of the area that this ratio is the highest, with rates of exchangeable aluminium sometimes of 18 meq/100 g. The yield in upland rice being frequently 2 tons/ha, it is difficult to talk about toxicity.

1.3.5. Conclusion

The high risks of erosion and intensive leaching of the soils create numerous agronomical problems. These problems are relatively easy to resolve for most of the perennial crops. On the other hand, the continuous use of such soils by annual dry land crops has always led to disastrous results in identical climates.

2. Development of valley bottoms (fluvisols)

The problem mentioned above was traditionally resolved in two distinct (or successive) ways according to the demographical pressure :

- In an extensive way by shifting cultivation
- In an intensive way by the development of valley bottoms and use of irrigation

The particular problems of the soils of the valley bottoms are due to their hydromorphy, to the risks of flooding and presence of peat.

The hydromorphy of the soils of the valley bottoms limits their use to plants which tolerate these particular conditions such as rice, cocoyam or sagu palm. Their slow percolation is a favourable factor for irrigated rice growing. Because of their topographical position, the valley bottoms are brought a lot of fertilizing matter by the running-off waters and the drainage. The nutritional level of the valley bottoms is always 2 to 3 times above that of the soils on the nearby slopes.

The risks of flooding are limited to the units 1 to 4 of the soil map. In the units 1 and 2 the submersion is nearly permanent. The flood water stays blocked behind the rims of the banks and it is possible that the level of stagnant water is less than the average level of the river. Definite topographical measures will be necessary in order to determine if drainage canals would permit the draining of these peat bogs.

In the units 3 and 4 the submersion is short. It varies between 1 to 10 days, rarely more. It is longer the more downstream it is situated. The case of Katingan river is very explicit : in Tumbang Lahang floods of over 3 to 4 days are not reported. They do not cause much damage to the rice. Further downstream in Buntut Bali the length of submersion can reach 10 days, and about 1 year in 6 the rice harvest is compromized. Still lower downstream in Kasongan, the rice is destroyed about one year out of three or four.

Drainage canals would enable the excess water to be evacuated more rapidly. This is, however, not sufficient to avoid the destruction of harvests in the case of prolonged flooding, above all downstream. It happens that the level of water inthe Katingan remains several days above the rim of the bank. A hydrological and topographical study is indispensable in order to evaluate the profitability of embanking works on the river.

Even if the units 1 and 2 could be developped they would not be usable for rice growing. In fact, they are generally covered with thick peat (sometimes more than 2 m). In Ivory Coast very productive banana plantations have been installed at great expense on thick peat. But in order that this sort of operation is profitable the commercialization of the product should be assured and preferably directed towards countries with a high buying power. The isolation of the area does not enable the product to be exported under good conditions at the moment.

In the units 3 and 4 peat is frequent in inclusions but it is rarely more than 1 meter thick. The rice fields in the valley of Katingan have been installed on peat of about one meter thickness. In 3 to 5 years this thickness is reduced to 0.5 meter and to 15 cm in 15 to 20 years for the older rice fields. And all that without drainage nor soil work other than the trampling down at the time of planting out the rice. The yields frequently reach 2 tons of paddy per hectare with local varieties, without soil work, without any water control, without fertilization nor phyto-sanitary treatments. This shows the particularly interesting potential of this unit for rice-growing, whereas according to the criteria usually used in Indonesia it would not be suitable for food crops.

3. The soils on sedimentary formations (Acrisols)

The Dayaks generally regroup the soils of units 5a and 6a with the podzols under the name "Tanah Gagas" which signifies bad land or soil unsuitable for crops.

These soils are very rarely used by the autochtones even for rubber tree plantations. They are very desaturated clayey sands, the structures are little developped and the porousness is low. The rate of exchangeable bases is of about 0.5 meq/100 g. Once cleared, the rate of organic matter decreases rapidly and therefore the exchange capacities which were already very mediocre before grubbing are also reduced.

In two to three years, a forest - although not very productive - is transformed into an Alang-alang (Imperata cylindrica) waste land which is practically irreparable. This phenomenum was observed many times in Kalimantan Tengah and Sumatra.

The use of these soils for transmigration is not to be considered.

4. The soils on granit and grano-diorit (Xanthic ferralsols)

These soils are sometimes grubbed by the Dayaks with the aim of planting rubber trees.

In general the section gives a clayey-sandy horizon on the surface and clayey horizon in depth. Although there is no major obstacle to the penetration, the tree roots remain on the surface. In certain places perched watertables appear. The levels of organic matter are low for soils under forest. The distribution of the O.M. is superficial and the exchange capacities are low; around 10 in the top soil and 5 meq/100 g in depth.

The desaturation here is often less than in other soils but it should be related to the low CEC. It would seem that the running-off is more intense in these soils but no measure is available.

The upland rice always remains poor on the slopes and seems deficient in nitrogen. At the bottom of the slope and in the valley bottoms the growth is normal. The rooting is always very superficial and rarely descends more than 5 - 7 cm. A period without rain of 7 to 10 days is enough to blight the crop.

On the other hand the rubber tree succeeds very well on these soils. It succeeds here even better than on more fertile soils. The absence of maintenance in the young plantations is the main reason. On these less fertile soils the forest regrowth is slower and the rubber trees easily dominate. On the more fertile soils the rubber trees are in competition with quick growing species of the secondary forest. This sort of thing will disappear with good maintenance of the plantations.

However, these soils are not really suitable for transmigration and should be destined to the local small-holder or industrial rubber tree plantations.

CHAPTER 3

PLANTS

DETERMINATION OF SUITABLE CROPS ACCORDING TO THE EDAPHIC AND CLIMATIC CONDITIONS OF THE AREA STUDIED

From the evidence it seems that the examination of only the soil and climatic factors, in order to determine the potentialities is but an intellectual exercise. The economic criteria are always preponderant. The notions of constraint or of favourable factors should only be considered in relation to their repercussions on the costs, volume and quality of the productions. Heavy inputs are tolerable if the outputs are sufficiently high. In order that a crop is suitable, it is sufficient that it be profitable.

The cultural aptitude of a soil is a particularly delicate notion, which is only of value in a well defined context and at a definite time. It should be periodically reconsidered in conjunction with the evolution of the economic, socio-cultural situations and knowledge.

The requirements of the main tropical crops are summarized in the appendices.

1. Perennial crops

In the study area we have counted an impressive number of plants cultivated either perennially or annually. Unfortunately there is no industrial plantation in the study area. The only plantations of a reasonable size are rubber and rattan smallholdings. The study only gives little information, taking into acçount their extensive character. The other perennial crops are grouped in orchards round the dwellings on the banks of the rivers. These plants are in very particuliar conditions because of their location. They benefit from kitchen manure and intensive maintenance. Therefore, they are not representative of plantation conditions. One finds mixed up together : coconut, areca palm, coffee (robusta and excelsa), pepper, clove, mango, citrus fruits, rambutan, durian, langsat, jackfruit, etc. but more rarely cocoa trees and oil palms.

1.1. Para rubber

Introduced a short while after the first world war, the rubber tree is found everywhere in the study area, nearly always close to the villages. The plants are grown from seed and the budding technique is unknown. The stumps are pulled up from the already established plantations, their roots are cut at 20 cm then replanted with the

EVALUATION OF THE SUITABILITY OF THE VARIOUS SOIL MAPPING UNITS FOR VARIOUS CROPS AND DEVELOPMENT TYPES

Table 3.

Mapping unit	Suitability for agriculture in general	Lowland rice	Dryland Food-crops	Rubber	Coconut	Oil palm	Coffee Pepper	Transmigration Projects	Local small holders	Estates
1	NS 1	NS 1	NS 2	NS 2	NS 1	NS 1	NS 2	NS 2	NS 2	NS 1
2	NS 1	S 3	NS 1	NS 2	NS 1	NS 1	NS 2	NS 1	NS 1	NS 1
3	S 2	S 1	S 1/2	S 3	S 3/2	S 2/3	S 3	S 1/2	S 1	S 3
4	S 2	S 1/2	S 1/2	S 3	S 3/2	S 2/3	S 3	S 1/2	S 1/2	S 3
5 A	S 3	NS 1	NS 1	NS 1	S 3/2	S 3/2	NS 1	NS 1	NS 1	S 3/2
5 F, 6 F	S 3	NS 1	NS 1	S 2	S 2	S 2	S 3	NS 1	S 3/2	S 2
5 P	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2
6 A	S 3	NS 1	NS 1	NS 1	S 3/2	S 3/2	NS 1	NS 1	NS 1	S 3/2
7 A	NS 2	NS 2	NS 2	NS 1	NS 1	NS 1	NS 2	NS 2	NS 1	NS 1
7 P	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2
8 Fp	NS 1	NS 2	NS 1	NS 1	NS 1	NS 1	NS 1	NS 1	NS 1	NS 1
8 Fo	S 3	NS 2	NS 1	S 3/2	S 3	NS 1	NS 1	NS 1	S 3/2	S 3
8 F-G	S 3	NS 2	NS 1	S 3/2	S 3	NS 1	NS 1	NS 1	S 3/2	S 3
9 F-G	S 2	locally S 2/1	S 2 - S 3	S 2/1	S 2	S 3	S 2	S 2	S 2/1	S 2/1
9 Fp	S 3	NS 2	NS 1	S 3/2	S 3	NS 1	NS 1	NS 1	S 3/2	S 3
9 Fx	NS 1	NS 2	NS 2	NS 1	NS 1	NS 2	NS 1	NS 2	NS 1	NS 1
10	NS 1	NS 2	NS 2	NS 1	NS 1	NS 2	NS 2	NS 2	NS 1	NS 1
11 Fx, 11 Fx-o	S 3	NS 2	NS 1	S 3	S 3	NS 1	NS 1	NS 1	S 3/2	S 3
11 FxR	NS 1	NS 2	NS 2	NS 1	NS 1	NS 2	NS 1	NS 2	NS 1	NS 1
12 F-G	S 2	locally S 2/1	S 2 - S 3	S 1/2	S 2/1	S 2	S 3	S 2	S 1/2	S 1/2
12 Fo	S 3	NS 2	NS 1	S 2	S 2/3	S 3	S 3	NS 1	S 2	S 2
13	S 3	NS 2	NS 2	S 3	S 3	NS 1	NS 1	NS 1	S 3/2	S 3
14	NS 1	NS 2	NS 2	NS 1	NS 1	NS 2	NS 1	NS 2	NS 1	NS 1
15	S 2	NS 2	S 2/3	S 1/2	S 2/1	S 2	S 2	NS 1	S 1/2	S 1/2
16	S 3	NS 2	NS 1	S 2/3	S 2/3	NS 1	S 2/3	NS 1	S 2/3	S 3
17	NS 1	NS 2	NS 2	NS 1	NS 1	NS 2	NS 1	NS 2	NS 1	NS 1
18 F-G	S 2	locally S 2/1	S 2/1 - S 3	S 1	S 1/2	S 1/2	S 1/2	S 1 - S 2	S 1	S 1
18 FH	S 2	locally S 2/1	S 2 - S 3	S 2/1	S 2	S 3	S 2	S 2	S 2/1	S 2/1
19	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2
20	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2	NS 2

S 1 : highly suitable; S 2 : moderately suitable; S 3 : marginally suitable; NS 1 : currently not suitable; NS 2 : definitely not suitable.
S 1/2 : highly to moderately suitable ... ; S 2 - S 3 : partly moderately, partly marginally suitable ...

the help of an ordinary stick. The first maintenance is usually carried out at the first tapping, between 10 and 20 years after the planting. The tapping rythm is not continuous, rarely more than 3 months a year, and above all it is in relation to the immediate financial needs of the owner. The tapping technique is rudimentary and traumatic, the bark seldom rebuilds itself. The rubber is commercialized in the from of "slap" (or smoked sheet on the Kahayan only) of a mediocre quality.

As far as we can judge the climate is suitable for rubber trees. The frequent nocturnal showers are, however, likely to interfere with the tapping (ref. climate). The rubber tree is satisfied with the very poor soils in Kalimantan and it is certainly one of the plants best adapted to the conditions of the environment. However, the hydromorphic areas, the slopes above 25% and very sandy soils of the 5a and 6a units (ref. table No. 4) should be excluded. Elsewhere the plantation on cleared and burnt land should ensure the fertilizing of young plants for several years without it being necessary to use fertilizers. The use of selected clones, of correct plantation techniques and a good upkeep should permit the opening of the tapping pannels in the 6th year and a high production.

Knowing the lack of enthusiasm shown by the Javanese for this crop, the techniques which they ignore, the plantations should be entrusted to the PTP (Industrial plantation companies). We have been able to appreciate the remarkable quality of their work on the transmigration centres of Baturaja and Rimbo-Bujang (Sumatra).

On the other hand the long term economic prospects are good for rubber and a commercial network is already existing on all the rivers.

1.2. Rattan (mainly Calamus caesius and C. trachycoleus)

Rattan is almost as widely cultivated as rubber. In the Mentaya basin it even dominates rubber. Multiplied by direct sowing or by planting out in the "ladang" (often interplanted with rice) its cultivation is very extensive. The young plants are abandonned in the forest regrowth and the cutting only takes place 10 to 15 years later.

The level of the rattan prices is very high at the moment and the commercialization is well organized.

Rattan is a plant which is still not well-known and to our knowledge no serious research has been attempted in order to improve the yields. Therefore, it is premature to include it amongst the crops which can be proposed to the transmigrants. In existance everywhere in a wild state in the forest, its adaptation to the climate and soils is obvious.

1.3. Coconut

The present planting of coconut palms is limited to the gardens of small dwellings. They are non-selected tall varieties and generally bearing few nuts. But these last being consumed before maturity it would be risky to draw hasty conclusions. The phyto-sanitary problems which were pointed out to us are above all the fact of caterpillars devouring the folioles.

In spite of the uncertainty which weighs on the knowledge of the sunshine, the climatic conditions seem favourable to the development of the coconut palms. On the other hand the very low nutritional level of the soils in Kalimantan implies a full fertilization in order to get a decent output. On table 4 we have classified the different units of the Soil Map according to their suitability for coconut.

The coconut palm is a priority for Indonesia, big consumer of coconut oil. In the near future Indonesia should have enough hybrid coconut seeds P.B. 121 to satisfy the demand. Requiring only relatively little care and harvesting, the coprah could be dried locally and stocked for several months.The marketting being assured, the coconut palm can be an interesting support for the transmigrant if the supply of fertilizer is assured.

If the growth of the cover crop allows it, one could even envisage associating animal husbandry to the cultivation.

1.4. Oil palm

The requirements of oil palm as regards climate and soil are similar to those of the coconut palm. The high level of fertilization - especially potassic - required for an optimum production implies a regular fertilizer supply.

The bunches must be harvested at a well defined stage in order to avoid excess acidity. This supposes frequent checking and a dense track network, for the transport of the bunches (10 to 25 kg on average but sometimes 50 kg) cannot be done on men's backs. The fruits cannot be kept for long and, therefore, the oil factories should be situated near the production areas.

For all these reasons, a profitable plantation of oil palms entails a large investment (factories, roads, transport facilities, etc.) and a perfect organization. A production structure of the "estate" type is required.

The units of the Soil Map have been classified according to their suitability to oil palm plantations in table 4. The privileged criteria are :

- The slopes which must be under 15% because of the high cost of construction and upkeep of a dense network of evacuation roads.
- The aptitude to fertilization of the soils due to the importance of the manuring in order to obtain high yields.

Also the transport of the processed product to a sea harbour will cause serious problems in these remote areas. The present port infrastructures are far from being adapted to this end.

For all these reasons - above all economic - cited above we cannot recommend oil palm plantations under the present conditions, and even less so in the transmigration centres.

1.5. Robusta coffee (or Excelsa)

The coffee shrubs are often planted around the small dwellings but never in plantations although numerous small-holder plantation projects are under study. The observation of these coffee shrubs gives little information except certain damage by borers.

The climate is favourable to the growth of the Robusta coffee shrub. However, the absence of a marked dry season, almost every other season and every other year does not enable the flowerings to be grouped. Sometimes very short periods without rain are enough to induce many flowerings. The soils are in general suitable for coffee shrubs (low pH, high O.M. content, good structure and good drainage) but their weak nutritional level and the intense leaching requires a high fertilization for an optimal yield. The suitability of the different units is resumed on the table 4.

The prices, although fluctuating on the world level are high at the moment and the national and regional markets can still absorb large quantities, above all for the production of instant coffee. New varieties such as Arabusta presently being perfected in Ivory Coast by ORSTOM - IFCC will enable the quality of the coffee to be improved.

The considerable amount of work needed for the cultivation of the coffee shrub means it cannot be the previledged income crop of the transmigrants in the first instance. However, the capacity of the coffee shrub to produce even without a high fertilization, on poor soils but with good structure, could be an interesting contribution. The berries, when dried, can be stored for a long time and the processing on the spot, even by traditional techniques could feed the regional market.

1.6. Pepper

The pepper plant is a traditional cash crop of the Dayaks, above all in Sarawak (North Borneo) and East Kalimantan. The very old treaties (1635) drawn up by the Dutch and the Banjarmasin Sultanate note the commercialisation of pepper. At the present time in Central Kalimantan the cultivation of the pepper plant is very limited.

The zone's moist climate is suitable for the pepper plant, but as in the case of the coffee shrub the absence of a well marked dry season does not always enable flowering to be grouped.

The prices are as high as those for coffee (600 - 700 Rps/kg) but due to the small production the commercial circuits are not yet organized.

The soils suitable for the pepper plant are the same as those for coffee. However, the pH should be raised one unit in order to be in the optimum conditions.

A heavy manuring is necessary to obtain high yields, but the plant can grow on soils which are chemically relatively poor if they are well structured and rich in organic matter.

The large amount of work required for the harvesting puts this crop on the same level as the coffee shrub. As a secondary crop it could be an interesting financial contribution for the transmigrant.

1.7. Clove

In face of the very high demand, especially in Indonesia (manufacturing of Kretek cigarettes) the prices have recently reached impressive heights. Following on this there has been a wave of plantations even in the furthermost islands of the archipelago. In a few years these clove plants will produce and the prices will rapidly fall.

As far as we can judge from our tours the absence of a marked dry season seems to cause problems of flowering induction. Serious trials are necessary before proposing this crop on a large scale to the transmigrants.

1.8. Cocoa

Even though it suits the growth of the cocoa trees the extremely high rainfall and hygrometry will cause serious phyto-sanitary problems. These problems, associated with the necessity of raising the pH and of strong fertilizing in order to obtain correct yields make the cultivation of cocoa trees marginal in the study area.

Under the present conditions this crop should not be recommended for transmigration projects in the study area.

1.9. Other perennial crops

The other perennial crops : nutmeg, cinnamon, citrus fruits, banana trees, sugar cane, various fruit trees are planted in to a limited degree in the gardens of the small dwellings. Their adaptation to the environmental conditions is often good (except in the case of citrus fruit trees and to a lesser extent the sugar cane) but the absence of large urban centres or commercial outlets and the high cost of transport does not permit their cultivation on a large scale to be considered.

2. Annual crops

Nearly all the tropical annual plants cultivated in Java are represented in the study area. Certain have been introduced very recently, others originate from Kalimantan and are, it seems, unknown in Java.

The upland and lowland rice occupies a preponderant place and is the only "large fields" crop of the Dayaks. The cassava is very secondary and sometimes takes over from rice but on smaller areas. A large variety of vegetables - mainly Cucurbitaceae - as well as maize are frequently planted in the rice. The density is always very low at the scale of the plots but higher near the pondoks (shelters on the fields). Also, around the small dwellings in the villages one often comes across vegetable gardens. The produce is destined for their own consumption and very rarely commercialized.

2.1. Rice

2.1.1. Upland rice

The Dayaks' system of cultivation has been thoroughly studied, but its description does not fit into the framework of this report. A census has been taken of a large number of local varieties (more than 50). They are of the Indica type with high straw and heavy panicles (more than 300 grains per panicle). Their cycle varies from 4.5 to 5 months. Some of them are very productive and under the shifting cultivation conditions, yields of 2 to 3 tons of paddy are possible. The average is around 1.5 t/ha but the interannual variations are very high.

The nutritional level of all the soils being very low, the yields are strongly linked to the quantity of ashes created by the burning. If the burning has been of a poor quality, due to heavy rains in September, the ladangs are nearly always abandonned.

The ladangs are usually only cultivated for one year. The nutritional level of the soils, considerably increased by the burning would in fact enable 3 or 4 years of successive cultivation according to certain authors (DRIESSEN et al. 1976).

However, the infestation by weeds is such that as from the second year after clearing (3rd year if clearing of primary forest) the yields of rice drop by half. The third year the rice is completely choked. When the pressure on the land is low,which is usually the case in the zone, the Dayak prefers to clear every year rather than to weed manually.

The crop cycle is limited to the period from September to April. That is, of course, due to the necessity of a relatively dry period - of which the maximum frequence is in September (cf climate) - in order to permit burning. From April until September no head of rice can been seen in the area. In a ladang which was sown lately (as the owner was ill) catastrophic damage was observed, all the parasites of the neighbouring ladangs were concentrated there. It was established by an enquiry that this phenomenum was general. The regrouping of sowing dates enables the parasite cycle to be broken, the host plants being absent seven months a year.

The observation of the Dayaks' system of cultivation is rich in information for the transmigrants :

- There already exists productive local varieties well adapted to the conditions of the environment. The seeds are available in sufficient quantities.

- A harvest cannot be hoped for if the supply of fertilizer is not assured.

- In permanent cultivation the weeding will create a bottle neck.
  This has been observed in the transmigration centres in Sumatra when one family struggles to weed 0.75 ha with tradional techniques. Large parts of the plots are abandonned. The use of herbicides is required.

- Several crops of rice per year will bring swarming of parasites and the necessity of using pesticides.

It is not certain that a system based on permanent cultivation of upland rice would be viable in the long run. Faced with the high costs linked to the fertilization, the battle against the weeds and parasites, upland rice would rapidly give way to cassava monoculture with all the bad consequences that would bring for the soils. The examples of this sort of development are prevalent in Indonesia (Way-Abung in Sumatra).

2.1.2. Lowland rice

The varieties of lowland rice (generic term Umbang in Dayak) are cultivated on the hydromorphic soils of the narrow valley bottoms or in the alluvial valleys of the main rivers. No water control is ever assured.

The number of varieties is more restricted than for upland rice (about 15). These varieties in general have been recently introduced (rarely more than 20 years) and have transited by Kuala Kapuas and Banjarmasin. They are usually of an intermediary type between Indica and Japonica. Their cycles are longer than those of upland rice, some such as Umbang Bakara reach 8 months, but the average is around 6 months.

In the Katingan valley, the only place the lowland rice is cultivated on a large scale, the seed beds are prepared on dry land as from the month of August. The 6 months old fallow fields which are covered by various Cyperaceae are then cleaned with the help of a long curved knife before the 1 or 2 months old seedlings are planted out. The treading down at the time of cutting of the Cyperaceae and during the planting out takes place of soil work. The rice rapidly takes over from the weeds and maintenance is more often than not inexistant. No chemical fertilizers, pesticides or herbicides are used as yet. Certain lowland rice fields have been planted for 20 years on a stretch without any serious carency appearing.

Under these conditions the average yield is around 2 tons of paddy per hectare and 3 tons in good years. But good years are rare. The floods often cause considerable damage, and some years the rats are assuming the harvesting.

As for the upland rice, the experience of the Dayaks will be useful for the transmigrants :

- In the irrigable areas the permanent cultivation of rice is possible, and correct yields can be obtained with small fertilizer inputs.
- Two or three annual crops are theoretically possible. At present the single annual crop wages a biological battle against numerous parasites (mainly stem borers and bugs). In fact, due to the absence of secondary host plants for 6 months of the year the cycle of these parasites is efficiently broken. If one opts for several crops a year, pesticides have to be used.
- Large works will be necessary in order to avoid regional flooding.
- From the beginning efficient means of fighting rodents must be envisaged.
- The supply of selected seeds of short cycle rice should be ensured, the local varieties having too long a cycle to allow more than 2 crops a year.
- In the absence of efficient extension services, it would be better to keep the system used by the Dayaks, and progressively improve it.

The transmigrant generally has a good knowledge of the techniques linked to the cultivation of irrigated rice. If his means allow him to call on modern techniques he will be able to produce a large surplus. But in a more critical situation, which is usually the case in the first years, he could at least ensure his self subsistence.

2.2. Maize

The cultivation of maize can be envisaged as an interpolated crop, with upland rice for instance. However, the very low pH of all the soils and the high rates of exchangeable aluminium should cause problems of toxicity (BOYER 1976). The maize providing a poor soil covering, should be abandonned as a single crop taking into account the high risks of accelerated erosion.

2.3. Soya

Soya is usually the main source of proteins of the Javanese transmigrant. Its cultivation can follow that of upland rice in the rotations. Varieties adapted to the environmental conditions must be sought and allow for sowing with rhizobium. In Sumatra, in more or less identical conditions, the low yields observed in the early years of cultivation are above all due to the absence of symbiotic bacteria. Also the pH of the soil should be increased by liming in order to be in optimal conditions for the development of the plant and of the symbiotes. This is unfortunately not always possible (cf. soils).

2.4. Groundnut

The conditions are not very favourable for the cultivation of groundnuts. The heavy rainfall will cause serious phyto-sanitary problems. The activity of the rhizobium of the groundnut is very slow and sometimes non-exitant if the pH drops below 5 or 4.5 (BLONDEL 1970). FAUCK (1956) stales that under 1 meq/100 g of exchangeable calcium the yields drop sharply. The deficiency in calcium appears as "the empty shell disease". This problem was pointed out to us in Tumbang Lahang. A large number of empty shells are harvested there in spite of an excellent vegetative growth of the groundnut.

But the main problem remains the difficulty of harvesting the shells in the heavy textured soils of the study area.

2.5. Other legume seed crops

The cultivation of the various Phaseolus, Vigna, Psophocarpus, Cajanus, Canavalia, Pisum, etc. will above all be in relation to the possibility of absorption by the local market. Under the present conditions these crops will be restricted to vegetable gardens.

2.6. Cassava

The cassava like the rubber tree succeeds very well on the acid and relatively poor soils of Kalimantan. However, its permanent cultivation without fertilizing has the effect of further impoverishing the soils until they are unsuitable for any crops. There are locally remarkably productive varieties. The growth of the plant is very rapid and it reaches more than 2 m in height in 3 to 4 months. The first tubers are harvestable at 4 - 5 months.

The varieties are sweet (except for rare exceptions) and we have almost never seen serious virus damage. The Dayaks are not very fond of this tuber and only eat it when there is no rice. They eat, above all, the young leaves as vegetables and feed the pigs with the tubers.

Cassava is not saleable on the local market. The installation of a tapioca factory would not be profitable due to the high cost of transport and the isolation of the area studied.

Cassava will assure the subsistence of the transmigrants but could not play a role as a cash crop.

2.7. Other annual crops

Yams, cocoyams and sweet potatoes could vary the daily diet of the transmigrant but they should only be grown in vegetable gardens. At this level nothing can stop the transmigrants from cultivating a large variety of species of Cucurbitaceae, Solanaceae, Zingiberaceae, etc.

3. Cropping systems

The study of suitable cropping systems, rotations, associations, etc. is not in the framework of the present report. However, they will be described in detail in the Phase 2 reports.

CHAPTER 4

ANIMAL HUSBANDRY AND PISCICULTURE

At the present time in the study area animal husbandry is very limited and pisciculture is unknown. The outlook is, however, very promising in both fields.

1. A high local demand

The local markets are very badly supplied in animal proteins. There is very little to offer although there is a great demand due to the relatively high buying power of the Dayaks and the employees of the logging companies. The necessity of sacrificing a large number of cattle and pigs during certain Dayak religious festivals (pesta tiwah) also affects the demand. The prices are always high : 100,000 to 200,000 Rps for cattle of about 150 to 200 kg, 2,500 to 3,000 Rps the kg for chicken, fish and pork are cheaper, about 1,500 Rps/kg.

2. A large variety of fodder

The absence of a dry season and the low density of population enables a relatively abundant domestic livestock to be fed without any problem. At Tumbang Lahang a mixture of Panicum maximum and Setaria sphacelata is cultivated and gives about 6 - 7 cuttings a year. The annual yield is about 30 tons/ha. Elephant grass (Pennisetum purpureum) yields about 40 tons/ha in a year.

3. Relatively good sanitary conditions

The disease which, under similar climates in Africa, usually limit cattle rearing are unknown in Kalimantan. At Tumbang Lahang they have opted for stable feeding because of tick infestation. For cattle, sanitary problems are minor. On the other hand the fowl are regularly thinned out by plague and cholera. More intensive care and breeding in hen houses would enable the risks of diseases to be considerably reduced.

4. Streams and ponds which can be developped

In certain places the construction of forest roads has blocked the talwegs and created ponds which are easy to develop for pisciculture. Elsewhere small deep streams will be easy to block by small dams where carp can be bred in sunken cages as is usual in Java.

5. A possible complementary income

Whilst waiting for the perennial crops to produce, the small domestic breeding will offer an interesting source of income for the transmigrant.

Pure hand bred cocks and modern breeding techniques should be introduced and above all a good sanitary supervision has to be organized.

The high prices of the produce and the large capacity of absorption by the local market will be the best incentives to the development of the breeding.

CHAPTER 5

POTENTIAL USES

The examination of the climatic and edaphic characteristics of the study area faced with the requirements of the main tropical crops enables the retaining or elimination of various potential uses.

The type of development : transmigration, estates or small holdings - also influence the choice of crops. In fact, certain crops even though well adapted to the environment do not suit the transmigration centres.

Taking into account the conclusions in the preceeding chapters we have envisaged seven potential uses and three types of development. The crops to be exploited : rubber, coconut, oil palm, coffee, pepper, lowland rice and annual upland crops. The development is assured either by transmigrants, or local small holders, or estates.

Each cartographic unit has been classed according to its aptitude to the various uses envisaged. The classification which has been used is that recommended by the FAO and usually employed in Indonesia. The results are resumed in table 3 and cartographed (mapped) on sheets 13a and 13c of the atlas.

1. The crops selected

1.1. Suitability for lowland rice cultivation

The criteria selected in order to evaluate the land suitability for lowland rice are as follows :

- no slope or only a very slight one
- a lowland position enabling irrigation but also drainage
- a heavy texture enabling the slowing down of the percolation by puddling and ensuring flooding.
- the absence of thick peat.

The enlargement of the grounds favourable to lowland rice growing is very limited. The units 3 and 4 are favourable and the unit 18 FG is for about 20% of its surface, the units 9 FG, 12 FG, 18 FH over less than 10% of their surface, the unit 2 is marginal.

The valley bottoms of units 18 FG, 9 FG, 12 FG, 18 FH could be developped by small preparation works which would cost little. The Javanese or Balinese transmigrants would be the best for this work.

The preparation of unit 3 necessitates works on a larger scale, which can be carried out on the level of villages which already exist. Certain irrigation projects are already under study as that of Tumbang Jutuh.

The unit 2 regroups hydromorphic soils and peat, flooded almost permanently. The evacuation of the stagnant waters not always being possible, precise studies are necessary in order to evaluate the benefit of preparation works which will, of necessity, be very costly. The thickness of the peat makes it doubtful that such a project is worthwhile.

The Katingan alluvial valley (unit 4) is by far the most interesting site for irrigated rice. The spread of the site, the quality of the soils, the higher demographic density, the already established rice growing tradition, are all favourable factors. The regional flooding hazard, above all downstream, must be controlled by costly embanking works.

If small irrigated units can be rapidly set up, they must, as from now, be integrated in a large planning project of the Katingan valley.

Big transmigration projects are not desirable as the site is already more than 80% occupied. On the other hand small units of 50 to 100 families of transmigrants, divided between the existing villages will represent an element of the development, indispensable to the success of an irrigation project.

1.2. Suitability for annual dryland crops

The essential suitability criteria for annual dryland crops are :

- Slopes inferior to 8% due to high erosion hazard.
- A good drainage, no flooding hazard.
- Intermediary textures and good physical characteristics.
- Aptitude to fertilization (high O.M. and CEC).

The extension of the favourable areas is almost identical to that of the irrigated rice growing. The parts which are more or less flat of units 18 FG, 9 FG, 12 FG, 18 FH can be used on condition that the drainage is assured.

A system of intensive cultivation based exclusively on annual food crops will only be viable on a short term basis under the conditions of Central Kalimantan. The systems, although very interesting, perfected by the CRIA - LP3 in Bogor (SURYATNA EFFENDI et al - 1979, INU G. ISMAIL et al 1978) cannot be maintained without intensive technical support. The almost general evolution is towards the cassava monoculture, the transmigrants not being able to, or not wanting to, face the high charges inherent in these intensive systems.

In the medium term irrigation must be provided for the units if one wants to ensure the self subsistence of the transmigrants.

These particular problems will be discussed thoroughly in the phase 2 reports.

1.3. Suitability for rubber plantations

The rubber trees large tolerance for varied edaphic conditions greatly reduce the selection criteria :

- avoid slopes over 25%
- avoid hydromorphic soils
- avoid too sandy soils.

The distinction between suitability classes will be made mainly in relation to the slopes.

The units favourable to rubber trees (S1) are 12 FG, 15 and 18 FG, the units moderately favourable 9 FG, 9 FP, 12 Fo, 13, 16 and 18 FH the marginal units 11 Fx, 11 Fxo, 8 Fo, 8 FG, 5 f, 6 f, 3 and 4.

The 18 FG unit and possibly the units 9 FG, 12 FG and 18 FH could be developped by transmigrants organized in a "nucleus-estate" system. The other units can only be exploited by industrial plantations where possible transmigrants would be workers and not small holders.

But before clearing new areas in order to establish rubber tree plantations, first of all the already existing ones should be rehabilitated. A big effort at popularization of this should be made as regards the local population. Grafting with selected clones must be introduced, planting and tapping techniques should be taught, and above all the quality of the commercialized rubber must be improved.

The Dayaks are looking for cash crops. The techniques used at present make the cultivation of rubber trees unattractive. The spot operations (2 to 3 by river) which show the profitability of modern production techniques will constitute the motivation for a rehabilitation of rubber tree plantations. They will also answer the often expressed wishes voiced by the local population.

1.4. Coconut plantations

The coconut palm is satisfied with very varied soils and can even produce on very poor soils. It responds very well to fertilizing and only requires a small amount of work per hectare. The yield obtained with the help of hybrid PB 21, developped by the IRHO on the Ivory Coast produces a particularly interesting crop.

The criteria used to evaluate the suitability of the various mapping units for coconut are :

- slopes less than 25%
- non-hydromorphous soils, without risk of prolonged flooding
- soils apt for fertilization.

The unit 18 FH is favourable, the units 5 f, 6 f, 9 FG, 9 FP, 12 FG, 12 Fo, 13 , 15, 16 FH and 18 FH are moderately favourable, the units 3, 4, 5a, 6a, 8 Fo, 8 FG 11 Fx and 11 Fxo are marginal.

Under the present conditions the development of large industrial plantations is not recommended in the area due to its isolation. On the other hand, in the unit 18 FG, the coconut palm could represent an interesting source of income for the transmigrant. The possibility of feeding several heads of cattle, from a well implanted leguminous cover crop, further increases this interest.

1.5. Suitability for oil palm plantations

The areas favourable to oil palm plantations are very limited (cf map 13). The special problems linked to the gathering of the bunches, to the processing and evacuation of the product make it a marginal crop under the present conditions in the study area.

The 18 FG unit is favourable, the units 3, 4, 5f, 6f, 12 FG and 15 are moderately favourable and the units 5a, 6a, 9 FG and 18 FH are marginal.

1.6. Suitability for Robusta coffee and Pepper plantations

Due to their relatively similar requirements, these two crops have been regrouped.

The criteria taken into account are mainly :

- a good soil structure
- a high level in organic matter
- a good aptitude for fertilization
- not very steep slopes, if possible
- a high nutritional level, if possible.

The unit 18 FG seems favourable, the units 9 FG, 15, 16 and 18 FH as moderately favourable and the units 3, 4, 9 FG, 12 FG and 12 Fo as marginal.

Due to a relatively high sale price and an easy commercialization, coffee and pepper will be excellent cash crops for the transmigrants.

The cultivated areas should be limited to a maximum of 1 ha by family, due to the large amount of work necessary for these crops, especially for the harvest.

In the well run plantations the yield can be very high. Pepper plants and coffee shrubs keep, however, the capacity to produce with more extensive techniques. Although low,the financial return is interesting.

Near large villages such as Tewah, where the pressure on the ground is relatively high, the local authorities could promote coffee shrub and pepper plant plantations. But the high cost of labour may prevent the putting into operation of intensive techniques.

2. Development outlook

2.1. Transmigration Centres

In order that a site is favourable to transmigrant settlements, the transmigrants must be self supporting and benefit from a proper income. The areas allotted to farmers for food crops being only 2 ha per family, the cropping systems must be fairly intensive.

The soils favourable to such systems are rare in Kalimantan Tengah. The units 3 and 4 allowing the production of lowland rice would only suit small transmigration centres, due to a high occupation rate of the soil. The problem of access to the land could be resolved by the development of the valley. In cases similar in Sumatra, the proprietors are given 1 ha of irrigated rice fields without payment but in exchange for the surrender to the transmigration of 2 to 3 ha of irrigable land.

The unit 18 FG is less suitable and 18 FH is moderately favourable. The relative extension of the lowlands in unit 18 FG should ensure the subsistance of the settlers. In more sloping parts a large variety of perennial plants could provide rather high incomes for the transmigrants.

2.2. Local small-holders

For the Dayaks the problem is different. They are looking above all for the maximum return from the work supplied. A working day spent in harvesting rattan, tapping rubber trees or in manufacturing "siraps" (wooden tiles) brings in about 3,000 to 5,000 Rps. In Java the pay for a day's work in the paddy fields is rarely more than 500 Rps. The Dayaks are consequently little interested in intensive crop systems. The rehabilitation of the rubber tree plantations would make it possible to assure them large incomes in relation to the work supplied.

The necessity of frequent tapping in the absence of good access roads, limits the plantations to the immediate edges of the villages. On map I3c of the atlas the favourable sites for local small-holders plantations are consequently less spread out than the corresponding units of the Soil Reconnaissance Map.

2.3. Estates

Industrial plantations enable the development of sites to which the accessibility is difficult for the natives. If the sites in question are also favourable to transmigration centres, a structure of the "nucleus estate" type would be the most appropriate. In the opposite case more classical structures will be required.

Two major problems arise in either case :

- The difficulties of evacuation of the produce due to the remoteness of the area and the absence of a road infrastructure, and therefore, high transport costs.
- A local labour force which is rare and expensive. In the logging companies of the area more than 90% of the labour force is foreign to Kalimantan. For the industrial plantations the high cost which an imported labour force represents, will considerably reduce the profit margin.

For all these reasons, it is feared that the industrialists will be in no hurry to invest in Kalimantan Tengah.

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CONCLUSION

From an agronomic point of view the study area presents many favourable characteristics for agricultural development. However, there are always balanced by constraints which do not preclude development but generally imply high inputs.

The climate is very suitable for nearly all tropical crops : even temperatures, sufficient sunshine, high hygrometry and very reduced drought hazard. But on the other hand the very high rainfall is responsible of a strong leaching of the soils. The hyper-humid climate will also favourize the development of pests, diseases and weeds.

Most of the soils have a good structure and are deep and well drained. But their very low nutritional level doesn't allow permanent cultivation without chemical manuring. The generally hilly to hillocky topography in addition to the heavy and numerous tropical rains induce a very high erosion hazard particularly under permanent cultivation of annual food-crops.

For all these reasons the prospects for plantation development are rather good. According to the low fertility of the soils the less demanding crops as rubber trees and coconut palm are the most suitable. Other perennial crops suchs as coffee, pepper, oil palm, fruit trees can also he planted in some areas but higher inputs will be necessary in order to obtain correct yields.

Food crops production will have to be limited to the irrigable valley bottoms or to the alluvial valleys. In most cases, to achieve food self-sufficiency will be the most difficult problem for transmigration projects in this upland area of Central Kalimantan.

APPENDICES

APPENDICE 1.

CLIMATIC REQUIREMENTS OF VARIOUS TROPICAL PERENNIAL CROPS

Crops	Optimal temperatures °Celsius	Annual rainfall in mm	Tolerance to excessive rainfall	Necessity of a dry-season	Hygrometry	Sunshine hours / year
Rubber	23 - 35	1800-2500 regular	if good drainage	no	moderate to high	no limitation
Oil palm	25 - 28	>1800 regular	if good drainage	no	high	>1800
Coconut	27 - 28	1500-2500 regular	if good drainage	no	high	>2000
Robusta coffee	22 - 26	1500-1800	good	to group the flowerings	high	no limitation
Cocoa	23 - 30	1250-2500 regular	phyto-sanitary problems	no	high	no limitation
Pepper	23 - 26	2000-3000	if good drainage	to group the flowerings	high	no limitation
Clove	24 - 33	1500-3000	if good drainage	to group the flowerings	moderate to high	>1800
Nutmeg	24 - 34	2000-3500	if good drainage	no	high	no limitation
Citrus fruits	15 - 37 but under 23 for good maturation	1200-1400	reduces the quality	to group the flowerings	moderate	>1800
Cinnamon	24 - 33	2000-3000	if good drainage	no	high	>1600
Sugar cane	28 - 34 with high daily amplitude	1000-3500	if good drainage	for a good maturation	high	>1800
Banana	25 - 30	2000-2500	"	no	high	>1600
Mango	24 - 27	1000-2500	out of the flowering	for inducing flowering	moderate	>1800

APPENDICE 2.

CLIMATIC REQUIREMENTS OF VARIOUS TROPICAL ANNUAL CROPS

Crops	Optimal temperatures °Celsius	Monthly rainfall mm	Tolerance to excessive rainfall	Tolerance to drought	Hygrometry
Lowland rice	20 - 30	>250	good	out of the sensitive periods	high
Upland rice	20 - 30	>200	good	"	high
Maize	25 - 35	100 - 200	phyto-sanitary problems	"	high
Soya	25 - 35	100 - 200	"	good	mean to high
Groundnut	24 - 33	150 - 300	"	good	mean
Castor	24 - 27	>100	out of the flowering	rather good	high
Cassava	20 - 25	>100	good	good	high
Y a m s	23 - 25	>120	good	rather good	high
Cocoyams	20 - 25	>170	good	mean	high
Sweet potato	22 - 30	>150	good	rather good	high
Pineapple	21 - 35	100 - 150	reduces the quality	very good	high
Tobacco	18 - 27	150 - 200	phyto-sanitary problems	mean	high

APPENDICE 3

REQUIREMENTS AND TOLERANCES OF TROPICAL PERENNIAL CROPS IN MATTER OF SOILS

Characteristics	Rubber	Oil palm	Coconut	Robusta coffee	Cocoa	Pepper	Clove	Nutmeg	Sagu palm	Citrus fruits	Sugar cane	Banana
Optimal textures *	S to A	S to A	SS to A	L to A	SL to AL	L to A	SL to AL	SL to AL	AL to A	SL to AS	L to AS	L to A
Textures to be avoided *	SS & AA	SS & AA	AA	S & AA	LS & AA	S & AA	SS & A	S & A	S	S & A	AA & SS	S & AA
Soil depth cm	>100	>100	>80	>80	>150	>75	deep			>150		
Distance to the water table cm	>200	>80	>150	>180		>200	>300	deep	near	150 - 200	150 - 200	>150
Optimal pH	5 - 6	6 - 7	5 - 7,5	4,5 - 5,5	6 - 7,5	5,5 - 7	4,5 - 7			5,5 - 7	6 - 8	6 - 7,5
Tolerated pH	3,5 - 8	4,5 - 7	4 - 8	4,5 - 7	4 - 8	4 - 7				5 - 8	4 - 9	5 - 8
C content %		>1	>1	high	>3	>2,3					high	high
N content °/oo		>1	>1			>1				high	high	high
Tolerance to hydromorphy	no	low	no	low	no	no	no	no	good	no	no	no
Tolerance to drought	30 days	low	1 - 3 months	2 - 3 months	very low	mean	low	low	very low	good	good	very low
Tolerance to organic soils	no	yes if 1m + drainage	yes if 1m + drainage	no	no	no	no	no	yes	no	no	yes if drained
Tolerance to soils with low fertility	yes	yes	yes	avoid	no	avoid	avoid	avoid	yes	yes	no	avoid

* SS : very sandy, S : sandy, L : loamy, A : clayey, AA : heavy clay

APPENDICE 4.

REQUIREMENTS AND TOLERANCES OF TROPICAL ANNUAL CROPS IN MATTER OF SOILS

Characteristics	Lowland rice	Upland rice	Maize	Sorgho	Soya	Groundnut	Cassava	Yams	Cocoyam	Sweet potato	Pineapple	Tobacco
Optimal textures *	AL to AA	SL to AL	L to AL	SL to AA	SL to AL	S to LS	S to AL	S to A	L to AA	L to AL	SL to AL	S to A
Texture to be avoided *	S	S & AA	S & AA	S	SS & AA	A & AA	A	SS & AA	S	S & AA	AA	SS & AA
Soil depth cm	>40	>80	>80	>50	>60	>60	>50	>100	>50	>50	>80	>60
Distance to water table cm	near	>100	>100	>80	>80	>80	>80	>120	near	>50	>80	>100
Optimal pH	5,5 - 6,5	5 - 7	5,5 - 7	6 - 8	5,5 - 6	6,5 - 7,5	5 - 6	6 - 7		5 - 6	5 - 6,5	5 - 6
Tolerated pH	4 - 8	4 - 7	4,5 - 7	4 - 8	4 - 7	4,5 - 8	4 - 7			4 - 7	4 - 7,5	4 - 7
C content	mean	mean to high	high	high	mean to high	mean						high
N content	high		high	high	mean to low	mean to low		high		mean to low		high
Tolerance to hydromorphy	yes	mean	no	mean	mean	no	no	no	yes	no	no	no
Tolerance to drought	mean	mean	low	mean	2 - 3 weeks	good	good	mean	low	mean	very good	mean
Tolerance to organic soils	no	no	no	no	yes	no	no	no	no		yes if drained	no
Tolerance to soils with low fertility	yes	yes	no	yes	yes	yes	yes	no	mean	mean	yes	no

* SS : very sandy, S : sandy, L : loamy, A : clayey, AA : heavy clay.

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