HUNTING TECHNICAL SERVICES

Regional Planning Study of the First Division Sarawak

Volume III

Natural Resources

REGIONAL PLANNING STUDY

OF THE FIRST DIVISION SARAWAK

VOLUME III

NATURAL RESOURCES

ANNEX 1

CLIMATE

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1. INTRODUCTION.

The annex concerning the climate of the First Division of Sarawak is divided into three parts. First a general description of the climatic features is given. This short chapter is followed by a section in which the most important data are analysed and interpreted. Finally some proposals will be discussed regarding the necessity of enlarging the meteorological recording, together with the timing in relation to the second five year plan of Sarawak and the long term planning.

2. GENERAL DESCRIPTION OF THE CLIMATE.

The characteristic features of the climate of Sarawak are an uniform temperature, high humidity and copious rainfall.

According to the climate-classes by Köppen it is a tropical rain forest climate (Af), according to Thornthwaite a perhumid climate (A).

By uniform temperature is meant the lack of large temperature fluctuations throughout the year. In the coastal areas the cooling effect of seawinds is greater than in the interior, but lack of sufficient data does not allow quantification of this difference. The mean annual temperature is 25-26°C (78-80°F).

The mean annual relative humidity is 85%, and this rather high figure is closely related to the high amount of annual rainfall.

According to the rainfall classification by Mohr the whole area can be placed in class 1, which is defined as a continuously wet climate without any month in the year in which the rainfall is less than 4 inches (= 100 mm). The mean annual rainfall varies between 195" (4950 mm) south west of Kuching to 111" (2820 mm) in the western part of the First Division. The variations in precipitation are quite high, mainly due to local topography and the distance from the coast.

Although it is possible to speak of a rainy season (= landas season), from November up to March, a specific dry season does not occur. In contrast with West Malaysia, where four seasons are distinguished (two monsoons and two periods between), in Sarawak such a distinction is not possible, and here only one rainfall peak occurs (January). Periods of dry weather are too short and not intensive enough to dry out soils appreciably, so leaching of soluble weathering products- and sometimes also colloïded material- is a continuous process.

The implications of this climate for agricultural development are:
- a continuous vegetative growth (which for a certain part restricts soil erosion)
- weak development of soil structure
- crops which need a specific dry period can not be cultivated
- air drying of crop products gives problems
- high expenses for drainage schemes (due to large structures and drains)
- flood danger
- erosion danger

3. ANALYSIS AND INTERPRETATION OF CLIMATOLOGICAL DATA.

3.1. Temperature

Temperature measurements of some duration are only available from the meteorological station Kuching Airport.

Large temperature fluctations throughout the year do not occur. The daily range of temperature is moderate, being 10-15°F (5-8°C), but due to the cooling effect of the sea the general day temperatures are lower than those of the continental tropical areas. The highest temperature observed is 97,3°F (36,2°C), in July 1958, and the lowest 64°F (17,7°C) in February 1940. Table 1,on page12 of this annex, gives some data of Kuching Airport during a period of 15 years, while more detailed observations are published monthly by the Meteorological Services of Malaya and Singapore.

3.2. Rainfall

3.2.1. General.

Over the whole of Sarawak, but especially in the First Division, many measurements concerning rainfall are available, obtained from ca 40 rain gauges, most of which have been installed during the last decade. The reliability of these figures however, is not very high, because up to 1969 readings were carried out by volunteers, without payment, and during holidays readings often were not carried out. The map in the back of the Hydrological Yearbook of the D.I.D. gives a survey of the location of the various rain gauges.

3.2.2. Annual rainfall

The mean annual rainfall is enormous, and varies between 111" (= 2820 mm) at the island Talang Talang and 195" (= 4950 mm) at Sungai China, but the location of both gauges is exceptional. For most of the stations the mean annual rainfall varies between 135" (= 3300 mm) and 180" (= 4570 mm). Absolute maximum annual rainfall may differ from the mean annual rainfall by average 29% (for all the stations), absolute minimum annual rainfall by average 21% (see table 3). In the tables 2 and 3 mean, maximum and minimum data are stated for stations with a recording period of at least 6 years.

3.2.3. Monthly rainfall

The distribution of the rainfall over the year is not uniform. Some 60% comes down during the 5 months of November up to March and these months form the "rainy" or "landas" season. A dry season does not occur. In contrast with West Malaysia and the other Divisions of Sarawak, the distribution of the rainfall in the First Division has a typical one top curve, with the peak in January. The rainfall during the months of June, July and August is more or less the same (6-9",152-229 mm) and fluctations within these months are far less than fluctations during the rainy season.

Tables 4 , 5 and 6 deal with the available data of the most representative stations in the First Division. It can be noted that the year is tabulated from July to June. It is customary to consider hydrological data over continuous twelve-month periods and in such a way, that peak discharges in one season are not split up if tabulated or graphed. For this reason the "water year" in Sarawak is assumed to start in July and to end in June.

3.2.4. Daily rainfall

During the period July 1963 - June 1969 for some stations the precipitation during each day is registered (by means of a daily rainfall gauge). As these data are very important for disign criteria for drainage and irrigation projects, table 7 gives the data for all these stations.

The figures are absolute maximum data (the absolute minimum is zero). Heavy showers (more than 9"/day) all occur during the landas season.

3.2.5. Hourly rainfall

From 12 stations, mentioned in table 8, rainfall intensity figures are known, for the periods of 1 hour, 3, 6, 12, 18 and 24 hours. As, except for Kuching Airport, the recording period is rather small, it will be advisable to use the maximum figure of Kuching Airport of 17,63" per 24 hours (08.00 a.m. - 08.00 a.m.) not only for relevant design criteria in areas relatively near, but for the whole First Division.

3.2.6. Time of rainfall

At Kuching Airport during January and February most of the rainfall occurs between 9.00 p.m. and 9.00 a.m., during the other months between 1.00 and 6.00 p.m.

3.2.7 Interpretation of rainfall data

Dividing the First Division into three zones - a coastal, mid and interior zone -, the next areas can be distinguished (see figure 1):

I : Coastal area : rain gauge numbers 3, 7, 13, 16, 26, 34
II : Midland area : id. 1,5, 6, 11, 14, 18, 24, 25, 26, 38
III : Interior area: id. 6, 27, 28, 31, 33, 35, 36, 37, 50

The mean monthly rainfall for these three zones is calculated from table , and is plotted in figure 2. Clearly can be seen that:

a) The rainfall peak occurs in January, in all the three zones.
b) The amount of rainfall in the landas season decreases, going from the coast to the interior land.
c) The amount of rainfall during the period April-November is more or less the same for the different zones.
d) The total amount of rainfall over the whole year decreases from the coast to the interior land.

An explanation of the difference in rainfall between the areas may be as follows.

In the landas season the prevailing wind direction in the First Division is North (see chapter 3.5) and these sea winds bring the northern tropical air masses into contact with the air masses already present; this zone of contact is called "the Intertropical Front". Along this front cyclonic movements develop, with a weak horizontal and a strong vertical component. The latter causes the moisture-laden air to rise, which results in cooling condensation and precipitation. This kind of precipitation is known as "cyclonic", in contrast with "convective" (= thunderstorm type) and "orographic" (= mechanical lifting of air over mountain barriers) precipitation. During the landas season the rainfall is mainly of the cyclonic type, causing a high amount of rainfall in the coastal area, less in the midland area, and of minor importance in the interior zone. Because the amount of rainfall during the months April-September is more or less the same in the various zones, it can be concluded that in general the coastal area receives the highest amount of rainfall during the whole year, while the interior area receives the lowest amount (yet still considerable).

This conclusion is of importance for drainage criteria for agricultural projects in the different zones.

During the months of June-August the Intertropical Front once more passes Sarawak, but now from the south, influenced by the South East monsoon. When this current reaches Sarawak, the rain has already precipitated in the mountain range at the Indonesian border, so no distinct rainfall peak occurs in this period in Sarawak (In fact, some stations in the First Division do show two rainfall peaks - the second one in July, very weak -, although these variations can also easily be attributable to differences in installation of instruments and altitudes).

The total amount of rainfall in the various Divisions tallies with the behaviour of the Intertropical Front, because the direction of this front in the landas season is to the South West along the Fifth, Fourth, Third and Second Divisions, and turns off to southern direction near the First Division because the Coriolis-forces near the equator decrease. So the Fifth Division (being firstly exposed to the sea winds) and the First Division have much rainfall, while the front parallel to the coast causes less precipitation in the other Divisions.

Table 9 gives information concerning the rainfall at some stations in the other Divisions, and the irregularity concerning number and time of rainfall peaks, influenced by the Intertropical Front and differences in location and physiography, is still greater there.

3.3. Evaporation

No comprehensive evaporation information is yet available. In 1963 a "Class-A" pan (Φ = 47,5" and h = 10") was installed at the station of Kuching Airport, and also in some places in the other Divisions (see table 10). These pans are normally installed on the ground surface and not dug into the ground with the upper side on equal level with the ground surface. For this reason the figures obtained are too high (splash-effect, and warmth-supply through the rims).

The mean daily evaporation in the First Division is 0,2" (= 5 mm), the mean maximum evaporation during dry periods is 7"/month (= 175 mm/month), while the mean monthly evaporation is 6" (= 150 mm). During the period of June-November the evaporation is fairly constant, while the maximum occurs in May (the top in January in figure 3 is due to the exceptionally dry month in 1965, which overrules the other data for the same month in so short a recording period).

According to table 10, the differences between the Divisions are rather high. The mean data are the lowest in the Second and Third Division (5,5"), higher in the First Division (5,9") and the Fourth Division (6,1"), and the highest in the Fifth Division (6,9"). These differences are due to varieties in rainfall (see 3.2.7.), sunshine (see 3.6.), humidity and/or wind velocity.

As the evaporation in the Fourth and Fith Division is higher than in the First Division, the water requirements for the growth of crops will also be higher.

Purely as an example in Appendix 1 the potential evapotranspiration at Kuching Airport is calculated for the month of July 1965 (making use of the Smithsonian Meteorological Tables and some other literature) according to Thornthwaite, Turc (1), Turc (2), and Penman.

3.4. Humidity

Again only data are available from Kuching Airport, and they show high figures. The mean relative humidity during 24 hours is 85%, while at 02.00 p.m. this is 69%. The course of the relative humidity over the various months is set out in figure 4.

3.5. Wind

For Kuching Airport data are available concerning wind directions, wind velocities and occurrence of thunderstorms, registered by means of resp. a weather-vane,an anemometer and visual observation.

The wind directions depend on the season. During the period October-April the prevailing wind directions are NNW, N and NNE, and during the period May-September they are SSW, S and SSE. The change-over between these directions is rather distinct, due to the change-over of the Intertropical Front.

The surface wind velocities are generally light (0-3 m.p.h.). Velocities of 13-18 m.p.h. are only experienced ca 7 times a year.

Thunderstorms occur mostly during the months of May-September, normally accompanied by moderate rainfall (0,02-0,07"/10 min.), but during the landas season some heavy thunderstorms also occur.

It is worth mentioning that Sarawak is situated in a small equatorial belt which is free of cyclones.

3.6. Sunshine

The duration of bright sunshine is registered at the meteorological station at Kuching Airport, by means of a Campbell-Stokes sunshine recorder. The average number of hours of bright sunshine per day for the period of September-March is less than 5 hrs, and for the period April-August 5,5 hrs or more. Figure 5 shows the absolute maxima and minima and the mean data for every month.

Comparing those data with the other Divisions, the next table appears:

First Division : Kuching Airport : 4,61 hours (mean)
Third Division : Sibu Airport : 5,47 " "
Fourth Division: Bintulu : 5,84 " "
Fourth Division: Miri : 6,66 " "

N.B. Of the Second and Fifth Division no data are available.

The higher values of the duration of bright sunshine in the Third and Fourth Division due to less clouds and winds parallel to the coast open possibilities for more radiation requiring crops, but at the same time these crops will need more water during the growing season (see also chapter 3.3.).

4. PROPOSALS.

4.1. Meteorological instruments

a) Rain gauges

Although already some 40 gauges are installed in the First Division, it is still not possible to obtain a reliable overall picture of the distribution of the rainfall in the area. For this reason it is proposed to place rain gauges in the following areas:

- in the catchment area of the S. Samunsam
- in the mountainous area near G.Berumput
- at the coast near Kpg.Sampadi and near Sebangan
- at the Indonesian border near Kpg.Stass and near Kpg.Embahn
- in the upper catchment area of the Btg.Kayan
- in the middle catchment area of the Btg.Samarahan
- at the border with the Second Division near Kpg. Munggu Ayer.

As it is most probable that these areas have insufficient access and lack of reliable observers, adequate measures to overcome these problems have to be taken.

However, it will not be necessary to purchase all these instruments because the number of gauges in some areas (near Kuching, near S.Bedup) can be diminished in order to install these instruments in the above mentioned places. Only then a reliable isohyete-map can be drawn, and Thiessen-polygons calculated.

b) Meteorological screens

At the meteorological stations of Sarawak "Stevenson" screens are installed, in which temperature and humidity data are measured by a thermometer, a maximum and a minimum thermometer and a dry- and wet-bulb. It is recommended also to install a thermohygrograph and an Assman-psychrometer in the screens of the meteorological stations. The advantage of a thermohygrograph is that it measures humidity and temperature continuously. Furthermore the maximum and minimum thermometer can thus be checked by using the thermometers of the Assman-psychrometer as an absolute calibration standard. This psychrometer, which is quite reliable for measurements of relative humidity three times a day, has to be used as a standard for one calibration point of the hygrograph. The costs of these instruments are roughly M$ 400,- each.

4.2. Agro-meteorological instruments.

The following instruments have partly a meteorological function, but have to be used and interpreted for agricultural purposes. For this reason it is recommended to install these instruments at the Agricultural Experiment Station Semongok.

a) Lysimeter

In order to obtain direct measurements of the actual evapotranspiration of the crop, a lysimeter should be installed. A very simple form of such an instrument is based on the design of Gilbert and Van Bavel (1954), which is described in the book of R.O. Slatyer and I.C.Mc. Ilroy: "Practical Micro-climatology", UNESCO, 1961, and in the Journal "Transactions", American Geophysical Union, Vol. 35, nr. 6, 1954. This lysimeter preferably should be installed in a wet-rice plot, and the installation, observation and maintenance should be carried out in close cooperation between the Department of Agriculture and the Drainage and Irrigation Department.

b) Radiation integrator

In order to obtain information concerning the radiation per day, it is advised to install a Gun-Bellani radiation integrator at the Experiment Station. Because of the fact that the duration of bright sunshine (see chapter 3.6) in the Fourth Division is higher than in the First Division, installation of such an instrument in the Fourth Division (at a Padi Experiment Station) should be expedient too. Because these instruments, approximately M$ 450,- each, have to be calibrated before use, they first should be installed at a station where radiation already is measured (e.g.Singapore?).

All these proposals should be realised within the period of the second five year plan of Sarawak, in order to obtain useful data in the following period.

4.3. Meteorological Branch.

Activities concerning meteorological observations at present are carried out by various departments. The stations Talang-Talang Island, Kuching Airport, Sibu Airport, Bintulu Airport and Miri are under control of the Department of Civil Aviation; the daily rainfall stations except those mentioned above are under control of the Drainage and Irrigation Department; the Department of Agriculture has the responsibility of observations at the Agricultural Experiment Stations.

This division of activities can be rather sound, because the (meteorological and statistical) interest of the Department of Civil Aviation is different from the (agricultural) interest of the Department of Agriculture and from the (hydrological) interest of the Drainage and Irrigation Department. These differences are also revealed in the meteorological year (January-December) and the hydrological year (July-June).

In how far each department will collect and interprete his own data is up to the department itself, but it is very essential that copies of all the data collected should be sent to one organisation, which is charged with the coordination and publishing.

As for the Federation of Malaysia and the State of Singapore a Meteorological Service already exists, it is proposed to establish for Sarawak (and Sabah) a separate branch, with a central office in Kuching or at Kuching Airport, headed by a director with meteorological experience, who will coordinate, interprete and publish all the meteorological data of the five Divisions of Sarawak, as mentioned above.

Furthermore, in each Division a meteorological station should be established (at present lacking in the Second and Fifth Division), manned by two observers with sufficient school-training, to analyse the instrument-readings at the station, to maintain and repair the instruments, to collect the readings of the rain gauges by the various part time observers in their Division and to mail these data to the central office. As far as not yet available, these divisional offices should be established within the second five year plan.

In order to obtain reliable rainfall data it is very essential that all part time observers (mostly teachers) of the various rain gauges scattered throughout the State of Sarawak receive an allowance for their activities (such an allowance was started in 1969).

The total costs of these proposals for whole Sarawak will be as follows:

a) Buildings :	- divisional offices	: 5xM$	8,500,-	= M$ 42.500,-
	- central office	: 1xM$	15.000,-	= M$ 15.000,-
b) Personnel :	- director	: 1xM$	1.250,-/month	= M$ 1.250,-/month
	- observers	: 10xM$	700,-/month	= M$ 7.000,-/month
	- clerks/typists	: 5xM$	350,-/month	= M$ 1.750,-/month
	- part time observers:			= P.M.
c) Instruments:	- thermohygrographs	: 5xM$	400,-	= M$ 2.000,-
	- psychrometers	: 5xM$	400,-	= M$ 2.000,-
	- lysimeters			= P.M. 1)
	- radiation integrator:	2xM$	450,-	= M$ 900,-

1) The lysimeters can be constructed with local material.

Table 1 Air temperatures at Kuching Airport (Fahrenheit)

(15 years' record)

	Mean Air Temp. 08.00 hr.	14.00 hr.	20.00 hr.[1)]	Mean 24 hrs.[2)]	Highest max. + year	Lowest min. + year
January	74.6	82.7	76.7	77.4	93 - 1950	65.2 - 1957
February	74.5	84.0	77.2	77.7	93 - 1950	64 - 1940
March	75.0	85.0	78.0	78.7	93.0 - 1960	65 - 1955
April	75.8	86.8	77.5	78.8	96 - 1941	69.0 - 1957
May	76.7	87.4	78.3	79.8	95 - 1950	69.3 - 1959
June	75.8	87.4	78.7	79.8	96 - 1952	66.4 - 1956
July	75.6	87.0	78.0	79.2	97.3 - 1958	67 - 1955
August	75.0	87.2	77.8	79.2	96 - 1953	65 - 1940
September	75.6	86.7	77.0	78.8	94.1 - 1957	66 - 1953
October	75.5	85.4	76.5	78.5	94 - 1951	68 - 1954
November	75.3	84.5	76.3	78.4	93 - 1949	68.2 - 1956
December	74.9	83.6	76.3	78.0	92.6 - 1960	66.9 - 1957

1) 9 years' record

2) 12 years' record

Table 2 Mean annual rainfall (N_{mean})

Lat. (N)	Long. (E)	Rain gauge	Nr.	Rainfall (inches)	Recording period(years)	Elevation (ft. above sealevel)
1°29'	110°20'	Kuching Airport	1	158.54	14	85
1°34'	110°20'	Kuching Post Office 1)	2	159.50	56	80
1°37'	110°12'	Sungai China	3	195.52	31	388
1°55'	109°46'	Talang Talang Island	4	110.96	17	?
1°25'	110°59'	Bau	5	143.88	26	?
1°12'	110°32'	Tarat	6	143.40	14	?
1°40'	109°50'	Lundu	7	137.10	29	?
1°35'	110°11'	Pangkalan Bentang 1)	9	158.78	6	?
1°21'	110°11'	Dahan Estate	11	169.07	17	?
1°43'	110°27'	Telok Assam	13	171.95	9	?
1°24'	110°20'	Semongok	14	162.02	9	?
1°48'	109°48'	Sematan 1)	16	178.21	8	8
1°20'	110°41'	Simunjan	18	163.78	14	?
1°16'	110°25'	Dragon School	24	134.32	8	90
1°32'	110°21'	Batu Lintang	25	160.45	11	15
1°35'	110°11'	Matang	26	165.56	42	385
1°05'	110°38'	Sungai Bedup	28	122.18	6	40
1°18'	110°33'	Samarahan Estate	38	149.69	13	?
1°22'	110°46'	Sadong Mines 1)	42	143.95	13	?
1°33'	110°14'	Sungai Tungah 1)	44	164.08	9	?
1°23'	110°19'	Leper Camp 1)	45	149.13	11	?
1°27'	110°17'	Batu Kitang	47	149.23	9	?
1°18'	110°30'	Tebakang 1)	50	136.41	8	?

1) Ceased functioning

Table 3 Maximum and minimum annual rainfall, absolute

Nr.	Rain gauge	Abs.Maximum		Abs.Minimum		$N_{max} - N_{mean}$		$N_{mean} - N_{min.}$	
		inches	year	inches	year	inches	%	inches	%
1	Kuching Airport	197.85	1962	124.66	1965	39.31	25	33.88	21,5
2	Kuching Post Office	225.59	1882	106.46	1888	66.09	41,5	53.04	33,5
3	Sungai China	273.30	1962	142.51	1926	77.78	40	53.02	27
4	Talang Talang Island	166.56	1957	47.72	1963	55.60	50	63.24	57
5	Bau	216.91	1918	80.25	1937	73.03	40	63.63	44
6	Tarat	169.05	1966	119.86	1953	25.65	18	23.54	16
7	Lundu	192.04	1966	101.33	1927	54.94	42	35.77	26
9	Pangkalan Bentang	181.01	1955	142.79	1951	22.23	14	15.99	10
11	Dahan Estate	237.61	1962	143.34	1959	68.54	42	25.73	15
13	Telok Assam	187.41	1968	144.81	1965	15.46	9,5	27.14	16
14	Semongok	200.02	1962	134.31	1959	38.00	23,5	27.71	17
16	Sematan	310.44	1962	119.69	1967	132.23	75	58.52	33
18	Simunjan	201.50	1962	133.85	1963	37.72	23	29.93	18
24	Dragon School	173.83	1962	98.32	1965	39.51	28,5	36.00	27
25	Batu Lintang	192.29	1962	138.51	1959	31.84	19	21.94	13
26	Matang	248.65	1916	121.48	1961	83.00	50	44.08	16,5
28	Sungai Bedup	133.81	1964	106.33	1968	11.63	9,5	15.85	13
38	Samarahan Estate	171.77	1954	131.11	1950	22.08	15	18.58	12,5
42	Sadong Mines	196.01	1917	115.59	1914	53.06	37	28.36	20
44	Sungai Tengah	198.38	1926	129.09	1918	34.30	21	34.99	17
45	Leper Camp	180.83	1932	119.41	1938	31.70	21	29.72	20
47	Batu Kitang	160.19	1963	130.97	1968	10.96	7,5	18.26	12
50	Tebakang	160.62	1964	125.29	1965	24.21	18	11.12	8
	Average						29%		21%

Table 4 : Mean monthly rainfall data (inches) of 12 representative rain gauges (for location see figure 1)

Month	Gauge nr.1	3	5	6	7	13	14	16	18	28	38	50
July	8.77	8.64	7.33	7.63	5.52	7.76	7.51	6.85	9.22	7.00	7.48	8.03
Aug	7.87	9.19	8.82	7.15	5.63	6.45	7.96	5.64	8.83	9.95	7.45	7.19
Sept	11.07	11.35	9.45	10.20	6.89	7.23	7.92	6.77	10.07	6.08	9.46	9.96
Oct	11.39	13.75	12.17	12.25	4.33	11.50	9.41	9.91	11.46	9.57	14.96	12.90
Nov	12.51	15.54	12.83	13.02	10.42	12.65	11.93	12.45	13.42	9.99	13.56	11.84
Dec	15.91	23.97	16.09	14.01	16.90	23.51	18.23	28.18	19.30	13.44	15.91	12.18
Jan	24.39	35.66	23.20	19.03	23.80	33.88	27.53	42.25	27.69	12.86	20.51	16.21
Feb	22.66	27.18	12.88	16.22	22.24	27.73	25.88	30.63	18.36	14.32	18.46	12.39
Mar	14.31	17.80	10.92	13.06	15.74	21.19	16.03	17.38	14.84	14.06	13.53	10.04
Apr	11.14	12.28	11.35	11.67	7.22	7.14	11.59	9.24	11.53	7.74	12.11	11.08
May	10.84	11.99	8.61	9.61	7.45	6.38	10.44	4.56	11.93	10.31	10.21	8.77
June	7.67	8.17	7.57	6.10	7.07	6.47	7.55	4.30	7.08	6.84	7.08	5.92

Table 5: Abs. maximum monthly rainfall (inches) and year of occurrence of 12 representative rain gauges

	1	3	5	6	7	13	14	16	18	28	38	50
July	17.54 / 60	19.02 / 55	15.66 / 60	13.47 / 64	11.93 / 57	15.98 / 68	11.49 / 64	15.80 / 64	14.51 / 56	8.90 / 64	15.82 / 64	13.75 / 52
Aug.	15.23 / 69	21.10 / 69	20.66 / 17	16.31 / 66	13.13 / 50	12.11 / 66	15.06 / 66	9.97 / 62	19.35 / 36	17.96 / 66	12.28 / 66	18.82 / 66
Sept.	22.11 / 68	15.72 / 62	19.19 / 19	19.71 / 51	23.74 / 50	11.87 / 67	11.90 / 60	11.04 / 62	14.07 / 36	7.91 / 62	14.57 / 68	20.26 / 55
Oct.	20.75 / 69	26.43 / 55	24.87 / 56	20.15 / 56	13.62 / 58	18.95 / 68	18.15 / 69	13.07 / 63	16.76 / 58	12.75 / 62	25.00 / 49	17.84 / 54
Nov.	16.01 / 54	24.38 / 48	30.68 / 18	22.30 / 50	29.71 / 50	18.07 / 61	20.87 / 69	17.61 / 61	21.14 / 67	14.62 / 66	23.80 / 67	20.57 / 66
Dec.	23.86 / 64	52.99 / 39	25.03 / 64	19.10 / 65	36.35 / 34	33.45 / 67	25.63 / 64	68.16 / 62	27.20 / 58	18.50 / 65	23.90 / 68	18.91 / 65
Jan.	45.88 / 63	65.37 / 62	52.59 / 64	27.39 / 53	55.56 / 18	47.64 / 62	50.19 / 63	81.39 / 62	61.37 / 63	17.54 / 66	38.65 / 62	23.79 / 53
Febr.	61.32 / 64	74.72 / 64	47.33 / 64	35.71 / 64	55.74 / 64	36.83 / 63	42.68 / 64	68.56 / 63	27.66 / 64	23.11 / 64	34.76 / 64	18.40 / 65
Mar.	23.53 / 68	29.69 / 45	22.10 / 17	20.09 / 68	48.22 / 67	29.25 / 67	25.14 / 68	25.22 / 64	21.00 / 67	15.72 / 64	19.90 / 68	20.71 / 50
Apr.	16.61 / 53	24.87 / 69	22.51 / 67	18.03 / 52	14.51 / 51	9.49 / 69	17.19 / 61	14.52 / 62	21.88 / 61	10.64 / 65	19.77 / 69	16.62 / 50
May	17.00 / 69	21.45 / 40	18.82 / 59	13.53 / 52	17.05 / 21	10.25 / 64	14.15 / 63	7.52 / 64	19.49 / 63	12.60 / 69	18.22 / 68	13.08 / 69
June	11.03 / 60	14.20 / 69	12.93 / 57	8.83 / 50	41.12 / 16	9.18 / 64	12.10 / 66	7.02 / 64	12.34 / 58	11.61 / 65	10.46 / 50	12.70 / 65

Table 6 Abs. minimum monthly rainfall (inches) and year of occurrence of 12 representative rain gauges

	1	3	5	6	7	13	14	16	18	28	38	50
July	3.36 / 67	3.75 / 43	1.71 / 39	3.56 / 55	2.40 / 65	2.83 / 67	2.68 / 61	3.00 / 69	1.55 / 58	3.69 / 65	2.71 / 65	3.73 / 65
Aug.	2.60 / 67	3.61 / 67	2.30 / 36	3.26 / 64	2.64 / 51	2.70 / 67	3.18 / 59	0.50 / 67	2.43 / 63	4.18 / 64	3.41 / 64	2.40 / 53
Sept.	4.88 / 65	6.38 / 66	2.67 / 32	2.16 / 67	1.89 / 66	5.09 / 61	4.63 / 67	2.80 / 67	5.22 / 63	3.30 / 65	3.37 / 61	4.26 / 69
Oct.	5.62 / 65	7.60 / 41	3.92 / 31	3.71 / 55	2.96 / 66	6.79 / 61	5.96 / 60	6.90 / 67	3.86 / 61	6.23 / 66	6.34 / 61	9.80 / 55
Nov.	8.42 / 65	7.80 / 57	5.85 / 33	5.31 / 63	3.81 / 61	8.99 / 65	6.35 / 63	5.54 / 60	2.92 / 62	6.30 / 63	8.67 / 65	6.86 / 63
Dec.	10.04 / 60	11.45 / 26	4.71 / 33	8.20 / 53	5.26 / 18	12.63 / 66	12.32 / 59	9.17 / 61	11.08 / 61	8.09 / 63	10.06 / 63	9.25 / 52
Jan.	11.32 / 64	12.39 / 50	4.63 / 56	10.61 / 65	6.59 / 31	19.40 / 64	15.60 / 64	17.90 / 69	13.52 / 65	6.53 / 69	10.25 / 50	10.23 / 69
Feb.	9.99 / 54	10.83 / 54	2.93 / 38	7.88 / 69	5.26 / 18	13.85 / 68	12.61 / 69	11.50 / 68	6.59 / 59	6.22 / 69	10.99 / 68	7.07 / 69
March	6.67 / 60	5.06 / 41	4.24 / 57	7.59 / 57	3.35 / 50	9.37 / 66	9.34 / 66	8.83 / 59	6.54 / 56	11.08 / 69	10.28 / 54	7.31 / 55
April	3.87 / 63	6.31 / 52	3.55 / 38	6.17 / 68	3.68 / 31	3.92 / 67	6.78 / 68	3.45 / 68	3.41 / 63	3.39 / 63	5.19 / 67	8.03 / 66
May	5.93 / 65	5.87 / 48	3.32 / 39	7.43 / 50	2.77 / 53	2.29 / 66	7.70 / 62	1.13 / 68	5.69 / 62	9.06 / 63	4.43 / 65	4.35 / 54
June	4.51 / 69	3.46 / 47	2.07 / 38	2.98 / 57	0.87 / 33	4.52 / 63	4.00 / 61	0.90 / 68	2.76 / 62	3.58 / 67	3.03 / 69	3.95 / 55

Table 7 Daily rainfall, abs.maximum data (inches)
Period: June 1963 - June 1969

Rain gauge Nr.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Febr.	Mar.	Apr.	May	June
1	2.57	3.36	3.16	4.83	3.52	6.95	10.96	16.30	5.14	3.05	5.27	3.35
3	2.25	3.61	2.10	3.00	2.96	4.57	12.80	12.01	6.35	4.50	3.50	3.00
5	2.57	4.60	3.47	3.45	3.50	4.82	3.28	8.11	2.93	4.80	3.40	3.20
6	3.27	2.95	3.15	3.09	3.01	4.64	6.01	9.66	3.01	3.65	5.45	2.55
7	2.57	3.08	2.30	1.81	3.52	7.92	12.40	10.64	9.61	3.83	3.41	2.31
11	2.71	3.46	3.85	5.01	2.30	7.57	6.60	7.43	5.00	2.72	2.96	2.56
13	3.42	5.60	6.48	4.95	3.56	8.30	9.40	8.95	7.77	2.55	3.82	2.62
14	2.86	3.50	2.47	2.85	2.70	6.92	5.91	10.86	4.58	3.17	4.56	3.01
16	8.51	3.47	6.30	5.03	5.25	9.00	11.09	6.10	5.95	6.10	2.39	3.19
18	2.27	2.40	4.60	2.57	3.30	5.35	5.60	4.13	4.80	5.00	3.73	3.25
24	2.42	2.84	2.80	3.21	3.60	5.00	7.40	4.10	3.60	3.10	3.75	2.45
25	3.29	2.67	2.80	3.65	3.15	8.80	5.94	9.90	4.93	3.10	2.80	4.38
26	3.50	3.00	1.72	2.50	4.67	7.86	6.50	7.00	7.35	3.47	7.00	2.79
27	3.51	3.36	3.20	4.87	4.26	3.86	3.22	4.50	3.35	2.99	3.11	2.36
28	2.80	6.90	2.84	3.92	4.30	3.78	8.37	4.92	4.00	3.76	5.62	2.12
31	4.94	3.60	3.27	2.96	2.50	2.65	2.79	3.91	3.45	3.76	2.09	1.87
33	2.57	6.89	2.71	3.00	3.15	3.60	8.94	6.84	3.23	4.14	3.37	3.91
34	4.30	3.45	2.59	5.85	6.50	5.97	9.63	13.55	7.15	2.49	7.30	3.02
35	2.55	3.08	3.55	2.90	4.41	2.73	8.80	3.78	2.39	2.80	4.28	2.13
36	2.82	6.89	2.73	2.60	3.92	2.47	3.88	6.82	3.00	2.97	3.10	2.30
37	3.48	2.90	2.13	2.84	2.37	3.30	5.77	3.37	4.20	2.87	3.34	2.42
38	2.45	2.50	3.50	3.21	2.75	3.80	3.00	6.10	4.00	3.90	3.45	2.00
50	2.57	4.39	3.31	3.55	3.28	2.68	3.00	5.36	4.48	2.31	6.75	1.98

Table 8 Abs.maximum rainfall per hour, 3, 6, 12, 18 and 24 hours (inches)

Rain gauge	Period	1 hr.	3 hrs.	6 hrs.	12 hrs.	18 hrs.	24 hrs.
1 Kuching Airport	1950 - 1969	4.28	8.27	14.88	17.06	17.08	17.63
6 Tarat	1962 - 1969	3.96	4.28	6.02	9.66	9.66	9.66
7 Lundu	1963 - 1969	4.28	6.61	8.43	9.49	9.64	12.40
13 Telok Assam	1962 - 1969	4.62	7.47	7.53	10.94	10.94	10.94
14 Semongok	1962 - 1966	3.50	5.00	7.00	10.12	10.76	10.86
25 Batu Kitang	1962 - 1969	3.75	5.27	7.50	8.70	9.25	9.90
27 Serian	1962 - 1969	3.20	4.55	5.62	6.15	6.37	6.37
28 S.Bedup	1962 - 1969	3.50	6.70	6.80	7.65	7.70	7.75
33 S.Merang	1963 - 1967	3.02	5.53	6.51	6.89	6.89	6.89
35 G.Semuja	1963 - 1967	2.75	4.45	4.65	5.35	5.35	5.35
36 G.Ranggau	1963 - 1967	4.70	5.65	6.60	6.89	6.89	6.89
37 S.Tab	1963 - 1967	2.70	3.45	4.10	4.20	4.20	4.30

Table 9 Mean monthly rainfall in the other Divisions (inches)

Div.	Location	Period (years)	J	A	S	O	N	D	J	F	M	A	M	J	Yearly
II	Simanggang	18	9.53	10.92	11.09	15.47	17.34	16.56	16.47	13.45	12.99	15.18	12.02	9.96	159.98
II	Lubok Antu	7	9.39	9.71	9.13	10.13	14.21	11.56	11.36	10.76	9.84	12.91	10.38	5.55	124.93
II	Lingga	8	8.04	8.66	10.03	10.49	13.37	15.18	12.66	14.38	9.08	9.84	8.35	5.56	125.64
II	Betong	8	10.22	10.17	11.33	18.55	14.59	17.92	13.98	12.86	10.36	10.69	9.65	5.82	146.14
II	Saratok	8	10.56	9.51	11.52	11.90	12.17	16.43	15.25	10.68	11.58	9.29	9.17	6.33	134.39
II	Mean Second Division		9.55	9.79	10.62	13.31	14.34	15.53	13.94	12.43	10.77	11.52	9.91	6.44	138.22
III	Sarikei	13	7.03	8.62	10.98	10.94	10.14	13.24	12.97	10.67	10.99	9.99	7.88	6.17	119.62
III	Sibu	22	8.20	9.21	9.93	11.09	11.26	12.62	13.61	10.99	12.11	10.43	9.15	7.53	126.13
III	Mukah	14	5.55	6.27	11.27	14.45	10.49	19.37	20.77	17.83	12.99	5.71	7.46	7.01	136.17
III	Matu	9	6.40	8.32	9.60	10.59	12.92	17.47	15.50	13.34	6.68	6.27	7.30	6.15	120.54
III	Belaga	8	12.11	7.22	9.75	13.86	12.59	15.19	11.31	13.65	11.23	14.35	11.69	9.26	142.21
III	Kapit	15	8.94	9.57	11.83	13.64	11.72	13.36	16.89	12.07	13.28	12.54	13.40	8.36	145.58
III	Mean Third Division		8.04	8.20	10.56	11.93	11.50	15.21	15.17	13.09	11.05	9.88	9.48	7.41	131.71
IV	Miri	31	8.03	8.16	12.57	13.89	14.87	14.38	12.39	7.34	6.43	7.43	9.01	9.67	124.17
IV	Baram	22	7.39	8.35	10.28	11.61	9.45	12.78	10.21	8.14	9.35	8.67	8.69	7.79	112.78
IV	Bintulu	33	9.16	10.80	13.23	15.54	15.84	17.74	14.35	11.84	11.36	10.77	10.30	10.92	151.85
IV	Mean Fourth Division		8.16	9.10	12.03	13.68	13.39	14.79	12.32	9.11	9.05	8.96	9.33	9.79	129.60
V	Limbang	21	9.26	11.18	13.16	13.68	13.25	13.96	14.31	10.50	9.83	11.17	12.57	11.35	144.22
V	Ukong	8	12.03	9.60	15.18	16.47	14.17	13.64	12.43	11.43	8.64	13.58	12.70	11.50	151.38
V	Lawas	26	11.77	12.67	15.57	16.73	16.53	16.25	12.31	11.27	12.25	13.02	14.78	12.89	166.09
V	Mean Fifth Division		11.02	11.15	14.84	15.63	14.67	14.61	13.02	11.07	10.24	12.59	13.35	11.91	153.90

Table 10 Evaporation of open pans (inches)

Div.	Location	Period (years)	Jan.	F	M	A	M	J	J	A	S	O	N	D	Mean
I	Kuch.Airport	7	6.25	5.39	5.50	5.82	6.30	5.96	5.81	6.07	6.04	5.98	5.80	5.66	5.90
II	Simanggang	7	6.04	5.15	5.65	5.62	5.33	5.37	5.33	5.42	5.25	5.92	5.39	5.38	5.49
III	Kapit	6	4.99	4.74	5.73	5.58	5.66	5.48	5.70	5.93	5.56	6.06	5.12	5.57	5.51
III	Belaga	5	5.76	5.02	5.47	5.83	5.60	5.26	5.40	5.16	5.40	5.54	5.32	5.95	5.48
III	Sibu Airport	6	4.91	4.83	5.28	5.46	5.57	5.78	5.76	5.45	5.40	5.42	5.12	5.07	5.34
IV	Bintulu Airp.	6	5.91	5.54	5.96	6.45	5.99	6.13	5.89	6.23	6.08	5.95	5.92	5.67	5.98
IV	Miri	6	5.49	5.66	6.35	6.70	6.73	6.62	6.61	6.58	6.26	6.19	5.74	5.63	6.21
V	Limbang	5	7.06	6.93	7.58	7.30	6.74	6.79	6.82	6.54	6.43	7.16	6.58	6.61	6.88

APPENDIX 1

Calculation of the potential evapotranspiration at Kuching Airport for the month of July 1965, according to resp. Thornthwaite, Turc (1), Turc (2) and Penman.

- Thornthwaite : $E_p = 1{,}6\left(\frac{10\,t}{I}\right)^a = 3{,}36$ mm/day (= 0,13"/day)

$[I = 140{,}92;\ a = 3{,}484;\ t = 25{,}8^{\circ}C]$

- Turc (1) : $E_p = \frac{P + 80}{1 + \left(\frac{P + 45}{L}\right)^2} \times \frac{31}{10}$ (for L > 10) = 5,43 mm/day (=0,20"/day)

$\left[H_A = 800\ cal/cm^2;\ L = \frac{(t+2)\sqrt{(0{,}29\cos\Phi + 0{,}54\frac{n}{N})H_A}}{16};\right.$

$\left.P_{july} = 0{,}185";\ t = 26{,}5^{\circ}C;\ \cos\Phi = 0{,}998;\ n = 6{,}71\ hrs/day;\ N = 12\ hrs\right]$

- Turc (2) : $E_p = \frac{0{,}40}{31}\frac{t}{(t + 15)}(R + 50) = 4{,}32$ mm/day (=0,17"/day)

$[t = 26{,}5^{\circ}C;\ R = 0{,}59.H_A;\ H_A = 800\ cal/cm^2]$

- Penman :

$$E_o = \frac{\frac{\Delta}{59}\ 0{,}95(0{,}29\cos\Phi + 0{,}54\frac{n}{N})H_A - 118.10^{-9}(273+t)^4(0{,}10+0{,}90\frac{n}{N})(0{,}56-0{,}092\sqrt{e_a})}{\Delta + 0{,}485}$$

$$+ \frac{0{,}485 \times 0{,}35\,(0{,}50 + 0{,}54\,u)(e_{max} - e_a)}{\Delta + 0{,}485} \text{ and } E_p = fE_o =$$

= 4,51 mm/day (= 0,18"/day)

$[\Delta = 1{,}50;\ \cos\Phi = 0{,}998;\ n = 6{,}71;\ N = 12{,}07;\ H_A = 800\ cal/cm^2;\ t = 26{,}5^{\circ}C;$

$e_a = 20{,}746;\ u = 1{,}5\ m/sec;\ e_{max} = 26{,}03;\ f = 0{,}8]$

Excluding Thornthwaite, the average E_p = 0,18"/day, and this figure corresponds with the pan measurements at Kuching Airport, taking into account that the pan figures (0,2"/day) are too high (see chapter 3.3, first alinea).

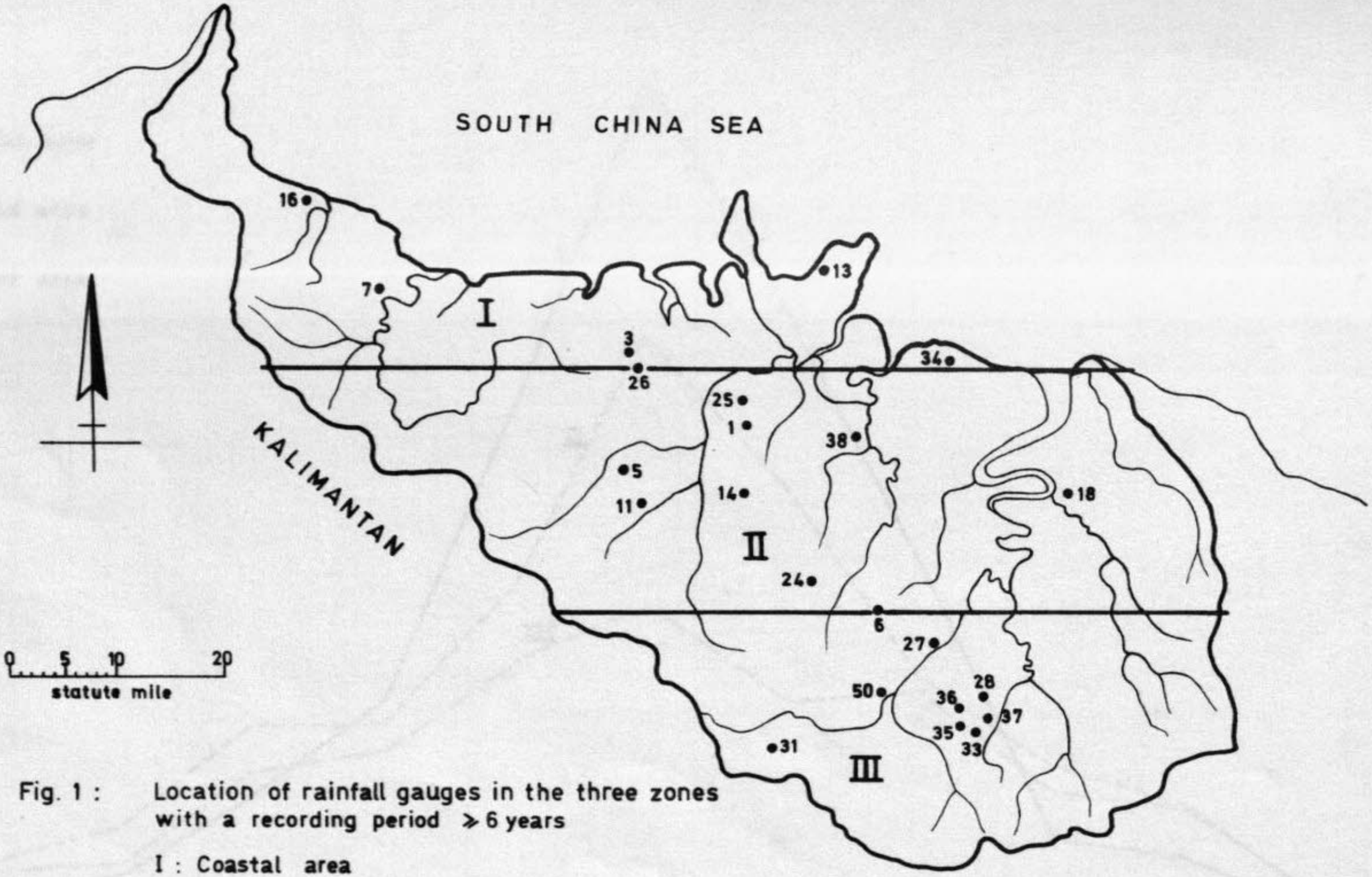

Fig. 1 : Location of rainfall gauges in the three zones with a recording period ≥ 6 years

I : Coastal area

II : Midland area

III : Interior area

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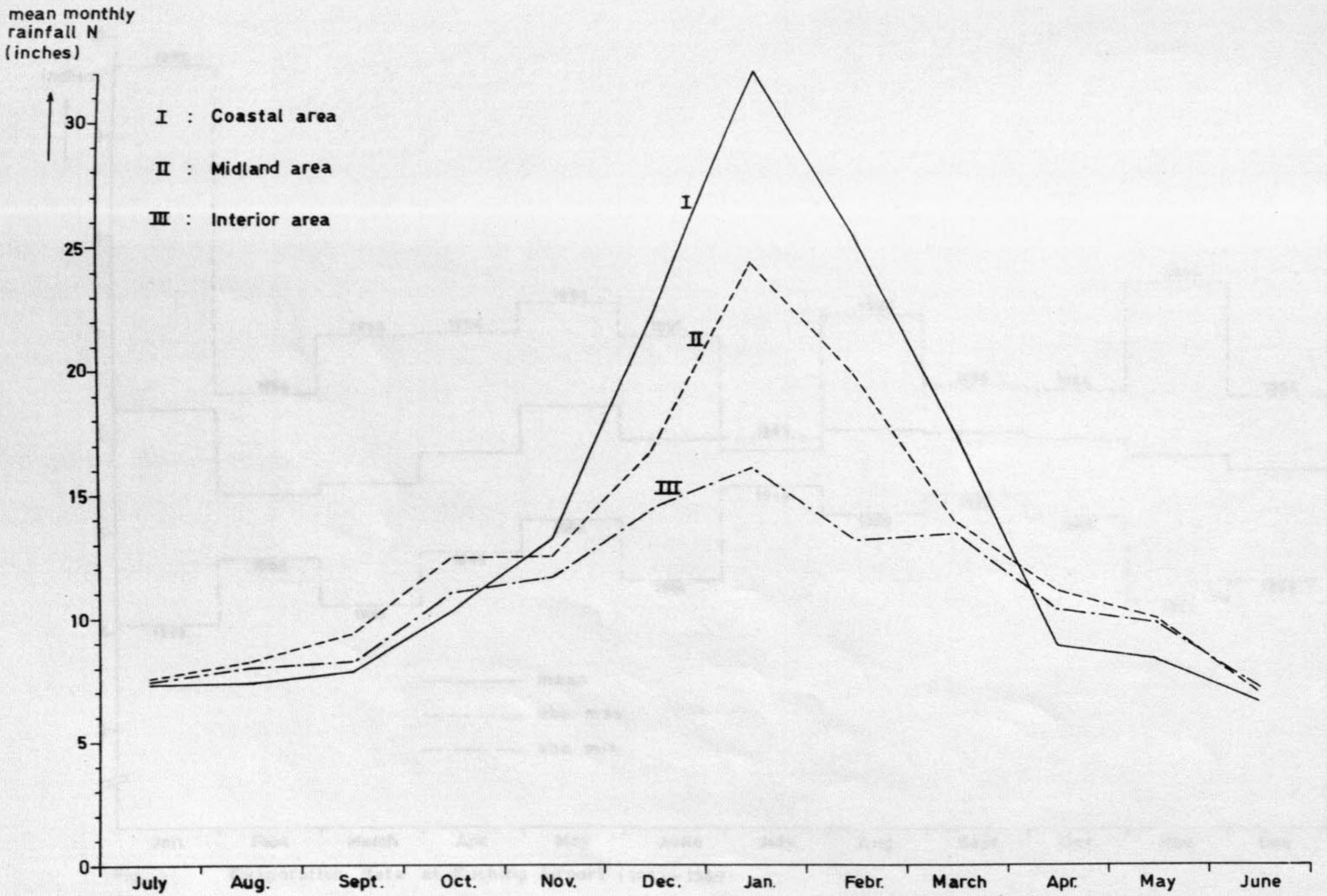

Fig. 2 : Mean monthly rainfall in the three zones

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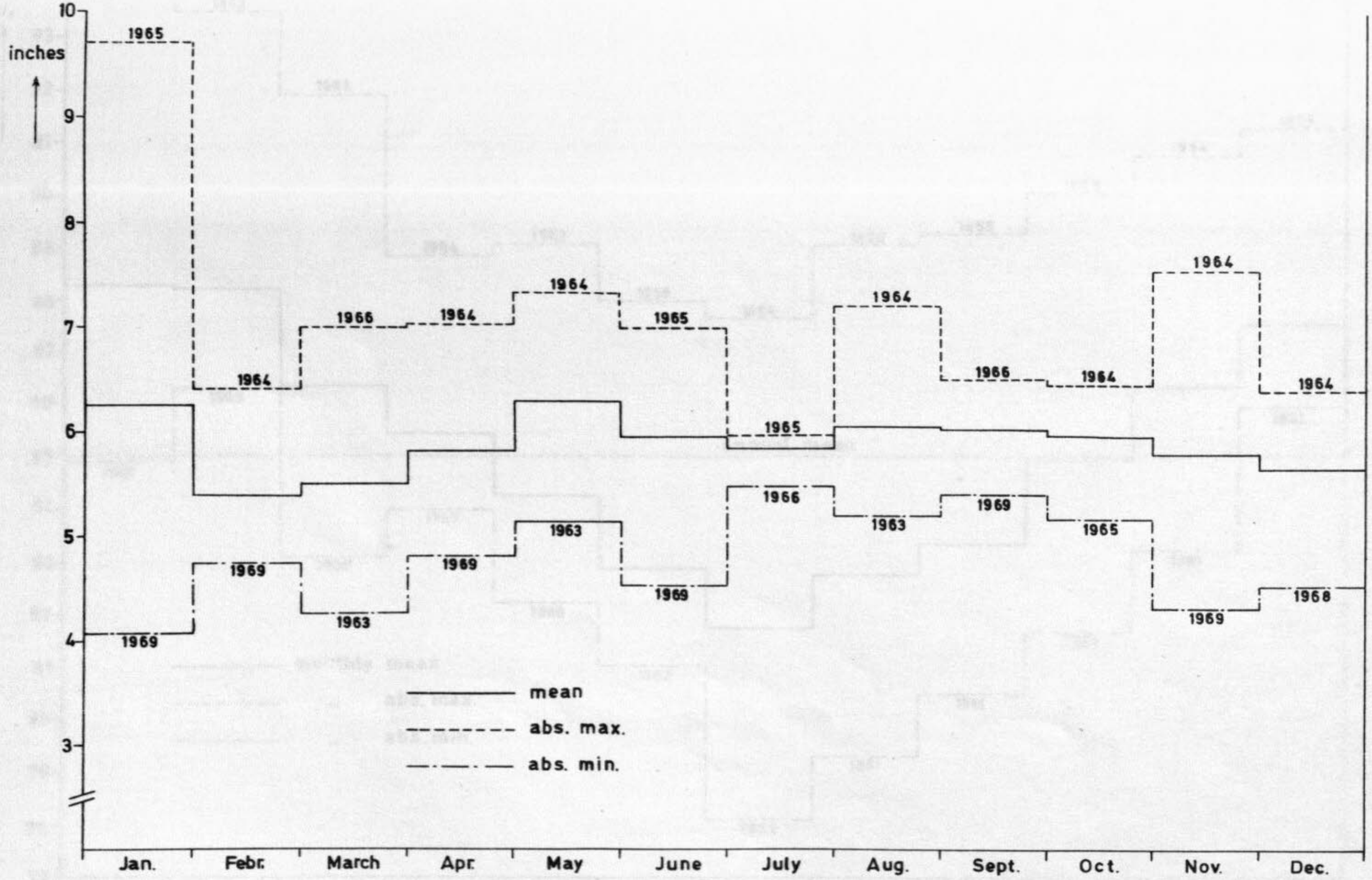

Fig. 3: Evaporation data at Kuching Airport (1963 - 1969)

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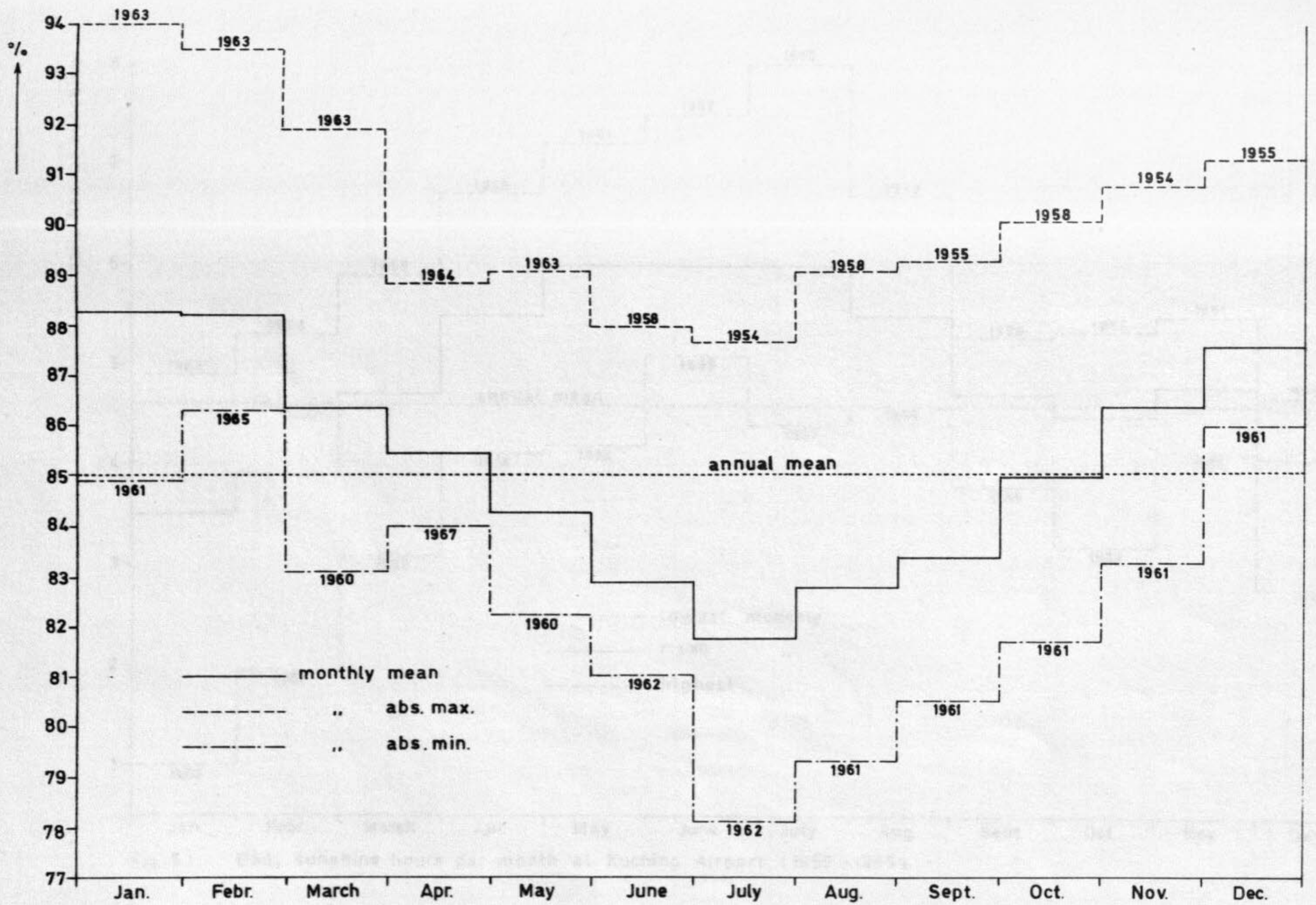

Fig. 4 : Relative humidity data at Kuching Airport (1953 - 1967)

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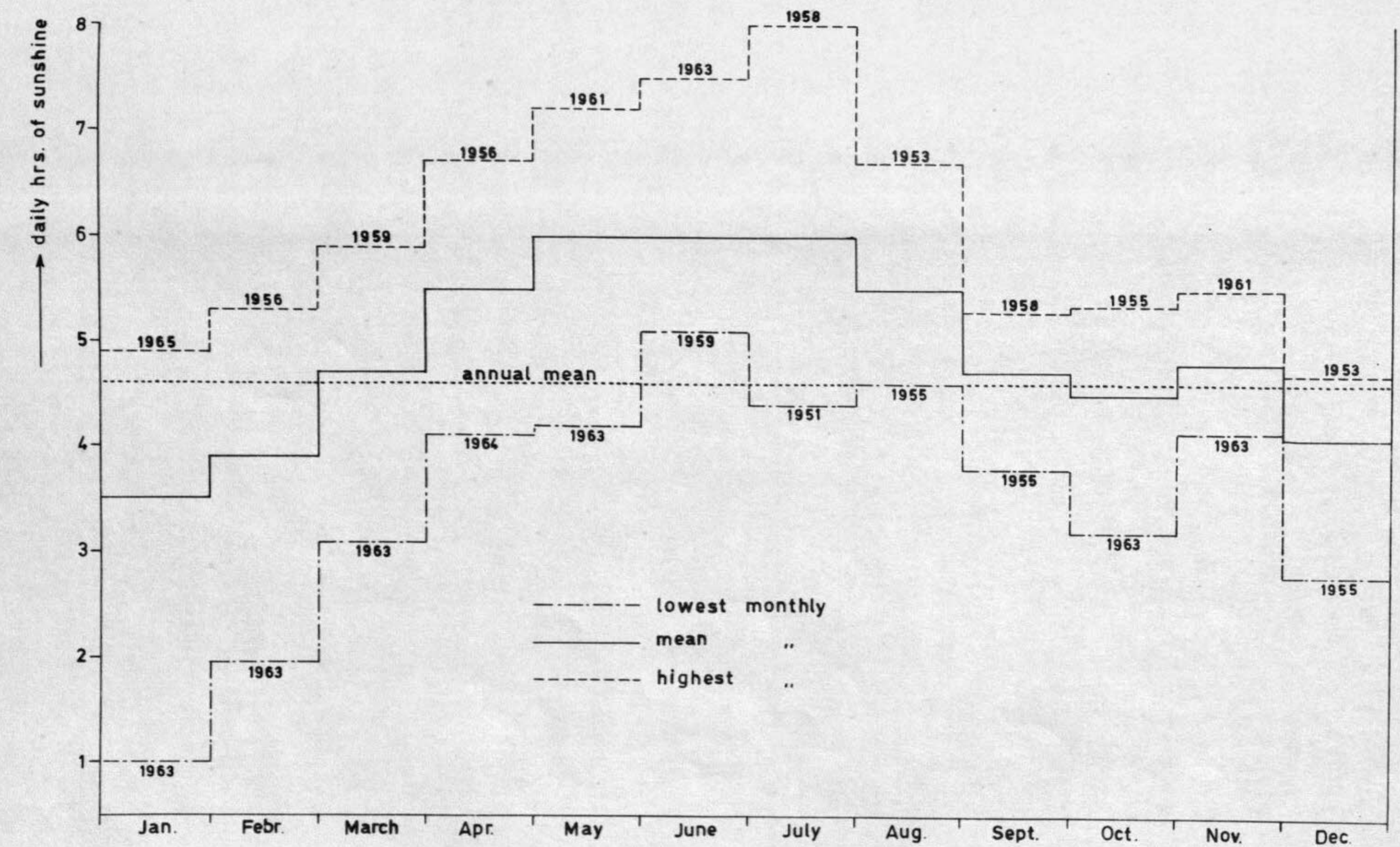

Fig. 5 : Daily sunshine hours per month at Kuching Airport (1950 - 1965)

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1. INTRODUCTION.

The natural hydrological situation in the First Division is not very favourable, from agricultural point of view, mainly due to the interaction of the three following factors:

1. An unfavourable topography,
2. An very high rainfall, with a distinct one-peak curve,
3. A strong influence of the tidal movements.

From a hydrological point of view the topography is unfavourable, because the interior land consisting of mountainous areas with steep to very steep slopes and a strongly dissected plain changes rather abruptly into a nearly flat, extensive recent plain of partly marine partly riverine origin. Heavy rainfall in the mountainous area is carried off rather rapidly to this plain, where the low gradient of the extensive meandering rivers prevents a quick discharge. Furthermore, the direct and indirect tidal movements in these large rivers effect the drainage and a combination of high (spring)tide and heavy rainfall often causes flooding, sometimes over large areas (e.g. 1963).

2. TOPOGRAPHY AND RIVER REGIMES.

In order to emphasize the correlation between topography and the regimes of the various rivers, these two items will be dealt with together. 4 Rivers have to be distinguished especially, and table 1 gives some data:

Table 1 : The most important rivers

River/Catchment Area	Approx.length		Approx.catchment area	
	miles	km	sq.miles	km^2
Btg. Kayan	62	100	415	1075
S. Sarawak	60	96	650	1700
Btg. Samarahan	62	100	360	960
Btg. Sadong	105	170	1380	3570

In general, the courses of these rivers can be divided into three parts, the upper, middle and lower course.

2.1. The upper courses, in the mountainous area.

The upper courses of the rivers are situated approximately between the Indonesian border[1] and the points, where the rivers cross the 50 ft. contourline (Sarawak Kanan: Bau; Sarawak Kiri: Kpg. Puruh; Sadong Kayan: Kpg.Retch; Sadong Kedup: Kpg.Tapuh). For the Btg.Kayan the same division can be made, although the river is "folded up" in north east direction, and for this river the upper course ends at the confluence of the two Sungais Kukoh.
In these upper catchment areas the discharge of rainfall takes place by means of numerous small streams and brooklets, often dry in the months of July and August, and small tributaries with high gradients, through narrow valleys which are often deeply incised. As these areas are only approximately 10 miles deep, the catchment areas are rather small and high rainfall intensities will result in distinct heavy peak discharges. The stream velocities are very high and eroded soil material is carried away.

2.2. The middle courses, in the hilly area.

The middle courses of the rivers are situated approximately between the above mentioned 50 feet contourline and the road 10th. Mile-Serian-Balai Ringing (for the Btg.Kayan the Bau-Lundu road), a strip of land also approx. 10 miles deep. The river slopes are ca. 20-33 inches/mile (30-50 cm/km) and the stream velocities are still rather high. Discharge of water may, however, be hampered by the indirect tidal movements[2]. This results in a slower discharge in the downstream part of the area and may, in places, cause minor flood plain development (deposition of river sediment) in the middle river course.

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1) South of the G.Udan Range an area of approx. 40 sq.miles drains to Indonesia, and for this reason it is not included in the upper catchment area of the S.Sarawak.

2) Indirect tidal movements cover the backing up and drawing down of the water level at resp. high and low tide, whereby the stream direction remains constant, i.e. downstream.
Direct tidal movements cover variatons of water level due to high and low tide, with conversion of the stream direction.

2.3. The lower courses, in the recent plain.

The lower river courses are situated in a recent plain, extending from the estimated 20 ft. contourline (the above mentioned roads) down to the South China Sea, a width of 20-30 miles. The average slopes of the meandering river courses are 3.3 - 6.6 inches/mile (5-10 cm/km), but these slopes are influenced by tidal movements. Normally, direct tidal movements are present in the river courses between the sea and Gedong (Sadong), Kpg.Siniawan (Samarahan), Batu Kitang (Sarawak) and Kpg.Munti (Kayan). During spring tide and during dry spells this direct influence may extend 5-7 miles more upstream. All these figures are rough estimates (no data are available, see chapter 5), and are influenced by the upper course discharges and the dimensions of the rivers.

3. POTENTIALS OF THE VARIOUS HYDROLOGICAL AREAS.

In this chapter the potentials per area will be discussed from the hydrological point of view, so only those areas are considered where water is a favourable or a hampering factor.

By hydrological area is meant the areas surrounding the parts of the river courses mentioned in chapter 2, while in addition the extensive recent plain is divided in two parts, the riverain areas with the back swamps, and the deltaic estuarine area.

3.1. The upper course areas.

Because the numerous brooklets and streams in this strongly dissected, steeply sloping landscape only function as rapid discharge canals of the rain water, the rather small and narrow valleys do not offer many agricultural potentials. The present system of shifting cultivation on the hill slopes, for which forest is felled and burned, promotes soil erosion. Control of this kind of erosion by means of terracing is very expensive and does not seem economically justified, because on these steep slopes numerous terraces and check-structures have to be constructed and only very small strips of land will be gained.

From the hydrological point of view covering of the soil with a permanent foliage is the best way to diminish this erosion hazard and to reduce the magnitude of the peak discharges in the small and large rivers.

In the area surrounded by the Bungo Range, a surface of approx. 28 sq. miles, a water reservoir could be made by damming the S.Taba.

The capacity of this reservoir is approx. $3.500.10^6$ ft^3, equal to a discharge of 123 cusecs (3,5 m^3/sec.) over the entire year, but the construction of such a reservoir is uneconomic (Snowy Mountains Hydro-electrical Authority, 19?2). Another reservoir possibility is the upper catchment area of the Btg.Kayan, and this will be dealt with in the annex concerning Physical Infrastructure.

3.2. The middle course areas.

In these areas inundations occur during the landas season mainly due to insufficient discharge capacity of the small and larger rivers during periods of heavy rainfall. A combination of rainfall with spring tide may aggravate this flood hazard, because in that case draining of water is temporary hampered. Furthermore it appears that the bridges and culverts in the Kuching-Serian-Balai Ringin road are too small or are blocked too quickly by logs and eroded material (the same is valid for the bridge over the Btg.Kayan, which was partly undermined in 1970). An amelioration of this situation by enlarging the cross-sections of the streams and rivers in this area, by straightening the courses, does not seem recommendable, because in that case:

- a strong increase of bed load can be expected, which after some time would result in
- a decrease of the river slopes, by possible sedimentation, in the lower courses,
- the peak discharges in the lower courses will be enlarged,
- by the mentioned scouring of the river beds it will be more difficult during periods of low discharges to maintain the present more or less natural inundation of the wet padi in the valleys.

To solve this last problem of flood hazard a great number of weirs and small floodcontrol dams will be necessary, but the costs to construct these will surpass the crop damages.

It appears more justified to maintain the middle courses as a kind of buffer while improving local irrigation possibilities of wet padi areas (A.P.P.Schemes). An example of such a scheme offers the 17th. mile, and especially in the valley of the Btg.Sadong between Tebakang and Serian such a scheme appears to be recommendable.

In general, for the A.P.P.Schemes it is necessary to improve the detailed water management to prevent flooding during high discharges, by diverting the small rivers around instead of through the scheme (or by embanking the rivers), by installation of permanent (concrete or wooden) structures and by levelling of undulating land.

Using these schemes for a second padi crop can not be recommended; nevertheless introduction of a non-irrigated crop during the off-season should be possible in most of the locations. As other areas in the middle courses of the rivers will be also suitable for this kind of schemes, a stock-taking of the potential area of wet padi fields, and the part of it that has to be improved, should be carried out.

3.3. The lower course areas, except the deltaic estuarine area.

In this extensive plain floods of various kinds occur:

- over low-lying river levees during exceptional high tide, especially when coinciding with moderate to high up-river discharges,
- in areas indirectly affected by tide, during high up-river discharges and spring tides,
- as a result of insufficient natural drainage capacity after heavy rainfall,
- as a result of overland flow from hilly areas.

Since the agricultural potentials of the vast peat areas in the back swamps are very doubtful and very high investments for adequate drainage would be needed, development of peat areas at present or in the near future will be left out of consideration.

Better possibilities are offered by the development of the river levees along the lower river courses; complete flood control (by means of embanking), proper drainage systems and adequate irrigation may make these areas suitable for double cropping of padi. A closer investigation into this subject is given in the annex concerning Agricultural Development.

This type of development partly has started already (Mid-Sadong Drainage Scheme, Tg.Purun Drainage and Irrigation Scheme, various scattered A.P.P.Schemes), but it is generally limited to those areas in which there is a salinity hazard.

3.4. The deltaic estuarine area.

The deltaic estuarine area extends, with variable width, along the sea coast; it is intersected by numerous small creeks and river estuaria. Mainly in the western part there are some narrow coastal ridges along the shore.

Three parts of this area need special attention:

a) The area between Kuching and the sea.
In this area a large drainage scheme, Santubong, is set up, to test the feasibility of growing coco-nut and padi on saline gley soils. The problems connected with this process, will be dealt with in a separate study of the Santubong area.

b) The Nonok coastal area.
In this area three hydrological features are intermingled, namely salt water penetration, discharge from peat areas and coastal erosion. Protecting of this area by means of dikes both on land and sea-side may partly solve the above mentioned problems.
By carrying out such a project, a large area (approx.23.000 acres) of agricultural land will be suitable for a great variety of crops.
Prevention of coastal erosion is such a complex technical enterprise, that it must be dissuaded to carry out high investments for investigation and prevention of this problem.

c) The coastal ridges.
Here both coastal erosion and salt water penetration occur. The erosion causes the falling down of mature coco-nut trees, while the salt water penetration, both by natural surface drains during high tide and by subsurface flow, hampers the supply of drinkwater for the people and the cattle.
These problems can partly be solved by embanking the areas from the sea, but as the agricultural possibilities on the soils of these areas are rather limited, too high investments will not be justified.

4.CATCHMENT AREAS.

4.1. Introduction.

If within the catchment areas a differentiation is made between the upper and middle courses on the one hand and the lower course on the other, it can be stated that the unit runoff from the latter area is totally different from the unit runoff of the other two areas. It is only partly possible to speak of a runoff of the plain to the lower river courses, because the peat areas will retain a great part of the precipitation, while also a great delay in discharge is caused by overland flow and tidal movements.

Because of the flood hazards in the recent plain, occurring during high up-river discharges, the extent of the catchment areas in the middle and upper courses is of primary importance. Table 2 gives the planimetric measurements for the main rivers.

According to the report of the Snowy Mountains Hydro-electrical Authority (1962) the minimum and maximum discharges of the rivers in Sarawak can be calculated by:

$Q_{min} = \frac{1}{7} \frac{\text{cusec}}{\text{sq.miles}} = 4$ l/sq.mile/sec. $= 0.004$ m^3/sq.mile/sec, and

$Q_{max} = 4500 \sqrt{A}$ cusecs $= 126 \sqrt{A}$ m^3/sec, when A is the catchment area in square miles and Q_{max} has a frequency of once in 30 years.

Applying these formula's to the rivers of the First Division, the next data appear (table 2).

Table 2: Minimum and maximum daily discharges for the upper + middle catchment areas.

River system	Area		$Q_{minimum}$				$Q_{maximum}$			
			calculated		measured[1)]		calculated		measured[1)]	
	sq.miles	km^2	cusecs	m^3/sec	cusecs	m^3/sec	cusecs	m^3/sec	cusecs	m^3/sec
Btg.Krang	145	370	21	0.59	--	--	54.000	1530	--	--
Btg.Sadong	375	970	54	1.53	202	5.7	87.300	2470	51.153	1450
Btg.Samarahan	135	350	19	0.54	--	--	52.000	1470	--	--
S.Sarawak Kiri	245	635	39	1.12	--	--	70.000	1980	85.000	2410
S.Sarawak Kanan	125	325	18	0.51	--	--	50.400	1430	--	--
Btg. Kayan	150	390	21	0.59	--	--	56.000	1580	--	--

1) For some rivers measurements concerning discharge are taken regularly or irregularly since 1962.

However, the calculation of the minimum (basic) flow according to the report of the Snowy Mountains Hydro-electric Authority is based on a measurement in a rocky mountain catchment area of little more than 1 sq.mile. Furthermore, the month of occurrence and the frequency of such a minimum flow are not mentioned. In order to know if enough water is available in the rivers, to be used for irrigation during the off-season, a more detailed approximation is indispensable.

The only large river for which such an approximation can be made, is the Btg.Sadong, because at Serian discharge measurements were taken daily during 5 consecutive years.

Chapter 4.2 will deal with a method by which a rough prediction of frequency of minimum flow can be made. Afterwards, the results obtained will be compared with the formula used in the Snowy Mountains Report.

4.2 Occurrence and frequency of the minimum flow of the Btg.Sadong at Serian.

Before any method can be applied, first an assumption has to be made:
At the point of recording of the discharge of the Btg.Sadong near Serian no tidal influences occur.

4.2.1. Estimation of minimum and maximum discharges by means of log-normal plotting.

Discharge measurements from 5 consecutive years (1964-1968) are available. For each month the daily discharges are arranged from lowest to highest (for example in April from 716 to 5179 cusecs), resulting in a list of 150-155 numbers below each other (5 x 30 or 5 x 31 days). These data are plotted on graph-paper with a horizontal axis in probability scale and a vertical axis in logarithm scale (for the months of April and August, see figures 1 and 2 resp.). The minimum flow of the 150 measurements in April is 716 cusecs, so the percentage of occurrence is $\frac{1}{151}$ (because of the probability scale, which always ends at 99.99% instead of 100%, the number of measurements have to be increased by 1, according to the formula: $\frac{100\ m}{n + 1}$ = cumulative frequency in %; m = rank-number; n = total number). For the same reason it can be said that a flow of 5179 cusecs or less occurs $\frac{150}{151}$ times = 99.3%. Between these two extremes all the other 148 daily discharges can be plotted and the area above the obtained line gives the probability of transgression (in percentage from 99.99 to 0.01%) and the area below this line gives the probability of non-transgression (from 0.01 to 99.99%).

The horizontal axis, expressed in percentage of probability, can also be used to indicate the frequency of occurrence in years. For instance, a flow in April of 716 cusecs or less occurs once in 5 years (according to the measurements), which is the same as 0.66%. So, 0.066% will be equal to an occurrence of once in 50 years (see figure 1). As a matter of fact extrapolation of the line to longer periods is not very accurate, but it gives a rough indication. So from figure 1 it appears that in April a flow of 450 cusecs or less may occur once in 50 years.

4.2.2 Comparison of results.

a) Minimum discharges.

According to the calculation of minimum discharge in the Snowy Mountains Report ($Q_{min} = \frac{1 \text{ cusec}}{7 \text{ sq. miles}}$) the minimum flow of the Btg.Sadong would be 54 cusecs (1.53 m3/sec) (see table 2). The month, duration and frequency of occurrence of this minimum flow are not mentioned. According to the estimation by means of log-normal plotting the month in which minimum flows occur is August and the frequency of occurrence of a daily discharge of 120 cusecs or less is once in 50 years (see figure 2). Comparison of these two data is, however, not possible because only the latter gives a duration period (24 hrs), while for the first no period is mentioned.

For irrigation requirements a deficit in supply of once in 10 years is acceptable. Since for use of irrigation water the discharge during the month of April is critical (see annex concerning Agricultural Development), it is important to know what the minimum daily discharge in April will be once in 10 years. According to figure 1 and table 3 this is 550 cusecs (= 15.5 m^3/sec).

Table 3 : Expected low discharges of the Btg. Sadong at Serian.

Period	In 10 years		In 50 years	
Month	cusecs	m^3/sec	cusecs	m^3/sec
April	550	15.5	450	12.7
May	505	14.3	410	11.6
June	305	8.6	285	8.0
July	230	6.5	175	4.9
August	165	4.7	120	3.4
September	270	7.6	215	6.1
October	300	8.5	230	6.5
November	480	13.6	375	10.3

From table 3 it can be seen that August is the month of lowest discharge, while in April still quite a lot of water is available for irrigation purposes.

As far as the other large rivers are concerned, an equally reliable prediction of frequencies of minimum discharges can not be made, owing to the fact that no discharge-data are available.

Extrapolating the results of the above calculations to the other rivers, on basis of the catchment area surfaces (see table 2), a very rough indication of quantity of discharges may be obtained (see table 4):

Table 4 : Roughly assumed low discharges in the middle courses of the various rivers

	$Q_{minimum}$ 1)			
	assumed in April		assumed in August	
River system	cusecs	m^3/sec	cusecs	m^3/sec
Btg. Krang	200	5.7	65	1.84
Btg. Sadong	550	15.5	165	4.67
Btg. Samarahan	200	5.7	60	1.70
S.Sarawak Kiri	400	10.1	140	3.97
S.Sarawak Kanan	200	5.7	55	1.56
Btg. Kayan	200	5.7	65	1.84

1) with a frequency of once in 10 years.

The assumed values of the figures in April in table 4 will be used in the annex concerning Agricultural Development.

b) Maximum discharges.

According to the calculation of the maximum discharge in the Snowy Mountains Report ($Q_{max} = 4500\sqrt{A}$ cusecs = $126\sqrt{A}$ m^3/sec.) the maximum flow of the Btg. Sadong would be 87.300 cusecs (2470 m^3/sec). The month of occurrence of this maximum flow is not mentioned, the frequency is once in 30 years. Calculating the maximum discharges of a river is mainly important for two things, (1) the flood hazards and (2) the calculation of the elevation of dikes for schemes along the river. A maximum discharge during some hours may already be fatal for large areas (flood) and for the dikes (collaps), so the estimation of maximum discharge by means of log-normal plotting, expressed in flow per day (24 hours), is not very practical in this case. Therefore it is assumed that the maximum discharges in the various rivers of the First Division will be those mentioned in table 2 and calculated with the formula mentioned above.

5. HYDROLOGICAL DATA AVAILABLE

5.1. Rainfall-gauges

See the annex concerning climate, chapter 3.2.

5.2. Evaporation

See the annex concerning climate,chapter 3.3.

5.3. Water level recording

The object of establishing water level stations is to obtain a truly representative record of river levels either for direct use (navigability, tide and flood predictions, drainage schemes) or as a step towards the recording of the river discharge (see 5.4.).

In the First Division three water level stations were installed before 1969, namely:

- L/1-1 : near Serian, in the Btg. Sadong,
- L/1-2 : in Kuching, in the S. Sarawak,
- L/1-3 : at the crossing of the Serian-Balai Ringing road and the S.Bedup.

Table 5 gives some information concerning these stations:

Table 5: Particulars of the permanent[1)] water level stations.

Station nr.	River	Type	Records available	abs.max. level[2)]	abs.min. level[2)]
L/1-1	Btg.Sadong	Lea recorder	Febr.'62 to date	21.8 fr	1.7 ft
L/1-2	S.Sarawak	Lea recorder	Sept.'62 to date	16.6 ft	0.0 ft
L/1-3	S.Bedup	Kent recorder[3)]	Jan.'64 to date	9.6 ft	0.1 ft
L/1-19	S.Sarawak	?	Jan.'69 to date	--	--
L/1-20	S.Sarawak	?	Jan.'69 to date	--	--

1) In order to obtain information for proposed projects some temporary stations are set up as well. These stations mostly are suspended after one year.

2) A temporary bench mark is set up at each station and the assigned value approximates by its elevation above the deepest point in the river bed. The zero data of these marks are not referred to the permanent bench marks of the network of the Department of Lands and Surveys.

3) with standing wave flume.

5.4. Discharge recording.

The method used to measure the discharge of rivers is based on measurement of velocity and wetted cross-section and subsequent computation of discharge at a given river stage. Two stations are set up in the First Division:

Table 6: Particulars of the discharge stations.

Station nr.	Name	River	Records available	Discharge (cusecs) abs.max	abs.min
L/1-1	Serian	Btg. Sadong	Jan.'64 to date	51.153	202
L/1-3	S.Bedup	S.Bedup	Jan.'64 to date	4.900	0.5

From the discharge data stage discharge curves and hydrographs can be plotted, from which maximum and minimum records may be obtained. In the Hydrological Yearbook for the water year 1966-1967 these curves are drawn.

5.5. Flood-record tables.

Since July 1966 the D.I.D. has been recording the occurrence, depth, extent and duration of floods. For data concerning these floods is referred to the Hydrological Yearbooks 1966-1967 and 1967-1968.

5.6. Tide levels.

At Kuching, Thompson road, a staff gauge wich the zero at 8.29 from M.S.L. (or Land and Survey Precise Datum) registers the daily ranges of the tide. The normal range between high and low tide varies between 8 and 16 ft. The daily course of the tides is published in the Hydrological Yearbooks. During the periods where in two peaks in the curve occur without a typical nadir for low tide by interference of two tidal streams, high upper discharges, resulting in flooding, are present, keeping the water table at high level.

5.7. Electrical conductivity.

Near the experimental station near Muara Tuang in two tributaries of the Btg.Samarahan and at the Tg.Purun Project in a tributary of the Btg.Kayan electrical conductivity measurements were carried out, at the first station daily during 3 years, at the second twice for 2 consecutive days.

Table 7 shows the data for the water inlet points of the experimental station in the Paya Paloh and S. Sueh.

Table 7: Monthly average electrical conductivity data of the water in the Paya Paloh and the S.Sueh (in micromhos/cm at 25^{o}C)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Paya Paloh 1965	-	-	100	500	1100	4200	9600	1500	6300	2600	250	150
S.Sueh 1966	350	150	350	300	250	400	2700	1800	500	250	-	-
S.Sueh 1967	50	50	500	1250	400	1900	1850	3500	4600	1350	100	200

Using the classification that[1]: < 750 micromhos/cm is excellent to good,
750-2250 " /cm is permissible, and
> 2250 " /cm is unsuitable,
it can be concluded that inlet of river water during the months of June, July, August, September and October cannot be allowed.

Besides, these two rivers drain from a peat area, and the tea coloured river water probably has a pH between 3,5 and 5. Although this acidity of irrigation water is not a hampering factor for a crop such as padi, the dissolved organic material in this water promotes a podzolisation process, which is disadvantageous because with this process an important part of the dissolved nutrients in the soil will be bound in complexes and will be leached, which results in a depletion of the soil.

Also near the Btg. Kayan in the S.Tangbang conductivity measurements were taken during two consecutive days in October 1967 and in April 1968, every hour of the day. The electrical conductivity at 4 ft below the water surface ranges between 35 (during low tide) and 8000 (during high tide) micromhos/cm. Irrigation of padi fields will only be possible during low tide.

6. PROPOSALS FOR HYDROLOGICAL RESEARCH

As the large rivers of Sarawak are the fountains of life for the inhabitants, it is of the utmost importance that the water regime of the large rivers can be understood and even predicted. For this reason it is advised to set up a thorough investigation programme; the next proposals, as specified in the following chapters, should be realised as soon as possible, at any rate before the end of the second five year plan.

6.1 Water level recorders.

Automatic water level recorders (approx. M$ 2000,- each) should be placed in the Btg. Kayan (at the bridge site of the Bau-Lundu road), in the Btg. Samarahan (near the Kuching-Serian road) and in the Btg. Krang (at Balai Ringin). The zero data of these recorders should be referred to the permanent bench marks of the Land and Survey Department.

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1) U.S.Salinity Laboratory Staff, 1954, "Diagnosis and improvement of saline and alkali soils", U.S.D.A., Handbook 60.

6.2 Discharge calculations.

In order to calculate the discharge, stage-discharge curves have to be plotted. For this, at the three above mentioned sites wetted cross-sections must be calculated and velocity-measurements must be taken (with a current-meter) at various moments, but especially during peak discharges. These stage-discharge curves should be checked yearly.

6.3 Recording of the tide levels.

This can be done either by automatic water level recorders or by staff gauges, read regularly by local people. Staff gauges should be placed in all the important rivers, at different points, in order to obtain information on how far inland tide levels do occur.

Where development schemes are projected near the coast, tide levels must be recorded in all the creeks and rivers in or near the project area (Tg.Purun, Santubong, Mid-Sadong, Nonok).

6.4 Electrical conductivity.

In order to use river water for irrigation purposes, in the tidal area water samples of each river have to be taken regularly at various sites, both during low tide and during high tide. These sites should not be restricted to existing project areas, because when in the future a project is proposed data should already be avaible.

These measurements have to be taken at different depth levels in the rivers, so as to determine the location and movements of the salt tongue as well.

6.5 pH-recordings.

Before river water, drained off from peat areas, can be used for irrigation purposes, the pH-value should be known. This can be determined for instance at the Paya Paloh Experimental Station and in the Nonok River.

6.6 Run-off.

By correlating rainfall and discharge in a certain catchment area, predictions can be made concerning the total run-off.[1] Due to different soil conditions, topography and vegetation, the results will differ considerably between the various catchment areas.

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[1] Total run-off consists of surface run-off (the discharge of water through surface streams of a drainage basin) and ground water flow that reaches the rivers.

Fig. 1: Relationship between discharges and probability of occurrence for the upper + middle catchment area of the Btg. Sadong in the month April (period: 1964–1968)

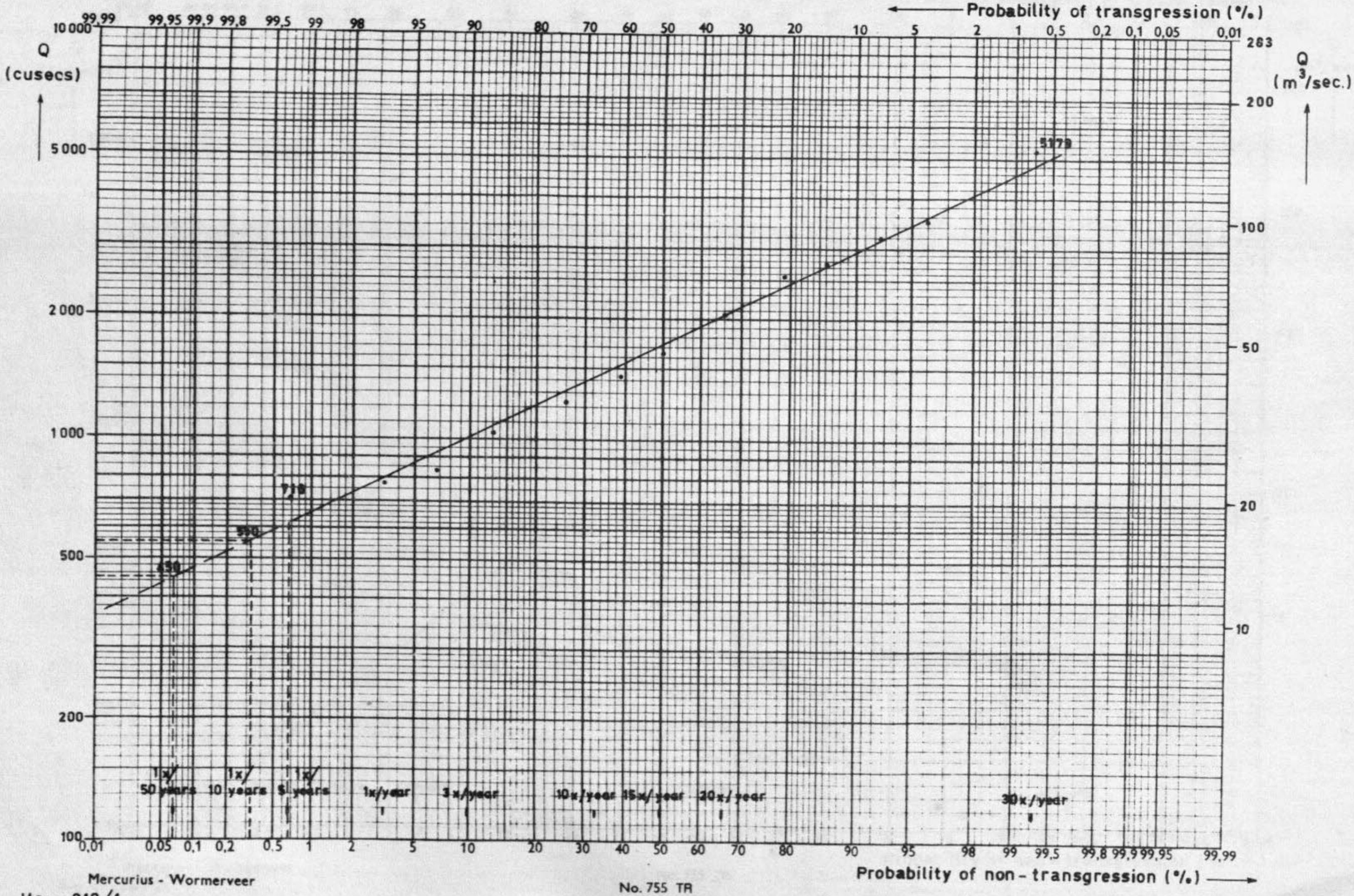

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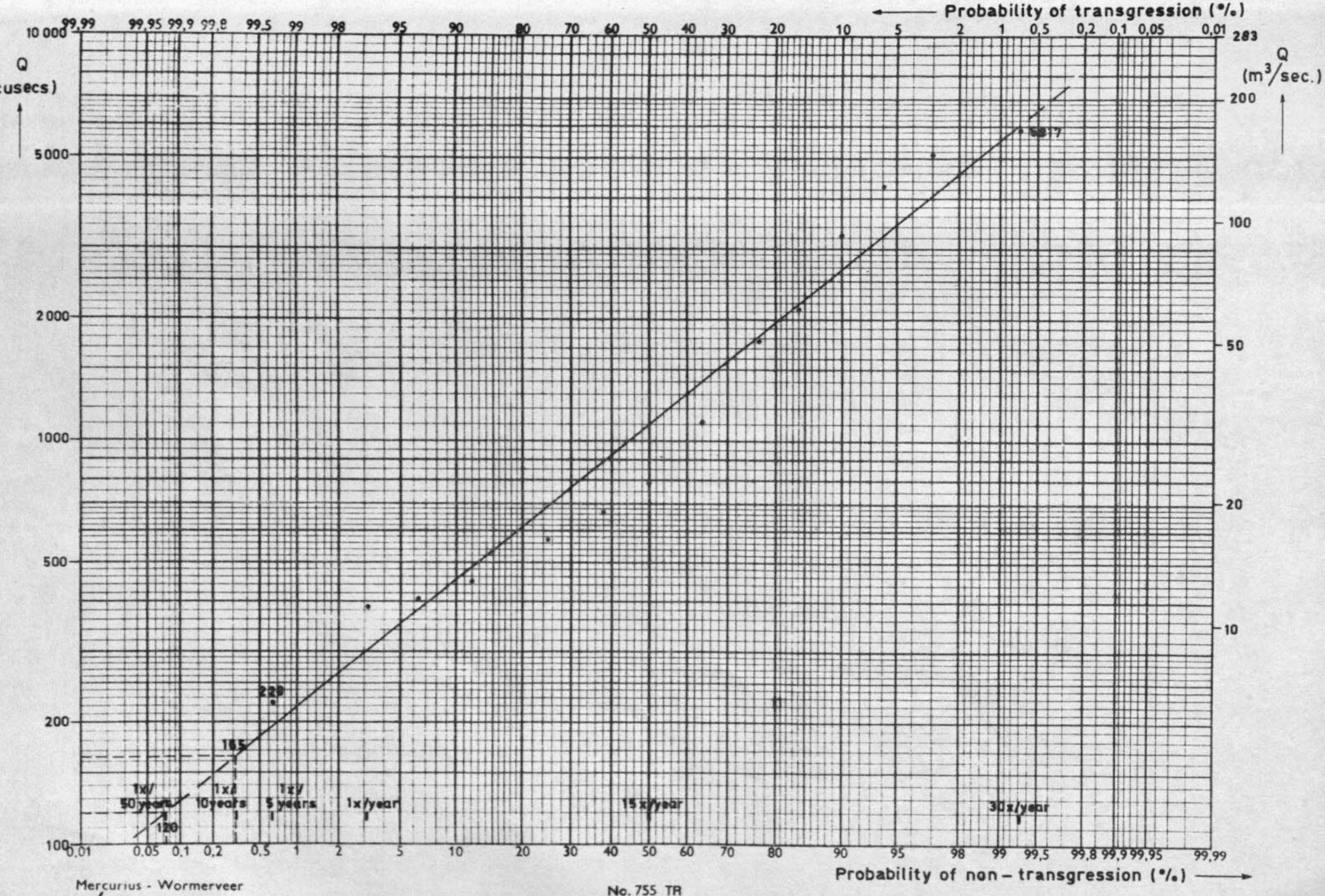
Fig. 2: Relationship between discharges and probability of occurrence for the upper + middle catchment area of the Btg. Sadong in the month August (period: 1964 – 1968)



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ANNEX 3

PHYSIOGRAPHY AND SOILS

CONTENTS

LIST OF TABLES

1. INTRODUCTION

This Annex consists of two parts. The first part (chapters 2 and 3) deals with the characteristics and shape of the land surface and the nature of the soil cover. These site characteristics will be discussed primarily with a view to their relevance for plant growth. However, for a proper understanding of the shape of the land surface, something need to be said on the geological history and the geomorphology of the area. For the same reason, it was sometimes necessary to include remarks on pedogenesis in the chapter on soils.

The second part of the Annex gives an interpretation of the site characteristics for the purpose of land use planning. This information has been presented in the form of an Advisory Land Use map on a scale of 1:50,000, which for technical reasons could not be added to this Annex or to the main report. In chapter 4 the reasoning behind this map is given as well as a description of the map units. The use of the map is further explained in chapter 6. The geographic units map on a scale of 1:250,000, to which chapter 5 refers, combines groups of map units of the Advisory Land Use map into subregions for socio-economic calculations.

A more detailed account of geology, morphology and soils of the First Division will be published as "Memoir on the soils of West Sarawak" (Andriesse, in preparation) and it would seem logic to refer to this publication for any basic information. There are two reasons for dealing with soils, morphology and geology in this Annex as well; firstly, it may be some time before the said "Memoir" will be printed, and, secondly the Advisory Land Use map cannot be understood without at least some knowledge of the basic landscape features.

2. GEOMORPHOLOGY

2.1. Geomorphological history

The geomorphological history of the area, which is rather complicated, will be dealt with only in so far as is thought necessary for a clear understanding of the present landscape. More detailed information is given by Haile (1954), Wilford (1955) and Liechti (1960) and in several Soil Survey Reports, notably no's 59, 25/2, 94 and 103. Reference will be made to 'physiographic units', map units of the 1:250,000 map "Physiography of West Sarawak", by J.P.Andriesse, x) (see volume VIII, map II). During the time the Study Team worked in Sarawak this map was not yet available.

The First Division consists of several distinct geomorphological units, which differ in age, geological history and level. Holocene riverain and marine sediments form a belt of varying width along the coast. This belt is bordered on the landward side by landscapes situated at higher levels. These landscapes can conveniently be brought together under the name 'interior land'.

The interior land comprises a dissected, Early Pleistocene erosion surface forming a summit plain at heights between 350 feet (100 m) and 150 feet (45 m), another, younger, summit plain at heights between 150 feet (45 m) and 50 feet (15 m), terraces and terrace remnants at heights between 50 feet (15 m) and 20 feet (6 m), and several mountainous areas and isolated, monadnock type, hills and mountains.

The summit plains are mainly built from sedimentary rocks of Triassic, Jurassic, Cretaceous and Tertiary age. Most rocks are fine- to medium-textured (shale, siltstone, mudstone, arkose), poorly consolidated and they weather easily.

The mountainous areas rise above the summit plains, reaching heights between 350 feet (100 m) and over 2,000 feet (600 m). Some consist of relatively harder rocks of sedimentary origin, which have withstood weathering and erosion better than the surrounding, softer sediments. Examples are Tertiary sandstone (Penrissen physiographic unit), and limestone hills, mainly of Cretaceous age (Bau physiographic unit). Other mountainous areas consist of intrusive and extrusive, basic to acid igneous rocks (Pueh and Stapok physiographic unit).

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x) The author is indebted to Mr. Andriesse for his permission to use this map.

During the Quaternary the sea level appears to have fluctuated considerably. In the Pleistocene, during glacial times the sea level must have been about 300 feet (100 m) below its present level, whereas during interglacial periods it was probably as much as 150 feet (45 m) above the present sea level.

Whereas above 150 feet erosion and dissection continued during Pleistocene times, areas below 150 feet were subject to alternate deposition during interglacial periods (sedimentation in a shallow sea), and dissection and erosion during glacial periods. So it appears that the old coast line at 150 feet (shown on the Physiographic map) is a major boundary between two landscapes:

1. A sloping (350-150 feet), strongly dissected erosion surface, where rock weathering and soil formation continued through the Quaternary (the Tebedu unit), and
2. An irregular surface situated at heights between 150 and 50 feet, originally part of the plain sub 1, but during the Pleistocene subject to periods of submergence with sedimentation of fresh deposits. These deposits have partly been eroded in subsequent periods of strong dissection so that, in places, a new cycle of soil formation could start in freshly exposed Tertiary and older formations. At present this landscape consists of large old valley floors with terraces, terrace remnants and valley fills. Pleistocene and older formations occur in an intricate pattern, and the soil pattern is equally complicated. This is the Quop physiographic unit.

In late Pleistocene the sea level must have been more or less stable for some time at a height between 20 and 50 feet above the present level. Dissection continued in the Tebedu and Quop units and the enclosed mountainous areas, and erosion material was deposited in a shallow sea. When the sea level dropped to almost its present level these deposits emerged as a marine terrace (old coastal plain), which subsequent dissection and erosion has reduced to a number of larger and smaller terrace remnants. This landscape is the Lundu physiographic unit.

The present coastal plain, of Holocene age, has developed below the 20 feet level. It consists of four physiographic units:

a. Fluviatile sediments building up levees along the meandering rivers (Samarahan physiographic unit);
b. Enclosed basins where peat formed (Nonok physiographic unit); the peat formation probably reflects the presence of a sub-recent erosion level at 10 feet (3 m);
c. Saline muds of deltaic-estuarine origin (Santubong physiographic unit);

d. In places, beaches and ridges along the present coast line (Sematan physiographic unit).

The latter two units are the youngest parts of the coastal plain.

2.2. Description of the physiographic units

The following section will give a short description of the physiographic units, in a more or less geochronological order. The major Great Soil Groups occurring in these units will be mentioned, and sometines some remarks on the agricultural potential will be made.

The physiographic units (see map II in volume VIII) are the following:

Igneous massifs and monadnocks (Pueh and Stapok unit)

The main igneous massifs are the Pueh and Gading mountains in the Lundu district, the mountains around Serian, several massifs along the Indonesian border and at the border with the Second Division. The general level is from 350 feet (100 m) to over 2,000 feet (600 m). Slopes are generally steep and the soils are often shallow. Where the parent materials are acid to intermediate, skeletal soils occur in association with Red-Yellow Podzolic soils (see Soil map 1:250,000); where they are basic - near Serian, between Serian and the Indonesian border, and on other locations - skeletal soils occur in association with Lateritic soils.

Karst landscape (Bau unit)

Monadnocks of Cretaceous limestone are found mainly in the Bau and Serian districts. They stand out abruptly against their surroundings and have a karst topography. The limestone is almost pure calcite and very hard. The surface is either bare rock, or thinly covered by organic layers or shallow brown clays. Skeletal soils and Brown Forest soils occur in association. The general level is from 350 feet (100 m) to over 1,000 feet (300 m).

Swampy alluvial flats underlain by limestone often surround the steep-sided limestone hills. These flats represent parts of the limestone outcrop which collapsed and were eroded (Wilford, 1955). These alluvial flats do not belong to the Bau unit itself, but generally to the Quop unit.

Undifferentiated strongly mountainous terrain (Undup unit)

Santubong peninsula and part of Bako peninsula have been mapped as Undup unit; undifferentiated, strongly dissected mountainous terrain; mainly sedimentary rocks. Skeletal soils occur in association with Podzols and Red-Yellow Podzolic soils.

'Cuesta'-landscape (Penrissen unit)

The Penrissen unit has a typical 'cuesta'-morphology (dip and scarp slopes, hogbacks, mesa's and buttes). Its general level is between 350 feet (100 m) and over 2,000 feet (600 m); locally it goes down to 150 feet (50 m). It covers some extensive areas, in particular most of the catchment area of the Batang Kayan (Lundu), the Bungo range and the area between this range and the Indonesian border, part of the Bako peninsula, and, in the south-east, some areas along the Indonesian border.

Generally the dip slopes are covered by Podzols and Grey-White Podzolic soils, while the scarp slopes are covered by Red-Yellow Podzolic soils and skeletal variants of these.

Dissected old erosion surface (Tebedu unit)

The Tebedu unit forms a moderately to strongly dissected old erosion surface. It appears as a hilly terrain with steep-sided valleys, in which very little sedimentation takes place. When viewed from a higher position it is clearly a plain: the highest hill tops appear to be on the same level. There is, however, some variation in the height of hills with the underlying rock formation due to differential erosion. This level slopes down from a height of about 350 feet (100 m) at the Indonesian border to a height of about 150 feet (50 m) where the unit borders more recent formations. The further inland the steeper the slopes and the more deeply incised valleys tend to become.

The rocks are of sedimentary origin. Red-Yellow Podzolic soils have developed from this material; the characteristics of the soils vary, depending on the nature of the underlying rock.

Quop physiographic unit

The Quop unit takes an intermediate position between the physiographic units described above and the coastal plain. It is situated at a lower level (generally between 20 and 150 feet (6 and 50 m)) and has less relief than the

Tebedu unit. Although at one time a strongly dissected erosion surface, probably not unlike the present Tebedu unit, the relief was smoothened by filling in with sediments deposited in a shallow sea. It is presumed to be submerged during the latest interglacial. Renewed dissection has taken place since, following a fall in sea level. Two subunits were distinguished: relatively slightly dissected (subunit a) and moderately dissected terrain (subunit b).

The Quop landscape has a complex nature: there are large old valley floors partly filled in with old alluvium, terraces and terrace remnants, recent valleys, and remnants of the original surface, where rocks were freshly exposed after erosion of the Pleistocene, unconsolidated sediments.

Most soils are Red-Yellow Podzolics, but in valleys there are Gley soils and Recent Alluvial soils.

Terraces and terrace remnants (Lundu unit)

The Lundu unit is formed by remnants of an old coastal plain formed between 20 and 50 feet (6 and 15 m) above present sea level. This plain was built out into the sea from riverain sediments, but it was subsequently eroded when the sea level subsided, probably during the latest glacial, leaving more or less flat-topped terrace remnants consisting of sandy and gravelly material. The soils are mainly Podzols and Grey-White Podzolic soils.

Present riverain flood plains (Samarahan unit)

The Samarahan unit consists of levees which developed along the main meandering rivers in the recent plain, and the transition to the Nonok unit (backswamps with deep peat). The recent riverain flood plains are situated between 0 and 20 feet (6 m) above sea level.

Wide stretches of the Samarahan unit are found along the Simunjan, Sadong and Samarahan rivers, smaller areas along the Sarawak and Kayan (Lundu) rivers. The soils are generally Gley soils.

Basin swamps (Nonok unit)

The basins between the riverain flood plains are filled in with deep organic deposits, generally more than 10 feet (3 m). The larger peat swamps are dome-shaped and may reach a height of 40 feet (12 m) above sea level. Peat soils is the only Great Soil Group present.

Young emerged coastal plain (Santubong unit)

In most recent times a coastal plain, built up of fine-textured estuarine and deltaic sediments, emerged. Most of this plain is situated just above normal high tide. It has a deranged drainage pattern, consisting of anostomosing channels and creeks, through which the plain is in direct contact with sea water and saline to brackish water of the river estuaries. The river mouths are large, funnel-shaped estuaries. Their present sizes do not correspond with the amount of water the rivers discharge, but should be ascribed to the eroding activity of the tidal movements.

Most of the soils are Saline Gley soils (Rajang soil family), but there are higher lying 'islands' of Gley soils (Pendam soil family), probably remnants of a slightly older coastal plain at a level of 10 feet (3 m). Included in the unit are some small terrace remnants and rocky outcrops. The saline gley soils are covered with mangrove.

Coastal ridges and beaches (Sematan unit)

The present coast line west of Santubong peninsula is mainly formed by recent beaches and ssnd ridges. The soils are Recent Alluvial soils, but in the older beaches strong leaching resulted into the formation of Podzols. East of Santubong peninsula such beaches do not occur, apparently due to the absence of a source of sandy material.

3. SOILS: OCCURRENCE, CHARACTERISTICS AND POTENTIALITIES

3.1. Introduction

Apart from 'ad hoc' soil surveys on different scales, often carried out in connection with specific development projects, the First Division of Sarawak has been completely covered by a systematic reconnaissance soil survey on a scale of 1 : 100,000 by the Soil Survey Division, Department of Agriculture. The results of most of these surveys were published in Soil Survey Reports no's 59, 25/2, 94 and 103 (Andriesse, 1965, 1966a, 1966b and 1969). A "Memoir on the soils of West Sarawak" (Andriesse, in preparation) will cover the entire First Division, as well as part of the Second Division (west of Batang Lupar). This Memoir will compile all the soil survey work carried out in the area concerned, including that upon which has not been reported earlier.

The taxonomic soil classification used (Soil Survey Staff, 1966) is largely based on the American classification of Baldwin, Kellogg and Thorp (1938), and Thorp and Smith (1949). The three highest categories (Orders, Suborders and

Great Soil Groups) are defined and described, and rules are given for a subdivision of Great Soil Groups into Soil Families and Soil Series. The Soil Series is the smallest taxonomic unit used in West Sarawak.

The mapping units on the 1 : 100,000 soil maps are Soil Families or associations of Soil Families, seldom Soil Series. Series and Families are described in the soil survey reports; they have been given geographical names.

Furthermore a soil map of Sarawak 1 : 250,000 was produced by the Soil Survey Division. This map is a compilation of reconnaissance and semi-detailed soil surveys conducted in the period 1955-1965, and is further based on air photograph interpretation and on geologic and land use maps. Only a few copies exist, hand-drawn and -coloured. Most mapping units are Great Soil Groups, some are associations of these units.

For printing purposes the 1 : 250,000 scale map was reduced to 1 : 500,000 and published in 1968. The reduction involved very little change in the mapping units in outline and simplification was only done for some minor areas in West Sarawak where the soil pattern was complicated. Moreover the 1 : 500,000 scale map was brought up to date before printing and reflects the survey position in 1968.

A new soil map on a scale of 1 : 100,000 covering the whole of West Sarawak (up to Batang Lupar) was prepared in 1969. It will be published with the "Memoir on the soils of West Sarawak", mentioned earlier. This map forms the latest compilation effort and gives an up-to-date representation of the soil pattern and of the soil classification employed.

For purposes of this Annex the latter map could not be consulted, since it was not yet completely finalized when the Study Team worked in Sarawak. Therefore the 1 : 250,000 soil map (map III in Volume VIII) is based on the old 1 : 250,000 soil map, but it has the legend of the 1 : 500,000 printed edition of 1968.

3.2. Description of Great Soil Groups

In the following paragraphs the soils of the First Division will be reviewed according to Great Soil Groups, following more or less the legend of the soil map. Separate families will be described if important differences occur on the family level of classification.

The following Great Soil Groups occur in the area:

1. Skeletal soils
2. Brown forest soils
3. Lateritic soils
4. Red-Yellow Podzolic soils
5. Grey-White Podzolic soils
6. Podzols
7. Gley soils
8. Salino Gley soils
9. Peat soils
10. Recent Alluvial soils

Skeletal soils

Skeletal soils are young and generally stony soils with an incomplete profile; they have a depth of less than 10 inches (25 cm) and overlie sedimentary and igneous rock types. They occur in steep mountainous terrain, often in association with Red-Yellow Podzolic soils and Lateritic soils. At present some of these soils are used for shifting cultivation. Because of insufficient soil depth and erosion hazard, the Skeletal soils are unsuitable for any type of agriculture. They should be under a permanent forest cover in order to protect the soil against erosion and reduce run-off from the steep slopes.

Brown forest soils

Brown forest soils are found on hard limestone . They are restricted to the Bau physiographic unit. They are under primary forest and should remain so. The steep slopes make agriculture impossible.

Lateritic soils

Lateritic soils developed from basic to intermediate rocks and occupy sloping to steep positions. They have excellent physical characteristics, good internal and external drainage, a good waterholding capacity and are relatively fertile. Phospate is often high, but there is a strong P-fixation.

At present the Lateritic soils are partly under natural forest - which should be maintained on shallow soils or on steep and mountainous land -, partly cropped in a system of shifting cultivation (mainly hill padi), or used for perennial crops such as rubber, pepper and fruit trees. They are very suitable for pepper and already largely in use for this crop.

There is some scope for the development of smallholdings. The rugged topography renders these soils unsuitable for large development schemes. The total area covered by Lateritic soils is rather small.

Red-Yellow Podzolic soils

The Red-Yellow Podzolic soils cover most of the dissected erosion surface in the interior areas (Tebedu physiographic unit) and also occur wide-spread in the Quop unit. They have mainly developed on shale, sandy shale, siltstone and arkose and sometimes sandstone. One family (Abok) occurs on acid igneous and metamorphic rock types. Some families occur on semi-recent alluvium in the Quop unit. Soil textures are defined by the parent material and range from sandy loams to clays. Apart from the overall textural group of a given profile, there generally is an increase of clay content with increasing depth and this has been ascribed to illuviation of clay.

The physical characteristics depend on soil texture and soil structure and are variable. Coarse-textured soils are highly erodable and may suffer from drought in the dry season (Nyalau and Bekenu soil families), fine-textured soils have a good resistance against erosion and a better waterholding capacity, but internal soil drainage may be a limiting factor for agriculture (Merit family).

Red-Yellow Podzolic soils are used mainly for hill padi (shifting cultivation), or for perennial crops (mainly rubber, and to a lesser extent, pepper). The prospects for large-scale development projects are very limited: unsuitable topography, scattered occurrence and great soil differences over short distances, due to variations in the parent material (e.g. alternating beds of finer- and coarser-textured sedimentary rock). The soils are suitable for rubber, pepper and sometimes oil palm, but fertilization is necessary. Without the use of fertilizers the soils are suitable for forestry. Notwithstanding the low productivity, the Red-Yellow Podzolic soils form an important group because they cover extensive areas.

The Malang and Semilayu families occur as valley fills, alluvial fans and river levees in the Quop physiographic unit. These soils are reasonably fertile and locally of great importance as very few suitable soils are otherwise available. The soils are suitable for the production of a large variety of annual and perennial crops.

Grey-White Podzolic soils

The Grey-White Podzolic soils are similar to the Red-Yellow Podzolic soils in most characteristics, but they are generally poorer in nutrients. The majority developed on parent materials with minerals very few susceptible to easy weathering (terrace remnants and Tertiary sandstone). On such rocks they often occur in association with Red-Yellow Podzolic soils and Podzols. Soil textures vary with the rock textures of the parent material. Present land use as well as agricultural and forestry potential are more or less as described for the Red-Yellow Podzolic soils, but for agricultural crops more fertilizers are needed to reach the same production level. Where Grey-White Podzolic soils occur in association with Podzols they can generally be regarded as unsuitable for agriculture.

Podzols

Podzols, in the First Division, developed from three different types of parent material, which have one characteristic in common: the almost complete lack of minerals susceptible to weathering. The poorest Podzols are found on the most coarse-textured rock types. Some soil families have coarse textures, a B-horizon rich in humus (either indurated or soft), others have finer textures, lack the B-horizon and have very pale colours throughout.

On coarse-textured terrace remnants Podzols are found in association with Grey-White Podzolic soils (Lundu unit). Podzols also occur in Tertiary sandstone (Penrissen unit) and on old coastal beaches (Sematan unit).

The natural vegetation on terrace remnants and Tertiary sandstone is 'kerangas'-forest (see Annex Forestry) which gives a very acid litter and this promotes the podzolization process. Podzols are seldom cultivated at present, except for some vegetable gardens near Kuching which receive heavy manuring and for some of the older coastal beaches in the Sematan unit when these occur together with younger, less leached, coastal sands. For the time being Podzols can be regarded unsuitable for agriculture and, being highly erodable, they should remain under a forest cover.

Gley soils

Gley soils developed on recent alluvium with high groundwater levels during at least part of the year. They occur in three physiographic units.

In the Samarahan unit (present riverain flood plain) Gley soils occupy river levee sites and the transition from levee to basin. They form a stretch of variable width along the main rivers. This is the Bijat soil family.

In the Santubong unit (young emerged coastal plain) Gley soils are found on the 10 feet level (3 m). They may have developed from Saline Gley soils from which the salts were leached. They find their greatest extension in the Nonok coastal area. This is the Pendam soil family.

Finally, some river valleys in the Quop unit have been partly filled in with semi-recent and recent sediments. There are also inland alluvial fans, e.g. near Muara Mongkos. On these sites soils of the Bijat soil family are found.

Gley soils have a high water-table during at least part of the year; they show rusty mottles where iron oxides and hydroxides have accumulated next to bleached spots which have lost iron. The soils are younger and therefore richer in nutrients than the Podzolic soils and the Podzols. They have a high potential for rice and coco-nut and for off-season crops. Double-cropping of wet padi is possible if the topography, the quality of the irrigation water and the availability of such water allow it. Most of the Gley soils are already in use (rice, coco-nut, sago), but cultivation can be intensified. The most serious limitations are lack of drainage, high groundwater levels and flooding. The Pendam soils may be subject to saline groundwater. If these limiting factors can be overcome, the Gley soils would belong to the most productive soils in the First Division.

Saline Gley soils

Saline Gley soils occupy most of the Santubong physiographic unit. There is only one soil family, Rajang. In the Santubong unit higher-lying sites are occupied by soils of the Pendam family; or they are 'islands' of sedimentary and igneous rocks.

A Rajang soil profile is saline throughout and has saline groundwater almost to the surface. Although seldom flooded, these soils are in direct connection with saline to brackish water from the sea or the tidal rivers through an extensive system of creeks and channels. Saline Gley soils contain sulphur in a reduced form, which upon drainage and subsequent desiccation may oxydize into sulphuric acid and sulphates. If the low pH's, resulting from this process, cannot be compensated, the soils may become definitely unsuitable for cultivation. Thus far the Rajang soils have been studied in the Proposed Sungai Sarawak Padi Scheme and the Santubong Drainage Scheme.

The Rajang family covers extensive coastal swamps in the eastern part of the First Division, and some smaller areas elsewhere along the coast. The natural vegetation is of the mangrove type, with Nypa fruticans often dominant.

Peat soils

Extensive peat deposits occur as filled in backswamps between the Samarahan and Sadong rivers and east of the Sadong river, stretching into the Second Division. Smaller backswamps with peat occur along the Kayan river, near the coast between Kuala Sampadi and Kuala Rambungan, and as a filled in old lagoon near Kuching. These peat formations form the Nonok physiographic unit.

The organic soils which developed from the peat have been classified as Anderson family: woody peats more than 40 inches (100 cm) deep, with a high watertable. The larger peatswamps are generally Anderson 3 (deep phase) which implies that the peat layer is more than 120 inches (300 cm) thick. The peats overlie fine-textured old riverain, estuarine and marine deposits.

Shallow peats are classified as Mukah and Igan families: woody peats, 10-40 inches (25-100 cm) thick, overlying clays and sand, respectively. They form the swamp margins and often merge into Bijat and Pendam family soils along the river. These shallow peats have been included in the Samarahan unit.

The peat soils are largely uncultivated. They carry valuable forest stands, which by natural regeneration treatment can give a sustained timber yield. Reclamation of the Anderson family is not recommended: drainage is difficult and will become increasingly difficult when the peat subsides and the land surface lowers untill the stage that all the organic material will have oxidized.

Moderately deep peats (Mukah and Igan families and sometimes Anderson, soil phase 1 (peat 40-80 inches (100-200cm) thick) are often cultivated. They generally mark the transition of river levee to backswamp and can be included in schemes which concentrate on the Gley soils of the river levees.

Recent Alluvial soils

Recent Alluvial soils are found in the Tebedu and Quop physiographic units on young deposits in the upper reaches of river valleys. They cover flat to undulating terrain, are generally well-drained and well-suited to agriculture, especially to perennials. They occur only in small areas but can be of great importance locally.

Similar soils are also found in the Sematan unit (coastal ridges and beaches). Older coastal soils develop into Podzols.

4. THE ADVISORY LAND USE MAP (LAND UNITS MAP) 1:50,000

4.1. Introduction

The Advisory Land Use map 1:50,000 is not a soil suitability map in the traditional sense. Most soil suitability maps give a graded classification on one subject (e.g. general suitability for cropping; suitability for one crop; for a group of crops; for irrigated crops; for pasture, etc.). In the map under discussion a choice is made out of the various crops wich climatically can be grown in Sarawak First Division, and the crops advised are regarded most suitable for a particular mapping unit from a point of view of soils and physiography.

4.2. Compilation and purpose of the Advisory Land Use map

The Advisory Land Use map was compiled as a working map for the regional development study of the First Division (see also chapter 6). It is available only in hand-coloured copies, each consisting of 21 sheets; three copies are available to the Sarawak Study Team, one copy is at the Soil Survey Division, Department of Agriculture. The 1:50,000 topographic map of Sarawak has served as a base map, and the sheets of the ALU-map correspond with those of the topographic series. A key and a map index are added to each of the four copies.

The Advisory Land Use map is a joint production of the Senior Soil Surveyor of the Soil Survey Division, Kuching (J.P. Andriesse) and the soil scientist of the Sarawak Study Team (W.A. Blokhuis).

The map units are based on the Reconnaissance Soil Map of West Sarawak on a scale 1:100,000 (Andriesse, in preparation). In compiling the ALU-map soil map units were 'translated' into land units, taking into consideration physiography and relief, as shown on the topographic map which served as a cartographic base and as known from local knowledge of the terrain. Where relevant knowledge of local agriculture in the various regions was taken into consideration.

For practical reasons the land units map was produced at a working scale of 1:50,000 and it was therefore drawn on transparent overlays placed over the original working sheets of the 1:100,000 soil map, which were at this scale. In using the ALU-map it must be realized that the information given is of a reconnaissance nature (i.e. corresponding with a mapping scale of 1:100,000) and it will therefore be quite possible that locally less detail is shown than would have been technically possible on the larger scale chosen for publication.

As the units of the soil map are largely compound units in which several soil units of different suitability for various crops occur, the land use advised for these complex units was based on the character of the dominant soils, disregarding smaller patches for which a different crop choice should be preferable. Small soil mapping units were sometimes disregarded on the ALU-map and the relevant areas, if not distinctly different in agricultural potential, enclosed within the neighbouring land unit.

On each soil map a certain unit contains some land which belongs to another unit, but which could not be mapped separately on the scale chosen (1:100,000); it also includes land occupied by kampong sites, roads, small rivers, etc. This also applies to units of the ALU-map. Therefore, when measuring the total surface area of a given map unit (e.g. in order to assess its agricultural potential), 25% should be deducted to allow for such impurities. This applies specifically to the small inland valley areas. In some cases these have been exaggerated in area because of the desirability to accentuate their existence.

4.3. Description of the land units

The key to the ALU-map, comprising a description of the land units, an advise for agricultural use and an indication of the limiting factors, is shown in table 1. It may serve to give an overall picture of the subject.
The various ALU-units will be discussed in more detail in this section, whereas in paragraph 4.4 due attention will be paid to the limiting factors for agricultural use.

Table 1 : Key to the Advisory Land Use map

Land unit	Tentative advisory land use	Limiting factors in agricultural use 1)
Uplands		
U - Steep mountains and ridges with little or no soil cover	Permanently unsuitable for agriculture; should remain under forest cover or be reforested	Soil depth (3) Topography (3)
B - Moderately to steeply sloping basaltic mountains and hills (good quality soils, relatively resistant to erosion)	Suitable for agricultural crops such as pepper, coffee; scattered development possible where slopes are reasonable, with proper conservation measures. Suitable for forestry.	Soil depth (2/3) Topography (2/3)
F - Interior hill land with slopes from 15° to 35° (moderately good soils)	Suitable for plantation forestry. Suitable for perennial crops: rubber, pepper in selected places (conservation measures); possible lowland tea or coffee.	Topography (2/3)
G1- Interior hill land with slopes generally less than 15° (moderately good soils)	Rubber; oil palm if sufficient land available; pepper, coffee, tea	Topography (1/2)
G2- Interior hill land with slopes generally less than 15° (good soils, basalt-derived)	Pepper, cocoa, coffee, tea (no oil palm)	Topography (1/2)
C - Mainly 'cuesta'-terrain built from sandstone or other coarse-grained sedimentary rocks; gentle to steep slopes	Forest cover to be maintained. If already in use: rubber (on lesser slopes, with conservation measures)	Topography (3)
Fans, terraces and coastal ridges		
I - Fans and terraces; flat to gently sloping (sandy and very permeable soils)	Rubber; also coco-nut. Fertilization necessary	
A - Coastal ridges and small coastal flats	Coco-nut with animal husbandry; watermelons; cashew nuts (?). Research into fertilizer needs required	

Table 1 (continuation)

Land unit	Tentative advisory land use	Limiting factors in agricultural use 1)
Lowlands		
D - Lower and middle riverain flood plains	Where flooding is moderate: wet padi with off-season crops; double-cropping of wet padi where feasible; alternative: coffee, coco-nut (with improved drainage). Off-season crops (where flooding is severe). Drainage improvement and flooding control necessary	Drainage (2/3) Flooding (1/3)
W - Wet interior valleys	Wet padi with off-season crops; Water management to be improved	Drainage (2) Flooding (2/3)
E - Upper and middle riverain valleys	All annual and perennial crops, except crops sensitive to flooding (pepper a.o.). Flush floods occur in places	Flooding (0/3)
H - Interior valley areas (flat to low hilly terrain)	Need for detailed surveying; generally suitable for agriculture and forestry, but suitability is varied	Flooding (0/2)
Problem areas		
P1- Deep basin peats	To be left under forest cover and to be treated on a sustained yield basis	Several serious limiting factors
P2- Estuarine areas with saline and potentially acid-sulphate soils	To be left under natural vegetation/nipah	Several serious limiting factors
P3- Podzols; both upland podzols on dip slopes of sandstone 'cuesta's', and lowland podzols on more or less flat-lying terrace summits	To be left under natural vegetation	Several serious limiting factors

1) 0 = no limitation; 1 = slight; 2 = moderate; 3 = serious (soil fertility is not taken into account)

U - Steep mountains and ridges with little or no soil cover. This land, with slopes of generally more than 35° should be under forest cover. Shifting cultivation should be abandoned; there is an increasing danger of soil erosion, while the annual returns from the hill padi are bound to be declining due to a continuing loss of soil fertility. Of even greater importance at present is the protection of the forest cover which retards the sudden discharge of rain water. Here most rivers have part of their upper catchment areas, and as a first step towards controlling flooding in the middle riverain valleys, a forst cover in the uplands should be given attention to.

B - Moderately to steeply sloping basaltic mountains and hills. Compared with soils developed from acid to intermediate igneous rocks and from sedimentary rocks (mainly Podzolic soils), those derived from basic igneous rocks (mainly Lateritic soils) are more resistant to erosion because of a better soil structure. They also have a slightly higher nutrient level. The soils are suitable for productive forests and for agriculture. As good soils are scarce in Sarawak, it is thought that the basalt-derived soils should be put under agriculture as much as possible; therefore a separate map unit was created, covering basaltic mountains and hills with slopes generally between 15° and 35°.

The physiography of land unit B shows long slopes, intersected by deep drainage channels. A rather large proportion of the land is taken up by such drainage channels and their steep slopes with shallow soils. So it is difficult to find large areas which can be cultivated; fields are generally small stretches of land between the drainage channels. The soils are very stable against erosion and all slopes up to 30° can be cultivated as far as soil erosion is concerned. However, the increased run-off of rain water when cultivating such steep slopes, is unfavourable and under these circumstances conservation measures have to be taken or the land should be kept under forest.

Where most of the slopes are more than 35° basaltic mountainous areas come under unit U. Sometimes a compound map unit U/B is used. In the case of the Serian area (mainly G.Sedong and G.Semuja Tamiong massifs) U/B indicates that steeply and less steeply sloping parts occur in such a way that separate mapping is not feasible. In some cases the contours may give some indication as to where the suitable agricultural land is most likely to be found. The area mapped U/B along the divisional boundary has a complex geology; on the soil map 1:100,000 it is mapped as an association of Red-Yellow Podzolic and Lateritic soils. As, moreover, the slopes are variable, it could only be mapped as U/B.

F - Interior hill land with slopes from 15° to 35° covers most of the upland areas which physiographically belong to the Tebedu unit. All slopes are highly complex. Often an upper slope is 15 to 20°, a lower slope (part of the same slope) 20 to 30°. In general areas with slopes of 15 to 20° only and of some managable size, are difficult to find. If one includes areas with slopes up to 30°, then areas of a suitable size for plantation forestry or a rubber plantation can be found. Hill slopes are not dissected by drainage lines as in unit B and therefore the total area which can be cultivated is larger. One should, however, give attention to the danger of an increased run-off of rain water if too much steep land is brought under cultivation; in such cases conservation measures must be taken or the land should be forested. Red-Yellow Podzolic soils of the Merit family (clay loams to clays) are dominant, and these are relatively resistant to erosion. However, the fertility of the soil and its stability against erosion are definitely less favourable than in unit B.

G1 - Interior hill land with slopes generally less than 15° (moderately good soils). This unit covers parts of the Quop physiographic unit; compared with F dissection is less and slopes are less steep. However, the soils are often sandier so that in the case of occasional steep slopes the erosion hazard and the danger of increased run-off is even larger than in unit F. Those parts should therefore be left under a forest cover. Red-Yellow Podzolic soils are dominant; the main soil families are Bekenu and Nyalau. The same crops can be grown as in area F, but there is more need for fertilizers. The unit occurs most distinctly in the Stinggang-Stungkor area. Oil palm has been suggested (Andriesse, 1967) as it is practically the only place in the First Division where a large, homogeneous and slightly undulating area of land suitable for this crop is available.

Another area with G1 is found west of Kuching. In general one can say that most of the G1-land is restricted to the younger (Tertiary) sedimentary rocks, occurring in the western part of the First Division, while F is mainly found on the older (Cretaceous) sedimentary rocks, occurring in the eastern part.

G2 - Interior hill land with slopes generally less than 15° (basalt-derived soils). Although the slopes in G2 are of the same category as in G1, the two land units are different in most aspects. G2 occupies gently undulating foot slopes around basaltic mountains; it often forms a rim around land unit B or U/B (see e.g. the Serian area). The soils have developed 'in situ' on basaltic rock or on colluvial material eroded from these rocks. They are either Lateritic soils (Tarat series), Recent Alluvial soils (Ramun series) or intergrades between these Great Soil Groups (Terbat series).

The soils are relatively fertile and they have a very good structure and therefore are of a much better quality than those occurring in G1. They can be used for a great variety of crops. Although land unit G2 is suited to rubber cultivation, more valuable agricultural crops are recommended.

C - Mainly 'cuesta'-terrain built from sandstone or other coarse-grained sedimentary rock. This land unit is characterized by long, gentle slopes interrupted by steep dip slopes; it covers part of the Penrissen physiographic unit. Coarse-grained sedimentary rocks weather into a sandy, permeable and highly erodable soil. The land should be kept under protective forest. Where rubber plantations exist and proper soil conservation measures are taken, these plantations can be maintained; heavy fertilizer dressings are, however, necessary. The land unit is mainly restricted to the Tertiary sediments in the western part of the First Division.

I - Fans and terraces. This land unit is of a complex nature, it contains inland alluvial fans, sandy river terraces and remnants of the old coastal plain: Lundu physiographic unit). The soils are sandy and very permeable. Because slopes are gentle, the agricultural potential is slightly higher than that of land unit C, but still low. Locally rubber and coco-nut can be grown, but the soils are too poor for more demanding perennials and for annual crops.

A - Coastal ridges and small coastal flats. Land unit A occupies small coastal strips west of the Santubong peninsula. The youngest, most seaward lying ridges still contain shell remnants and have a higher nutrient status than the more inward lying, older and more strongly leached ridges. The succession is Kabong, Sematan and Jerijeh soil families; the first two are Recent Alluvial soils, the latter is a Podzol. Kabong and Sematan soils can be used for coco-nut in combination with animal husbandry, and for water melons, possibly also cashew nuts. Topography and soil permeability are favourable, but low chemical fertility and in places, high water tables and flooding (often by salt or brackish water) are limiting factors. Jerijeh soils are, in their present condition, unsuitable for cultivation (see P3) but can be included in a cultivated area where Jerijeh and Sematan soils occur together in a mosaic-like pattern (see Reconnaissance soil map of Kuching-Bau-Lundu area; soil survey report no. 25/2; 1966). Fertilizer trials are needed.

D - Lower and middle riverain flood plains. There are two forms of land unit D; these are similar in soils, but differ in hydrology, geographic position and origin. They have not been mapped separately.

One form consists of levees along the main rivers, and the transition to the deep basin peats behind the levees. This represents the Samarahan physiographic unit. The boundary between D and P1 is that between Anderson soil family phases 1 and 2, i.e. at a line where the peat is 80" (200 cm) thick. The soils belong to the Bijat and Mukah soil families and to the Anderson soil family, phase 1. The peat soils with a depth of between 100 and 200 cm (Anderson 1) form a narrow transition zone between Bijat or Mukah soils and the deeper peat soils (Anderson 2 and 3). Anderson 1 soils are marginal for agriculture. They are included in ALU-unit D, but should only be cultivated if their location necessitates inclusion in agricultural schemes with mainly Bijat and Mukah soils. In land unit D the rivers are tidal, with both direct (brackish water penetration and tidal movement) and indirect tidal influence (no brackish water penetration, but water levels influenced by the tide). The tidal movements of the river facilitate external drainage of the land during low tide. The present land use is mainly wet padi and some coco-nut. Cropping is not intensive and often has the character of 'shifting cultivation'. Rice production could be intensified (Andriesse, 1965, p. 58). External drainage is necessary during the 'landas' season. Flooding from the river is rare; it occurs in places at 'king' tide during a period of high rainfall. Small bunds are sufficient to protect the levees from this type of flooding. Flooding from the basin peat does not normally occur, although groundwater is at surface level during the 'landas' season. However, if the zone of shallow peat is drained and brought under cultivation, the 'peat sponge' is 'tapped' and the adjoining levee soils may suffer from flooding. Wet padi cultivation can be combined with off-season annual crops, and double-cropping of rice may be considered. Perennial crops, such as coffee and coco-nut, could also be grown, preferably on the (high lying) levees. When flooding cannot be remedied, cultivation should be limited to off-season crops and, in the wet season, wet padi.

In the Nonok coastal area - higher lying ground in the deltaic-estuarine areas - clay soils of the Pendam family are found, which resemble those of the Bijat family, except for having slightly saline subsoils. They can be used for wet padi, coco-nut and various other crops.

W - Wet interior valleys and flats. Land unit W is characteristic for the middle courses of the main rivers where they cross gently undulating to hilly interior areas and terraces. Bedload sedimentated in the river valleys to the

extent that more or less flat-lying valley bottoms have developed, which are suitable for wet padi cultivation. Shallow peat may occur. The soils are Recent Alluvial soils and water-tables are high throughout the year. External drainage generally needs to be improved, and flood hazards may exist.
Another occurrence of land unit W are swampy alluvial flats with Recent Alluvial soils, surrounding hard limestone hills. These are underlain by flat-bedded limestone, and form good 'payas' for wet padi cultivation. If irrigation water can be tapped from a small river near by, wet padi can also be grown in these 'payas' during the off-season.

E - Upper and middle riverain valleys. Land unit E often occurs as the part of a river valley situated between H (discussed below) and W, or it takes the place of H. Like land unit W those valleys are filled in with recent alluvial material and are flat-bottomed. As they are situated higher upstream, ground-water levels are generally low in the off-season. In the rainy season water levels are higher and flush floods are a serious bottleneck. Throughout the year ground water levels are variable, and this makes the area unsuitable for wet padi cultivation, as irrigation is not feasible. Otherwise land unit E contains some of the most valuable land of the First Division and almost all annual and perennial crops can be grown, with the exception of crops sensitive to flooding (e.g. pepper).

H - Interior valley areas. Land unit H is highly complex. It can take the same position as E; in other cases E is absent and W merges into H when going up-stream. In land unit H recent riverain sediments and (older) alluvial terraces (or terrace remnants) are found, together with colluvial fans and local out-crops of sedimentary rock. The soils thus can occupy various positions in the valley, and only where situated at a low level are they liable to flooding. There is a great variety of soils in unit H as the soil characteristics differ with the parent material and the geographic position. In places flat lying valley bottoms, suitable for wet padi cultivation, may occur, but these are scarce, and as a whole land unit H is not suited to this crop. It is generally suitable for agriculture, especially for fruit trees, rubber and other perennials, and for plantation forestry; yet in the key no land use has been recommended since the heterogeneity of this land is too great for giving recommendations applicable for the whole map unit. To assess its potential to the full, detailed surveying is necessary.

P - Problem areas. Three widely different land units were grouped together under P. Their common characteristic is that they are regarded unsuitable for agriculture under present technical and economic conditions.

P1 - Deep basin peats. A considerable part of Sarawak (First and Second Divisions) is covered by deep peats occupying basin sites (Nonok physiographic unit). Towards the edges the peats merge through mucky peats into Gley soils (Pendam and Bijat families). At present they are unsuitable for agriculture and will remain so in the foreseeable future. Reclamation of these peats for agriculture would imply drainage; this would result into soil shrinkage and lowering of the land surface, and would create new drainage problems. Moreover, the peat is very acid and low in plant nutrients and offers little support for tree crops. At present, this land type is covered by peat forest which is being exploited. The basin swamps are the main source of timber in Sarawak, and the policy should be to ensure a sustained valuable timber production by means of natural regeneration treatment.

P2 - Estuarine areas with saline and potentially acid-sulphate soils. This land unit is characterized by the Rajang soil family: Saline Gley soils which may develop into acid-sulphate soils upon drainage and oxidation of the ferrous sulfides present. Most of the Santubong physiographic unit corresponds to land unit P2. Research that has started in the Santubong Drainage Scheme should be continued and diversified. At present the high cost of reclamation and the great danger of acidification make this land unfit for agricultural development.

P3 - Podzols. Land unit P3 consists dominantly of one Great Soil Group, the Podzols, characterized by a sandy texture and the almost total absence of plant nutrients. A B-horizon, rich in humus and often indurated, may occur in the subsoil, and this may impede internal soil drainage. If the B-horizon is lacking, or situated at great depth, these soils are excessively drained. When put under agricultural use they would need excessive amounts of fertilizer, as the base-retention capacity of the soil is extremely low.

Most of the Podzols have a natural vegetation of 'kerangas'-forest. This forest cover should be maintained as a protection against erosion; species trials are needed to explore the establishment of more valuable forest stands.

Podzols are found on flat lying terrace remnants (lowland Podzols), on gently sloping dip slopes of sandstone 'cuestas' (upland Podzols) and on some of the older coastal ridges (included in land unit A). Where occurring near large markets, mixed farming is possible or the land can be used for industrial purposes.

4.4. Limiting factors in agricultural use

In the key the limiting factors in agricultural use and the degree of the limitation are given for each land unit. Soil fertility has not been indicated since this is a limiting factor for almost all the soils of Sarawak First Division; in general it can be said that Sarawak soils are poor in nutrients and need fertilizers for a sustained yield. Physical soil characteristics such as soil texture, soil structure, porosity, etc. have not been included as limiting factors, although they have a bearing on agricultural land use. However, since these are soil characteristics which are generally closely related to specific soil series, they may be variable within a given land unit. On the other hand the limiting factors are site characteristics pertinent to a certain site (or land unit), and to some extent independent of the soil series. Sometimes the seriousness of a limiting factor is the consequence of both site and soil characteristics; this is e.g. the case for topography where not only the gradient of the slope, but also the soil texture is taken into account.

The soil characteristics were commented upon in chapter 3.

4.4.1. Soil depth

Soil depth is a moderate to seriously limiting factor on moderately steep to very steep terrain. It is added as a limiting factor to land units U and B, but soils too shallow for cultivation may be found in all land units where topography is a limiting factor, especially in F and C. Apart from soil depth itself, rockiness of the surface and occurrence of much stones and rock fragments in the soil can be regarded as aspects of limited soil depth.

4.4.2. Topography

Topography refers to the steepness of slopes and to the erosion danger if cultivation is practised on such slopes. Where soil depth is a limitation, topography generally is a limitation as well, but the reverse is not always true: there is moderately steep to steep terrain where soil depth is sufficient for cropping, but the danger of soil erosion and of increased run-off of surface water prohibits agricultural use.

In order to get a clearer picture of topography as a limiting factor, something need to be said on the relation between slope gradients (both in degrees and in percentages) and the possibilities for crop growth. In table 2 the slope classification for East Malaysia (Wong, 1970) has been compared with that of the United States Department of Agriculture (Soil Survey Staff, 1951). In Malaysia slopes are expressed in degrees and percentages were given for each classification.

Table 2: Classification of slopes in East Malaysia and in the U.S.A.

		East Malaysia		U.S.A.	
single slope	complex slope	degree	%	degree	%
very steep	very steep	over 35	over 70	over 25 to 33	over 45 to 65
steep	steep	25 - 35	47 - 70	11½/17-25/33	20/30-45/65
moderately steep	hilly	12 - 25	21 - 47	6/9 -11½/17	10/16-20/30
sloping	rolling	6 - 12	10½- 21	3/4½- 6/9	5/8 -10/16
gently sloping	undulating	2 - 6	3½- 10½	1/2 - 3/4½	1/3 - 5/8
level	level	0 - 2	0 - 3½	0 - 1/2	0 - 1/3

(Remark: 10/16 - 20/30 should be read as follows: lower limit of slope 10 to 16 percent, upper limit of slope 20 to 30 percent).

It appears that generally there is a difference of one unit between the U.S.D.A. and the Malaysian classification (e.g. slopes of 12-25^{o} are called steep in the U.S.D.A., but moderately steep in Malaysia). This difference in classification reflects the fact that in Sarawak with its wet tropical climate and when the terrain is covered by luxurious vegetation, erosion is not so serious in the same topographic conditions as in the U.S.A.

In the soil suitability classification for Malaysia (Wong, 1970) the degree of the topographic limitation is given separately for light-textured and for heavy-textured soils. The U.S.D.A. textural class names - which are the ones used in Sarawak - are grouped together in light-textured and heavy-textured soils respectively, as follows (Soil Survey Staff, 1951):

light-textured soils: sandy clay, sandy clay loam, sandy loam, loam, silt loam, silt, loamy sand and sand;

heavy-textured soils: clay, clay loam, silty clay, silty clay loam.

Table 3 shows the relationships between degree of topographic limitation, soil textural group and slope degree.

Table 3: Topographic limitation and soil textural group

	Topographic limitation				
soil textural group	very serious	serious	moderate	minor	none
light-textured soil	over 25°	12-25°	6-12°	2- 6°	under 2°
heavy-textured soil	over 35°	25-35°	12-25°	2-12°	under 2°

For pepper, rubber and hill padi the cropping possibilities and restrictions as determined by slope in relation to soil texture, are given in table 4.

Table 4: Cropping possibilities in relation with soil texture and slope

crop	light-textured soils	heavy-textured soils
pepper	soils generally unsuitable; cultivation possible on slopes up to 6°.	unterraced up to 12°; on basalt-derived hills (ALU-unit B) up to 30 - 35° (pepperfields are often unterraced)
rubber	unterraced up to 15° (broad-based terracing is possible; bench terracing disturbs the natural slope gradient and thereby increases erosion danger)	unterraced up to 15°, terraced 15 - 35°, for convenient management restricted to 15 - 30° (on steep slopes clearing of undergrowth and terracing in a rubber plantation should be done with great care. If sufficient ground cover is available, the soil protection given by a rubber plantation approaches that of a secondary forest. Terracing provides an additional soil protection; at present terracing is mainly practiced for convenient management)
hill padi	slopes up to 15° (unterraced) (regulated shifting cultivation, with one crop every 15 years)	slopes up to 35° (regulated shifting cultivation, with one crop every 15 years)

4.4.3. Soil drainage

Soil drainage consists of

a. external soil drainage;

b. internal soil drainage, which refers to the downward flow of excess water; it is a function of soil permeability[x)], the presence of contrasting soil

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x) Soil permeability is the capacity of a soil which enables it to transmit water or air (disregarding groundwater level and possible impervious layers).

layers and the presence of groundwater level. In Sarawak soil drainage is mainly a problem of high groundwater levels. In the soil suitability Classification for Malaysia (Wong, 1970), the U.S.D.A.-classification (Soil Survey Manual, 1951) was followed in defining soil drainage classes (table 5):

Table 5 : Soil drainage classes and grade of soil drainage limitation

soil drainage class (USDA)	limitation grade (Wong, 1970)	limitation grade ALU-map
very poorly drained	serious	3
poorly drained	serious	3
imperfectly drained	moderate	2
moderately well-drained	none	0
well-drained	none	0
somewhat excessively drained	minor	+)
excessively drained	minor	+)

+) Limitations due to excessive drainage have been disregarded in the ALU-map. Excessive drainage can be a serious limitation in dry climates, but for Malaysia it is regarded a minor limitation (Wong, l.c.).

4.4.4. Flooding

Flooding of land in Sarawak occurs at times during the 'landas' season when rainfall can continue more or less uninterruptedly for several days. Often the flooding is the result of a combination of this heavy rainfall in the upper catchment areas of the rivers, and the indirect tidal influence which is felt far upstream. During high tide the water levels in the main rivers are so high that their tributaries cannot discharge into them. The flooding due to this stagnated discharge is known as 'backflooding'.

The remedy of the backflooding must be sought first of all in a retarding of the discharge in the upper catchment areas, e.g. by changing annual cropping into perennial cropping, plantation forestry or protective forests. However, the remedy can only be incomplete as the other factor, the tidal influence, cannot be changed.

4.4.5. Summary

In the upland areas the main limitations for agricultural use are soil depth and topography, in the lowland areas soil drainage and flooding; in the deltaic-estuarine areas and the coastal ridges brackish and salt water penetration may be added. No limitations have been indicated for the coastal ridges and the fans and terraces. There are such factors - flooding and salt water penetration in some of the coastal ridges, and excessive drainage in the terrace soils - but in general these are not the major limiting factors. Low chemical soil fertility and sandy textures are the main limitations in these soils.

In the problem areas several limitations are serious; they have been discussed in paragraph 4.3.

4.4.6. Suitability of the land units for agriculture

The ALU-map shows the geographical distribution of the ALU-units. On this map the surface area of each separate occurrence of an ALU-unit can be measured. The area suitable for agriculture in such an outlined unit can be calculated after allocating a suitability percentage. The procedure will be further discussed in chapter 6.

The suitability percentages given to the ALU-units are as follows:

U	0	I	50	P1	0
B	10 - 30	A	50	P2	0
F	30 - 60	D	75	P3	0
G1	70	W	75		
G2	70	E	75		
C	0	H	70		

The logic of these percentages can be appreciated from the discussion in the foregoing paragraphs. The maximum suitability percentage is 75 (see 4.2). The percentages are based on local knowledge, on experience in the Soil Survey Division and on observations made during field trips in which members of the Soil Survey Division and of the Sarawak Study Team participated. Naturally, the percentages as used are the entire responsibility of the Sarawak Study Team.

Special attention is asked for the suitability percentages for the ALU-units F and B. From a physical point of view land use can be regarded safe if only 30% respectively 10% is used for agriculture. However, percentages of 60 for F and 30 for B as averages, can be accepted if precautions are taken against soil erosion and chances of increased run-off. Such an extension of the area under cultivation in F and B should be considered only if there are strong socio-economic pressures.

5. THE GEOGRAPHIC UNITS MAP 1:250,000

5.1 Introduction

The First Division of Sarawak has been divided into 45 geographic units.

They serve to group together various occurrences of specific land units, in such a way that subregions are formed of a size convenient for socio-economic calculations.

The 45 geographic units differ widely in their physical complexity, i.e. in the number of composing land units and in their geographical pattern. Some of the geographic units are subdivisions within one large geomorphological entity. Although the reason for subdivision in such cases is to create subregions of a convenient size for socio-economic calculations, the delineation is mainly along physiographic boundaries. Other geographic units are separate occurrences of one and the same physical entity, often a physiographic unit c.f. map II.

The geographic units map was compiled from the soil map of Sarawak 1:250,000 (map III) and the physiographic map on the same scale (map II). The provisional boundaries were then transferred to the 1:50,000 ALU-map and where necessary delineated more precisely. The thus corrected lines of boundaries were transferred back to the geographic units map to make the definite boundaries of the geographic units.

5.2 <u>General remarks on the geographic units</u>

The geographic units 1 to 23 inclusive, each contain several to many ALU-units, in different geographical patterns. If only physical criteria were applied less units would have been created. The geographic units 10 and 12 e.g. do not differ from a physical point of view; the same can be said of the units 20,21 and 22. In these cases the subdivision was made in order to arrive at units suitable for socio-economic calculations with regard to future land use (cf. chapter 6). So it can also be understood why geographic units in areas of low agricultural potential and sparse population density (1 to 16 inclusive) are generally larger than those in areas of higher agricultural potential and greater population density (10 to 23 inclusive).

Geographic unit 17 consists of higher lying ground, occurring as 'islands' in the peat swamps. This unit was subdivided (17a to 17f inclusive) according to each individual occurrence.

Geographic unit 18 is the Santubong peninsula, consisting of five land units.

Geographic unit 19 is the Bako peninsula, composed entirely of one land unit, U (steep mountains and ridges).

Geographic unit 24 consists dominantly of two land units; U (lower and middle riverain flood plains) and P1 (deep basin peats), both associated with the Batang Kayan (Lundu). In other cases the riverain flood plains (25 to 29 inclusive) and the deep basin peats (35 to 44 inclusive) were separated.

Geographic units 25 to 29 inclusive are separate occurrences of the Samarahan physiographic unit (map II), viz. river levees and levee/basin transitions (shallow peat overlying clay). Moreover this physiographic unit consists of one land unit only, D.

Geographic units 30 and 31 essentially comprise two land units: P2 (estuarine areas) and D. The difference between the two geographic units is to be found in the relative areas of land covered by either P2 or D, and in differences in the geographic position of D.

Geographic units 32, 33 and 34 consist of land unit P2, with a varying amount of land taken up by P3: much in 32, less in 33 and almost none in 34. P3 represents terrace remnants with Podzols.

Geographic units 35 to 44 inclusive, are various occurrences of the Nonok physiographic unit (map II), coinciding with land unit P1 (deep basin peats). The subdivision is according to separate occurrences; each one is an entity enclosed by riverain flood plains and other physiographic units. An exception is unit 43 which consists of various small basins. Geographic units 35 and 36 are slightly different from the rest of this group in geographical position and mode of formation.

Geographic unit 45 comprises various occurrences of the ALU-unit A: coastal fringes and small coastal flats.

5.3. Description of the geographic units (physiography, soils, units of the Advisory Land Use map 1 : 50,000 (ALU-units))

The geographic units were named after a kampong, river, mountain or other geographic feature in, or near the area.

1. Tg. Datu
   The NW point of Sarawak. Soil conditions and terrain physiography variable. Mainly Grey-White and Red-Yellow Podzolic soils and Skeletal soils. Main ALU-units: B, U, G and F.

2. Kpg. Limo
   Consisting largely of terraces and terrace remnants with Podzols. Poor soils. Main ALU-unit is P3; some P1, H, U, P2 and C.

3. Gunung Pueh
   Mainly steep mountainous ridges with Skeletal and Red-Yellow Podzolic soils. Main ALU-unit is U, covering approximately 90% of the unit.

4. Kpg. Sebeko
   Relatively slightly dissected terrain; consisting of large old valley floors, terraces, terrace remnants and recent valleys; some mountain ridges. Grey-White Podzolic soils and Podzols; poor soils. Main ALU-units: C, P3, E and G1.

5. Gunong Gading
The Gading mountains and foot slopes, fringed in the north, east and south by recent landscapes, and in the west by geographic unit 4. Soils are variable. Main ALU-units: E and U; also B, G1, C and P3.

6. Kpg. Kuali
Small area with mainly Red-Yellow Podzolic soils, situated between the podzol-dominated geographic unit 7 and recent landscapes. Main ALU-unit is F.

7. Batang Kayan (Lundu)
Largely the upper catchment area of the Btg.Kayan. Mainly 'cuesta'-landscape, built from sandstone. Generally Podzols of very poor quality. Main ALU-units: C and P3.

8. Stinggang
Relatively slightly dissected terrain. Rather poor soils, mainly Red-Yellow Podzolics, but favourable physiography. Main ALU-units: F, G1 and H.

9. Bau
Slightly to moderately dissected terrain, with large old valley floors, terraces, terrace remnants and recent valleys; some mountain ridges. Mainly Red-Yellow Podzolic soils. Main ALU-units: F, U, H, G2, I and W.

10. Krokong
Moderately to strongly dissected terrain and mountainous ridges. Mainly Red-Yellow Podzolic soils. Main ALU-units: F, H and U.

11. Bungo Range
'Cuesta'-landscape with Skeletal soils, Podzols and Red-Yellow Podzolic soils. Main ALU-units: U and C.

12. Tebedu
Moderately to strongly dissected terrain and mountainous ridges (continuation of geographic unit 10). Mainly Red-Yellow Podzolic soils. Main ALU-unit is F; also U, B, W and H.

13. Muara Mongkos
Rather complex geographic unit, consisting of moderately to strongly, and relatively slightly dissected upland terrain, with many old and recent valleys. Mainly Red-Yellow and Grey-White Podzolic soils, but locally Gley soils and Recent Alluvial soils are of importance. Main ALU-units: F, I, H, and B.

14. Pang. Amo

Mountainous area along the southern border, with Skeletal soils, Lateritic soils and Red-Yellow Podzolic soils. Main ALU-unit is B.

15. Balai Ringin

South-eastern fringe of the First Division. Mountainous areas, 'cuesta' sandstone landscapes and variably dissected erosion surface. Skeletal soils, Grey-White and Red-Yellow Podzolic soils. Main ALU-units: C, U, I, H, B and P3.

16. Munggu Ayer

The interior areas in the eastern part of the First Division, bordered in the south by geographic unit 15. Complex physiography and variable soil conditions. Main ALU-units: C, U/B-complex, P3 and F.

17. Islands in the backswamps of the eastern part of the First Division:

17a. Bt.Punda)
17b. Bt.Keladan)
17c. Kpg.Temiang) Physiography and soils vary with the parent rock.
17d. G.Silabu) For details see table 6.
17e. Mawang)
17f. Benat)

18. Santubong peninsula

Rocky massif, largely unsuitable for agriculture. Main ALU-units: C and U.

19. Bako peninsula

Comparable to geographic unit 18. ALU-unit U exclusively.

20. Kuching

Complex geographic unit consisting of terraces and terrace remnants, dissected upland terrain and recent riverain landscapes. Main ALU-units: I, P1, D, G and P3.

21. 15th Mile

Relatively slightly dissected upland terrain with old valley floors and recent valleys; some basaltic mountains. Variable physiography and soil conditions. Main ALU-units: I and G2.

22. 24th Mile

Relatively slightly dissected upland terrain with old valley floors and recent valleys and terrace remnants. Variable physiography and soil conditions. Main ALU-units: F and I.

23. Serian

Moderately dissected uplands and valleys, surrounding two basaltic mountain groups. Red-Yellow Podzolic, Lateritic and Skeletal soils; in valleys Gley soils and Recent Alluvial soils. Main ALU-units: F, U/B-complex, G2, G1, W, E and I.

24. Lundu

Lower Batang Kayan and associated deposits (levees, levee/basin transitions and backswamps). Mainly Gley soils and shallow to deep peat. Main ALU-units: D and P1.

25. Sungai Tuang)
26. Batang Samarahan)
27. Batang Sadong)
28. Sungai Simunjan)
29. Sungai Sebangan)

Separate occurrences of lower riverain levees (Gley soils), levee/basin transitions (Gley soils) and shallow peat. Almost exclusively ALU-unit D.

30. Nonok

Nonok coastal area or Nonok peninsula, consisting of deltaic-estuarine deposits with Gley soils and Saline Gley soils. Main ALU-units: D and P2.

31. Muara Tebas

Deltaic-estuarine deposits, mainly mangrove-nipah swamps with Saline and some Non-Saline Gley soils. Main ALU-units: P2 and D.

32. Santubong

Deltaic-estuarine deposits with included terrace remnants. Mainly Saline Gley soils and some Podzols. Main ALU-units: P2 and P3.

33. Sungai Sampadi

Deltaic-estuarine deposits at Kualas Sampadi, Lundu and Sekambal. Main ALU-unit P2.

34. Kpg. Tembaga

Deltaic-estuarine deposits at Kuala Sematan. Main ALU-unit: P2.

35 - 44 inclusive: Backswamps

35. Sungai Asa
36. Kpg. Matang
37. Kpg. Pinang
38. Sungai Ensengai
39. Gedong
40. Sungai Kepayang

41. Kpg. Mansika
42. Sungai Spaoh
43. Sungai Bedup
44. Batang Krang

Separate occurrences of back swamps with deep peat. Almost exclusively ALU-unit P1. Geographic unit 43 consists of some five separate backswamps, all other units in this group are an entity each.

45. Sematan

Identical to ALU-unit A. Geographic unit 45 consists of various coastal ridges and flats, separated by river mouths or deltaic-estuarine deposits.

6. USE OF THE GEOGRAPHIC UNITS MAP AND THE ADVISORY LAND USE MAP FOR PLANNING PURPOSES

The smallest map unit used for planning purposes is the ALU-unit. With the allocation of a suitability percentage (see 4.4.6.), both the total area and the area suitable for agriculture can be measured for each separate occurrence of an ALU-unit.

The procedure to obtain these data was as follows:

a. On each map sheet of the ALU-map 1:50,000 each individual occurrence of an ALU-unit was planimetered and the results inserted on a transparent overlay. The figures on the overlay are 'nonius-units' of the planimeter used (Ott Kompensation Polar Planimeter). One nonius unit equals 2.5 hectares. One complete set of ALU-maps, annotated in this way has been prepared.
b. The boundaries of the geographic units were plotted on the transparent overlays (see 5.1). This made it feasible to conduct the calculations of total area and area suitable for agriculture for each geographic unit separately (differentiated according to ALU-units) and, similarly, for the whole of the First Division.

In table 6 the first figure under an ALU-heading gives the total surface area, the second the area regarded suitable for agriculture. The latter data give an indication of the agricultural potential of the First Division. They served as a base for agronomic and socio-economic calculations. The geographic units have been specifically used as units for calculating the future carrying capacity (in terms of farm population). For planning purposes the data have also been grouped together into larger units, generally groups of geographic units, sometimes excluding particular ALU-units (agricultural regions; subregions for development).

Table 6

Geographic units, subdivided into ALU-units: total area and area suitable for agriculture in acres.

Geogr. unit	ALU-unit	U	B	F	G_1	G_2	C	I	A	D	W	E	H	P_1	P_2	P_3	complex units	total area / suitable area
1	T*	1,670	4,120	800	1,150							180				280		8,200
	S*	0	1,240	480	810							140				0		2,670
2	T	1,300	260				1,690						4,160	5,970	1,170	30,800		45,350
	S	0	80				0						2,910	0	0	0		2,990
3	T	28,350	3,980	820			180				310	500				650		34,790
	S	0	1,190	490			0				230	370				0		2,280
4	T	1,910	250	1,580	9,300		27,600				1,030	8,760	450	370		14,580		65,830
	S	0	80	800	6,510		0				770	6,570	310	0		0		15,040
5	T	11,770	3,920	250	4,370		5,420				40	6,160	570		120	3,460		36,080
	S	0	1,180	150	3,060		0				30	4,620	400		0	0		9,440
6	T	4,590		7,510	2,280		1,310	130					200			880		16,900
	S	0		4,500	1,590		0	70					140			0		6,300
7	T	220	500				64,930				110		820	980		36,450		104,010
	S	0	150				0				80		580	0		0		810
8	T			16,950	9,530		3,550			1,270			9,290			770		41,360
	S			10,170	6,670		0			950			6,500			0		24,290
9	T	51,820	5,020	80,690	13,890			8,460		1,240	9,160	6,840	22,460			3,040		202,620
	S	0	1,510	48,430	9,720			4,230		930	6,870	5,130	15,720			0		92,540
10	T	11,310	24,110	57,620		870		670			1,890	3,050	9,930					109,450
	S	0	7,230	34,570		610		330			1,350	2,290	6,950					53,330
11	T	38,630		720			23,450									9,690		72,490
	S	0		430			0									0		430
12	T	11,700	11,170	105,510	2,440	1,850		1,190			1,070	1,500	10,570					147,000
	S	0	3,350	63,310	1,710	1,300		590			800	1,120	7,400					79,580
13	T	810	7,250	61,010	250	4,360	890	12,710			1,950	1,750	10,840	580		240		102,640
	S	0	2,180	36,610	170	3,050	0	6,360			1,470	1,320	7,590	0		0		58,750
14	T	1,560	20,380	4,310									540					26,790
	S	0	6,110	2,590									380					9,080
15	T	11,340	4,910	2,800	1,170	70	48,080	9,360		740		220	5,180	350		4,570	760	89,550
	S	0	1,470	1,680	820	50	0	4,680		550		170	3,630	0		0	40	13,090
16	T		3,700	6,990	2,420		18,920	10,230		2,190	270	580	3,270	410		9,850	11,830	70,660
	S		1,110	4,200	1,690		0	5,110		1,640	200	430	2,290	0		0	590	17,260
17a	T	400	930	900							70							2,300
	S	0	280	540							60							880

Continuation Table 6

Geogr. unit	ALU-unit	U	B	F	G_1	G_2	C	I	A	D	W	E	H	P_1	P_2	P_3	complex units	total area / suitable area
17b	T						2,710											2,710
	S						0											0
17c	T	930	370	1,800						1,410						2,260		6,770
	S	0	110	1,080						1,060						0		2,250
17d	T	2,050	2,520							300								4,870
	S	0	760							230								990
17e	T	150		6,160				350										6,660
	S	0		3,700				180										3,880
17f	T															1,480		1,480
	S															0		0
18	T	3,680					4,510	280							140	310		8,920
	S	0					0	140							0	0		140
19	T	9,120																9,120
	S	0																0
20	T	40	150	240	3,590	1,240		9,850		4,030	1,010	230	730	3,490	1,430	3,420	4,440	33,890
	S	0	40	140	2,510	870		4,930		3,030	760	170	510	0	0	0	0	12,960
21	T	280	1,850	1,900	1,330	4,750		14,550			1,310	1,390	1,800					29,160
	S	0	560	1,140	930	3,330		7,280			980	1,040	1,260					16,520
22	T	140		9,640	2,050	100		8,550			1,220	2,750	660					25,110
	S	0		5,780	1,440	70		4,270			910	2,060	470					15,000
23	T	1,000	4,340	32,810	7,060	10,750		7,210		470	8,640	4,440	3,900	780		490	22,050	103,940
	S	0	1,300	19,690	4,940	7,520		3,610		350	6,480	3,330	2,730	0		0	1,100	51,050
24	T			690	1,030		3,340	140		16,490	940		120	14,700		2,470		39,920
	S			410	720		0	70		12,370	700		90	0		0		14,360
25	T	50		60				60		5,520				320				6,010
	S	0		40				30		4,120				0				4,210
26	T			240	690					37,630				740	450			39,750
	S			140	480					28,230				0	0			28,850
27	T		60	270				90		62,060				50				62,530
	S		20	160				40		46,550				0				46,770
28	T		980	100						19,460								20,540
	S		290	60						14,590								14,940
29	T		410							7,410				430				8,250
	S		120							5,560				0				5,680
30	T									28,260					9,740			38,000
	S									21,190					0			21,190
31	T	20	490	270		290	150	1,430		24,050					53,920			80,620
	S	0	150	160		200	0	710		18,040					0			19,260

Continuation Table 6

Geogr. unit \ ALU-unit		U	B	F	G_1	G_2	C	I	A	D	W	E	H	P_1	P_2	P_3	complex units	total area suitable area
32	T		560					560		3,180					27,500	4,290		36,090
	S		170					280		2,390					0	0		2,840
33	T						360								12,700	850		13,910
	S						0								0	0		0
34	T														3,930			3,930
	S														0			0
35	T													3,220				3,220
	S													0				0
36	T													11,450				11,450
	S													0				0
37	T													11,840				11,840
	S													0				0
38	T					150		530						109,930			1,080	111,690
	S					100		270						0			270	640
39	T				70		190	160						79,480		50		79,950
	S				50		0	80						0		0		130
40	T		560	230			690							87,850				89,330
	S		170	140			0							0				310
41	T													3,770				3,770
	S													0				0
42	T		180											12,570				12,750
	S		50											0				50
43	T		40	50				370						3,790				4,250
	S		10	30				190						0				230
44	T													5,220				5,220
	S													0				0
45	T								11,270									11,270
	S								5,630									5,630
Total	T	194,840	103,010	402,920	62,620	24,430	207,970	86,880	11,270	215,710	29,020	38,350	85,490	358,290	111,100	130,880	40,160	2,102,940
	S	0	30,910	241,620	43,820	17,100	0	43,450	5,630	161,800	21,690	28,760	59,860	0	0	0	2,000	656,640

* T = Total area
* S = Area suitable for agriculture

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A N N E X 4

M I N I N G A N D Q U A R R Y I N G

CONTENTS

1. ANALYSIS OF THE PRESENT SITUATION

1.1. Introduction

Mining in the First Division, as well as in the State of Sarawak, is of minor importance (< 1% G.N.P.). In the First Division it is restricted to the production of small amounts of gold and antimony by a number of local, small-scale producers and in a more or less haphazard way.
The most important mining activity in Sarawak is located outside the First Division and concerns the winning of oil at Miri by a foreign company.

Quarrying is more important than mining. The First Division as well as the State of Sarawak are self-supporting in the production of stone for road construction.

1.2. Production value

In 1967 the total value of the production of minerals and of raw material for building and construction in the First Division amounted to about M$ 1.5 million, some 30% of the total production value of the State of Sarawak (M$ 4.5 million, oil included). In the First Division M$ 0.3 million was contributed by mining and M$ 1.2 million by quarrying; in the State M$ 2.2 million by mining and M$ 2.3 million by quarrying (also see table 1 and 2).

1.3 Location of production and producers

The mining of gold and antimony is located near Bau. In this area 12 gold mining companies are registered, of which only seven were in operation in 1967. Mines are closed down and opened up again frequently. The mining leases of the twelve companies cover about 2000 acres. Antimony is mined by two of the gold mining companies.

In the First Division quarrying is operated by private companies (four) and P.W.D. (five or six). The quarries mainly are located near the main roads. Now and then, as needed, a P.W.D. quarry is closed down, and an old or a new one at an other site is brought into production. P.W.D. quarries for road maintenance usually produce about 20.000 tons per year; production of private quarries and P.W.D. quarries for road construction may rise to 300.000 tons. About half of the total number of quarries in Sarawak is located in the First Division.

Sand extraction is a primitive undertaking. Most of the sand used near Kuching is extracted from the Sarawak river. Sand extraction from this river, between Batu Kitang and Kampong Tandjong, is a privilege of the locally living indigenous inhabitants; it is done by hand. The sand is sold to sand dealers, who need a licence and have to pay royalties.

1.4 Labour force

Mining and sand extraction is labour intensive. The exact number of labourers in mining and quarrying is unknown and is roughly estimated at 300 to 400. About 140 of them are working in the gold and antimony mines near Bau.

1.5 Revenues

Revenues are obtained from licences, mining leases and royalties. The annual fee for general prospecting licences comes to M$ 10, that for exclusive prospecting licences to M$ 100, and for licences to remove sand and gravel to M$ 25. Mining leases for gold and antimony cost M$ 2 per acre. Royalties must be paid for the production of antimony at 5% of the export value, for stone produced by private companies at 5% of the production value, and by sand dealers at M$ 0.25 per cubic yard. It is estimated that in 1967 in the First Division revenues obtained from licences amounted to M$ 200, from mining leases to M$ 2.900 and from royalties to M$ 45.000 (mostly from quarrying).

1.6 Potentials

According to the geological structure the most promising mining prospects, except for oil, appear to be located in or near the First Division. Many occurences of a large number of ores are known, such as: mercury, lead, copper, zinc, nickel, molybdenum, bauxite and iron ores. So far, however, no deposits of commercial value of these minerals have been located. A deposit of glass sand near Sematan probably will have little or no commercial value, because in the Fourth Division the outlook for mining of glass sand is far better (mining was started there in 1970).

A number of deposits of kaolinitic clay, occuring in the Telagus area near the border of the Second Division, together containing about 15 million tons, may have commercial value. There are indications that at least a part of the deposits is suitable, after treatment, for use as filler (and coating) clay in paper manufacture.

A coking coal deposit at Silantek in the Second Division, near the border with the First Division, has been known for some time. Prospecting by a foreign company appears to have proved the presence of about 7½ million tons, while indicated reserves may exceed a further 50 million tons.

The First Division has "unlimited" reserves for quarrying of stone and the extraction of sand for road construction and building. Moreover limestone and argillaceous material suitable for cement manufacture occur at more than one favourable location.

2. FUTURE DEVELOPMENT

To predict future development in mining is very hazardous. Therefore the following is of a speculative nature.

It is presumed that the production value of mining and quarrying will increase in the future. This is based on the following assumptions:

a) The production value of gold together with antimony will remain more or less at the same level for many years to come.

b) The known deposits of mercury, lead, copper, zinc, nickel, molybdenum, bauxite, iron and glass sand will not lead to mining activities.

c) The quality of kaolinitic clay located in the Telagus area will, at least partly, prove to be suitable, after treatment, for filler (and coating) purposes in paper manufacture.

d) World demand for coking coal will increase considerably in the years to come. Under the present plans, in Japan alone, the steel capacity will be nearly doubled by 1975. This implies the need to increase the import by then with about 40 to 50 million tons of coking coal a year. In this connection the exploitation of the deposit of coking coal at Silantek seems likely. Although the deposit is situated outside the First Division the mining of this deposit will have an important effect on the economy of the First Division (transport, electricity, labour, harbour, etc.).

e) A cement factory with a capacity of 100,000 tons will be established in the near future. Limestone will be used as the main raw material.

f) Stone quarrying and sand extraction for construction and building and the manufacturing of concrete will increase with a trend of 5 to 10% per annum.

3. RECOMMENDED POLICIES

a) In general it is sound policy to know in an early stage of development the mineral resources of one's country, not only because the mining industry can be used as a lever for development, but also because in a later stage of development conflicting interests between mining and other forms of land use, such as agriculture and forestry, may arise and past investments might be lost. In this light it is suggested to carry out an aero-geophysical survey covering the more promising areas of Sarawak.

b) At present the development of the mineral resources seems to be left to a large extent to the initiative of foreign companies. It is recommended that the government plays a more active role in the promotion of the mining industry and strengthen their position at the negotiation table. This could be achieved by promoting feasibility studies and seeking advice, where needed, from foreign experts before entering into negotiations.

c) The development of the proved deposits of kaolinitic clay and coking coal near the border of the First Division (transportation, shipping) is essential for the establishing of a mining industry in this part of the country.

d) The sand extraction from the rivers now achieved by hand, should be mechanized to meet the growing demand from the construction and building industry.

e) The activities of the Department of Mines and the Geological Survey are impeded by lack of personnel. It is recommended that more personnel should be appointed as soon as possible. The staff should be assisted, where needed, by specialists of the Central Federal Agencies.

f) The Department of Mines and the Geological Survey are two separate organisations. This may lead to lack of communication, conflicting interests and overlapping of certain activities. It appears advisable to merge the two organizations. Because mining is a federal subject, the merger could be established only by the Federal Government.

TABLE 1

PRODUCTION	VOLUME 1966	VOLUME 1967	VOLUME 1968	VOLUME 1969	VALUE 1966	VALUE 1967	VALUE 1968	VALUE 1969
MINING AND QUARRYING								
Total value								
First Division						1,529,000		
State						4,529,000		
First Division percentage of State						35		
MINERALS, ETC.								
First Division								
Gold	2,600	2,500	2,800	2,300	319,000	308,000	332,000	277,000
Antimony	150	70	50	90	56,000	28,000	15,000	46,000
Total value					375,000	336,000	347,000	323,000
Other Divisions								
Oil	47,000	45,000	199,000	440,000	1,904,000	1,844,000	8,962,000	25,000,000
First Division percentage of State					12	11	4	1

Volume of: Gold in ounces, antimony in long tons, oil in long tons,
Since 1968 oil production has increased considerably, owing to new off-shore fields outside the 3 miles-limit. (West Luting- 1968; Kuala Baram - 1969). Production and value in 1969 are estimates.

TABLE 2

PRODUCTION (cont.)	VOLUME				VALUE			
	1966	1967	1968	1969	1966	1967	1968	1969
QUARRYING, ETC.								
First Division								
Stone	302,000	200,000	234,000		1,651,000	1,140,000	1,423,000	
Sand and gravel		16,000	18,000			53,000		
Clay	?	?	?		?	?	?	
Total value						1,193,000		
Other Divisions								
Stone	245,000	131,000	221,000		1,613,000	1,030,000	2,250,000	
Sand and gravel	126,000	46,000	68,000		397,000	126,000	260,000	
Clay	?	?	?		?	?	?	
Total value						1,156,000		
First Division percentage of State						50		

Volume of stone, sand and gravel in cubic yards.

Sand and gravel First Division is estimated.

Clay: no figures available.

A N N E X 5

F O R E S T R Y

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1. PRESENT SITUATION

1.1. Introduction

The climatic conditions in Sarawak - an uniform temperature, a high mean annual rainfall, a monthly rainfall which exceeds 4 inches (100 mm) and a high humidity - are very favourable for tree-growth; the forest vegetations are luxuriant despite the low fertility of the soils.

1.2. Main forest types

In the First Division of Sarawak from the coast to the inland the following main natural forest types can be distinguished (Browne, 1955).

Along the coastline, with its shallow stormy seas and difficult river entries, appears a fringe of littoral forest or mangrove. Scattered, rather narrow strips of sandy beaches above the high water mark are occupied by a beach forest, only a few chains wide, which contains relatively few species. One of the common species is Casuarina equisetifolia. On the build-up land, under more sheltered conditions along the coast and in the estuaries of the large rivers, mangrove forests occur. The mangrove mainly extends into the estuaries of the Sungai Serayan, S. Kayan and S. Sampadi, Batang Rambangan and the linked estuaries of the Sungai's Siba, Santubong, Sarawak and Samarahan. A succession of types can be recognized from the early pioneer stage to a vegetation closely resembling inland forest. The common species are: Avicennia spp. on mud banks exposed by low tides, Sonneratia spp. along sheltered river banks, which both mostly form pure stands; Rhizophora spp. the most important mangrove species, also on soft mud banks, followed by Bruguiera spp. on higher banks with a ground vegetation of Acrostichum ferus. Other mangrove types are dominated by palms: in swamp areas still under influence of salt water, Nipa fruticans is often covering large areas while on drier parts and more scattered the nibong palm (Oncosperma filamentosa) occurs.

Behind the coastal fringe in the eastern part of the First Division, the flat basin of the meandering lower course of the Batang Sadong and its tributaries and part of the Btg. Samarahan, is largely covered with swamp forest growing on peat. These peatswamps - recorded depths of the peat may exceed fifty feet (15 m) - are of the raised bog type, oligotrophic, with stilted water table and surface drainage; the groundwater is typically tea-coloured and markedly acid. The vegetation types are found in a catenary sequence from the perimeter to the centre of a raised bog, differentiated on floristic composition and structure. Six phasic communities have been recognized (Anderson, 1963), of which the mixed swamp forest (phase community 1) is the most developed type in the area mentioned; with a width of several miles it is the most important and extensive one. The structure is irregularly storeyed, no one species dominates, although the valuable timber tree ramin (Gonystylus bancanus) is often most numerous; other species may be also abundant: jongkong (Dactylocladus stenostachys), nyatoh (Palaquium spp.), keruntum (Combretocarpus rotundatus), jelutong (Dyera lowii), sepetir paya (Pseudosindora palustris), kapur paya (Dryobalanops rappa) and the swamp merantis (Shorea spp.). In the alan forest Shorea albida dominates, which is almost invariably hollow, the large crowns have an appearance of being moribund; regeneration is almost entirely absent. This second phasic community which is a transitional phase to the third (the alan bunga forest) is, with the other four communities, of minor importance in the First Division.

The western part of the First Division, mainly the basins of the Sungai Semusan, S. Serayan, Btg. Kayan, S. Sampadi and Btg. Rambangan, is characterized by a lowland heath forest type, locally known as kerangas. The trees are relatively small, only a few species exceed a girth of 6 feet (diameter of 29 cm), often with stilted roots, while the top canopy is rather light and open. The composition varies with the topography of the terrain, the soil type and the depth of groundwater level; it mostly occurs on poor, acid soils which are usually podsolized and consists of a course white sand overlying a hard acid pan at varying depths. The white, course sandy soil is often covered by a layer of undecayed litter; the streams have dark tea-coloured water. This vegetation type extends over a considerable part of the area, interchanged with a poor type of lowland Dipterocarp forest; it also appears in small patches within the lowland Dipterocarp forest (Brünig, 1968). In the lowland heathforest various tree species occur that normally are found in the mixed Dipterocarp forests and in the peatswamps. Characteristic indicators are Gymnostoma nobile, Dryobalanops fusca, Shorea albida, Calophyllum sp., Agathis borneensis (syn. A. alba).

On strips of flat land along the banks of the rivers, subject to occasional flooding, riparian forest occurs; as the soil is very fertile most of it has been destroyed by cultivation. It contains some valuable tree species as e.g. Shorea macrophylla which is the producer of the oilbearing illipe nuts.

In some places in and close to the peatswamps and kerangas areas hills with steep slopes occur, remnants of the Tertiary peneplain, sometimes only

200-300 feet (61-91 m), in several places up till about 3000 ft (914 m) above sea level. They are covered with mixed Dipterocarp forest.

In the upland regions behind the peatswamp and kerangas vegetation the relatively well drained soils from sea level up to an altitude of about 5000 ft (1524 m), in sofar as the natural vegetations have not been destroyed by men, are covered with mixed Dipterocarp forest. Most of this area has an elevation of less than 1000 ft (305 m), in the western part relatively undissected, to the east strongly dissected. Towards the boundary with Indonesia the height increases, forming steep mountains and stretches of irregular ridges.

The still existing Dipterocarp forest in the western part of the First Division adjoining the kerangas on the low, undulating hilly terrain below 500 ft (152 m), is of poor quality. In the eastern part of the Division mainly the catchment area of the Batang Krang is still under primary Dipterocarp forest. The area in between is almost entirely - even the dissected terrain and numerous of the steep slopes - occupied by shifting cultivation which is practised in short fallow cycles often only of 5 or 6 years. In the primary forest Dipterocarp species dominate, but trees of other families occur too, although usually often in small numbers.

1.3. Forest policy

Some of the main natural forest types in the First Division carry sufficient quantities of commercial tree species giving opportunities for economic logging operations, which came into operation to a growing extent. Beach forests only a few chains wide, rarely contain important timber. Mangrove, formerly a supplier of cutch, is still of importance as a source of firewood, charcoal, poles, the varied products of the nipah and the wood of the nibong palm. In the First Division most of the timber exploited is obtained from the peatswamp forests in the Sadong river basin. As an average the exploitable stands have 13 Hoppus tons to an acre (58.5 m^3 per ha) + of commercial species. Of the total area of mixed swamp forest (table 1) only approximately one quarter still contains such stands. Alan forest is of no commercial interest, at least not in the First Division. Kerangas forest has little commercial value, where merchantable timber could be obtained it already has been exploited, which also is the case with the riparian forests.

+) See for conversion factors Appendix 1.

On the low and undulating terrain of the western part of the First Division the stands of the mixed Dipterocarp forest will be no more than approx. 6 H.tons to an acre (27 m^3 per ha), in the eastern part the stands will as an average not exceed 14 H. tons per acre (63 m^3 per ha) of class 1-3 timber (see Appendix 2). Of the original area of mixed Dipterocarp forest (table 1) at least one third has been felled for shifting cultivation.

According to the Annual Report of the Forest Department for 1967 the main forest types occupied the following land areas originally.

Table 1 Main forest types in the First Division

Main forest types	Sq. miles	ha.
Mangrove and Nipah swamps	201.7	52,220
Mixed swamps	590.9	152,984
Alan	22.2	5,748
Kerangas	305.1	78,990
Other forests (mainly mixed Dipt.forests)	648.0	167,767
	1,767.9	457,709

Especially the peatswamp and the better mixed Dipterocarp forest constitute a commercial value. The forests on steep slopes in the hilly terrain and on broken hills serve as a guard against deterioration of the soil, run-off of the precipitation and flooding.

The main objects of the forest policy of the Government (according to the Land Code all forest in Sarawak belongs to the Government) can be summarized as follows (official statement of 23rd December 1954):

"(1) To reserve permanently for the benefit of the present and future inhabit-
" ants of the country forest land sufficient
" (a) for the assurance of the sound climatic and physical condition of
" the country; the safeguarding of soil fertility, and of supplies
" of water for domestic and industrial use, irrigation and general
" agriculture purposes; and the prevention of damage by flooding
" and erosion to rivers and to agricultural lands;
" (b) for the permanent supply (in perpetuity and) at moderate prices
" of all forms of forest produce that can be economically produced
" within the country, and that are required by the people for
" agricultural, domestic and industrial purposes under a fully
" developed national economy.

"(2) To manage the productive forests of the Permanent Forest Estate with
" the object of obtaining the highest possible revenue compatible with
" the principle of sustained yield and with the primary objects set out
" above.
"(3) To promote, as far as may be practicable, the thorough and economical
" utilization of forest products on land not included in the Permanent
" Forest Estate, prior to the alienation of such land.
"(4) To foster, as far as may be compatible with the prior claims of local
" demands, a profitable export trade in forest produce".

The realisation of this policy is laid down in the Forest Law of Sarawak (Forest Ordinance, 1953, Cap. 126) which is, as stated: "an Ordinance to provide for the protection and management of the forests of Sarawak, and to regulate the taking of forest produce". It provides for three types of permanent forests:

1. Forest Reserves (F.R.). Permanent forests where no forest produce may be removed except under licence or permit or with permission in writing.

2. Protected Forests (P.F.). In Protected Forests the forest law admits that any inhabitant of Sarawak may, without licence or permit, remove forest produce exclusively for his own domestic use, and not for sale, barter or profit.

3. Communal Forests (C.F.). Communal Forests are forest reserves of a convenient area as a source of domestic supplies of forest produce for a particular community for which no other suitable source of supply is available.

Table 2 Area of permanent forests in the First Division

Reserved forest areas	Number	Acres	Sq. miles	ha.
Forest Reserves	17	327,463	512	132,524
Protected Forests	6	69,495	109	28,125
Communal Forests	6	3,348	5	1,355
	29	400,306	626	162,004

Of the Communal Forests only one area (mangrove) has an greater acreage of 2,150 acres (870 ha), the others of 640- 72 acres (259 to 29 ha) are too small to be convenient for a sustained supply of forest produce for a community of some size.

In the Forest Ordinance no provisions have been made to install protective forest reserves. Under the existing climatic conditions (heavy annual rainfall of 111 inches (= 2819 mm) to 195 inches (= 4950 mm) and high rainfall intensity during the lardas season), the function of the forest vegetation on steep slopes is not sufficiently recognized. When covered with forest stands the absorbing capacity of the forest floor retards the run-off and prevents deterioration of the soil and flooding of the small valleys, which in the dissected terrain to a great extend are used for wet padi cultivation; too often the padi-yield of the valleys is lost by flooding. It is in the interest of agriculture to reserve the forest on steep slopes.

1.4. Forest management

In the First Division not yet all permanent forests have been enumerated. At the end of 1967 in the permanent forests (only F.R. and P.F., total 621 sq. miles = 160,649 ha) the following surveys were carried out:

	Sq. miles	ha
Reconnaissance survey	426.8	110,499
Low intensity survey	303.7	78,628
Working plan inventories	400.3	103,638

Communal Forests should be managed by the community under the direction of the District Officer (with the advice of the Conservator of Forests), but in practice they are not managed at all.

The methods of surveying the growing stock in the different periods varied considerably (Brünig, 1963). Forest inventory started with simple examination along parallel lines in mangrove forest (1924), followed by systematic distribution of one-chain wide linear sample plots or by line plot sampling; moreover due to lack of control of the field parties, the earlier surveys were not so very reliable. More efficient methods for the peatswamp forests were introduced in 1961 (Forest Survey and Inventory Code 1.9.4.). The sampling design was based on preliminary forest type maps (from aerial photographs) with a stratification scheme, and the sampling units were distributed in such a manner that it became possible to estimate the sampling error. This inventory procedure was used for the working plan inventories in the First Division.

For the peatswamp forests of the Sadong basin the following working plans were prepared:

Sedilu F.R., Code 628.12, 28,420 acres (11,502 ha) Estimated growing stock (1-1-'68) 641,110 H.tons (1,153,998 m^3) class 1-3 timber.

Simunjan F.R., Code 628.13/15, 47,090 acres (19,057 ha) Estimated growing stock (1-1-'66) 633,480 H.tons (1,140,264 m^3) class 1-3 timber.

Ensengei F.R., Code 628.14, 36,000 acres (14,569 ha) Estimated growing stock (1-1-'68) 433,710 H.tons (780,678 m^3) class 1-3 timber.

The procedure of inventory in Dipterocarp forest is still in an experimental stage (Murthy and Yong, 1968). In the First Division the following working plan inventories of mixed Dipterocarp forest were carried out, only a rough estimate of the growing stock can be given.

Gunung Pueh F.R., Code 628.16, 61,790 acres (25,006 ha) Estimated growing stock of part of an area 37,580 acres (15,209 ha) 503,036 H.tons (905,465 m^3) class 1-3 timber.

Sabal F.R. 11,969 acres (4,844 ha)
Code 628.18
Balai Ringing P.F. 49,600 " (20,073 ha)
Total estimated growing stock 873,338 H.tons (1,572,008 m^3) class 1-3 timber.

In the swamp forests the permissible annual yield which is allowed to be worked is derived by dividing the total growing stock (reduced with a view to the defectiveness of some of the species) by the rotation.

The rotation adopted in the peatswamps is 60 years, the period in which it is expected that the commercial species (with the exception of ramin and jongkong which are slow growers) will reach exploitable dimensions. The working plans are based on area control. The annual cut comprises an area in which the prescribed annual yield can be obtained. A sophisticated system of control including penalties for waste damages and infringement of certain licence conditions, has been developed, which needs an adequate staff for supervision. This system of yield control is still in its infancy (Yong and Murthy, 1968).

The extraction of the timber in the peatswamps by the exploiting agency is done through a light railway; on both sides the forest is divided into blocks of 15 acres (= 6 ha). An average per block of 200 H.tons or 13.3 H.tons per acre (= 60 m^3/ha) can be expected. In the blocks the logs 12-27 ft (4-9 m) long are transported on corduroy roads by means of a sledge. A crew of 12 men cut and transport per week approx. 40 H.tons (72 m^3), per man per day (8 hours) 0.56 H.tons or 1 m^3 (Brünig, 1965, estimates 0.7 m^3 per man per day). Brünig estimates the total costs of extraction, including depreciation of investment, based on annual operation of 20,000 m^3, (11.112 H.tons) for ramin M$ 14,91, for other species M$ 13.38 - 11.02 per m^3 (M$ 26.84 and M$ 24.08 - M$ 19.84 per H.ton).

Adjoining the peatswamp forest reserves in the Sadong basin, not-reserved areas in this peatswamp region are licenced under felling plans and annual licences. Usually forest land not reserved as permanent forest can be exploited under felling plans prior to alienation as for instance for agriculture; peat-swamps, however, can hardly be used for anything else but forestry. The peat-swamp felling plans and annual licences areas cover an acreage of approx. 80.000 acres (32,376 ha), three quarters of this area has already been worked out (page 12).

In the mixed Dipterocarp forest only the combined working plan of the Sabal F.R. and the Balai Ringing P.F. was accepted by an exploiting agency, opening-up of the area and logging operations have, however, not yet started.

In the western part of the Division some areas, comprising mainly kerangas mixed with Dipterocarp forest, are granted under annual licences; they are in operation only to a limited extent.

1.5. Forest production

Prior to the First World War timber production in Sarawak was mainly of importance for the local market. Timber played a minor role in the export trade, contrary to other forest produce as gutta percha, cutch, jelutong, rottans, illipe nuts and others.+

From 1918 till 1940 the yearly average of the output of wood products was for the whole of Sarawak approx. 40,000 H.tons (72,000 m^3), for the First Division 17,000 H.tons (30,600 m^3). Timber export was still of minor importance.

+ In the First Division these forest products are no longer of any importance, only from the Lundu district illipe nuts are obtained periodically.

After the Second World War the rise of the production and the export of timber has been spectacular, and it is still increasing. The rise started with a swamp forest species, ramin (Gonystylus bancanus), previously not used at all, later followed by other swamp species. In 1967 the ramin export still was 56% of the timber export of the First Division.

Table 3

Production and export of timber, revenue of forest produce in the whole of Sarawak

Year	Production equivalent round timber H.tons	Royalties permits M$	Export: Round timber cub.tons	Export: Round timber F.O.B. value 1000 M$	Export: Sawn timber cub.tons	Export: Sawn timber F.O.B. value 1000 M$	Export duties M$
1949	93,850 ($168,930 m^3$)	349,813	22,133 ($31,350 m^3$)	434++	16,697 ($23,650 m^3$)	544++	213,59
1967	2,059,753 ($3,707,555 m^3$)	12,915,714	1,243,054 ($1,760,164 m^3$)	99,797	194,244 ($275,050 m^3$)	36,222	2,159,25

++ estimate

The "surplus" of the Forest Department (established in 1919, with only once a deficit in 1920) increased considerably.

Table 4: "Surplus" of Forest Department

Year	Surplus M$ (Customs export duties not included)
1930	4,300
1940	21,700
1950	247,800
1960	4,560,035
1962	8,123,148
1967	11,324,932

As in the whole country, the production in the First Division also increased, 1949: 16,800 H.tons (30,240 m^3), 1967: 174,243 H.tons (313,637 m^3) in equivalent round timber (For the production of timber in the First Division and in the whole country from 1922 - 1967 see fig. 1). The revenue of forest produce in the First Division increased from M$ 45,939 in 1949 to M$ 2,341,074 in 1967.

The extraction of timber from forest land in the First Division as compared with the forested areas in the other Divisions, has been considerably higher. It can be expected that in the First Division the timber production will decrease in the coming years. The output in 1968 and the estimation for 1969 already show a decline.

Table 5: Total wood and log production in the First Division

Year	Total equivalent round timber Production H.tons	Log production First Division H.tons	Of which logs production in the Sadong working plan areas H.tons
1967	174,243 (313,637 m^3)	160,093 (288,167 m^3)	21,103 (37,985 m^3)
1968	168,851 (303,932 m^3)	155,909 (280,636 m^3)	34,286 (61,715 m^3)
1969	112,215 (201,987 m^3)	98,910 (178,038 m^3)	50,910 (96,638 m^3)

Wood production other than logs in the First Division concerns mainly firewood, charcoal, poles (chiefly obtained from the Sarawak Mangrove F.R.) and sawn timber and shingles from annual licences.

The logs are practically all obtained from the peatswamps in the Sadong river basin area. Logs other than those from the working plans along the Sadong river are coming from felling plans and annual licences in the same area. According to the estimation made on the basis of the information from the Forest Department, it is expected that the production of the felling plans and the licences in the Sadong river basin will decrease gradually to approx. 24 000 H.tons (43,200 m^3) in 5 years, and to 12,000 H.tons (21,600 m^3) in 10 years time.

The allowable annual cut of the Sadong working plan areas (Ensengai. Sedilu and Simunjan) amounts to 40,890 H.tons (73,602 m^3); with a total available growing stock (class 1-3 timber) of 1,708,300 H.tons (3,074,940 m^3) and considering the quantity already extracted (118,223 H.tons = 212,801 m^3), the annual cut may continue during the next approx. 3[illegible] years. If wood production other than logs in the First Division is carried on to the same level, the expected production of the areas under consideration will be:

	H.tons 1975	H.tons 1980
Log production working plan areas	40,890	40,890
Log production other areas	24,000	12,000
Wood production other than logs	13,000	13,000
Total	77,890	65,890
	(140,202 m^3)	(118,602 m^3)

No other peatswamp areas of some size are available in the First Division, so that the output of swamp species will decrease considerably. To what extent in the coming years the output of the mixed Dipterocarp forest reserves will compensate for the lower swamp forest production remains to be seen.

Owing to the diminishing timber production in the First Division the employment possibilities in logging will decrease.

1.6. Silviculture

Forests are renewable resources and should be treated as such, then they can contribute to the welfare of the country continuously. Through silviculture and management techniques a perpetual supply of timber can be ensured. The importance of adequate regeneration and re-afforestation should be recognized in Sarawak's interest in the long run.

1.6.1. Regeneration of peatswamp forests

The current rate of exploitation in the peatswamps does not keep pace with the natural or artificial regeneration. Preliminary work on peatswamp forest regeneration [illegible] research in the ecological conditions of the swamp forest (Anderson, 1963, 1964), laboriously achieved owing to lack of manpower and funds. Economic alternative uses of peatswamp forests do not exist, so it is important to maintain the valuable timber production on a sustained yield basis.

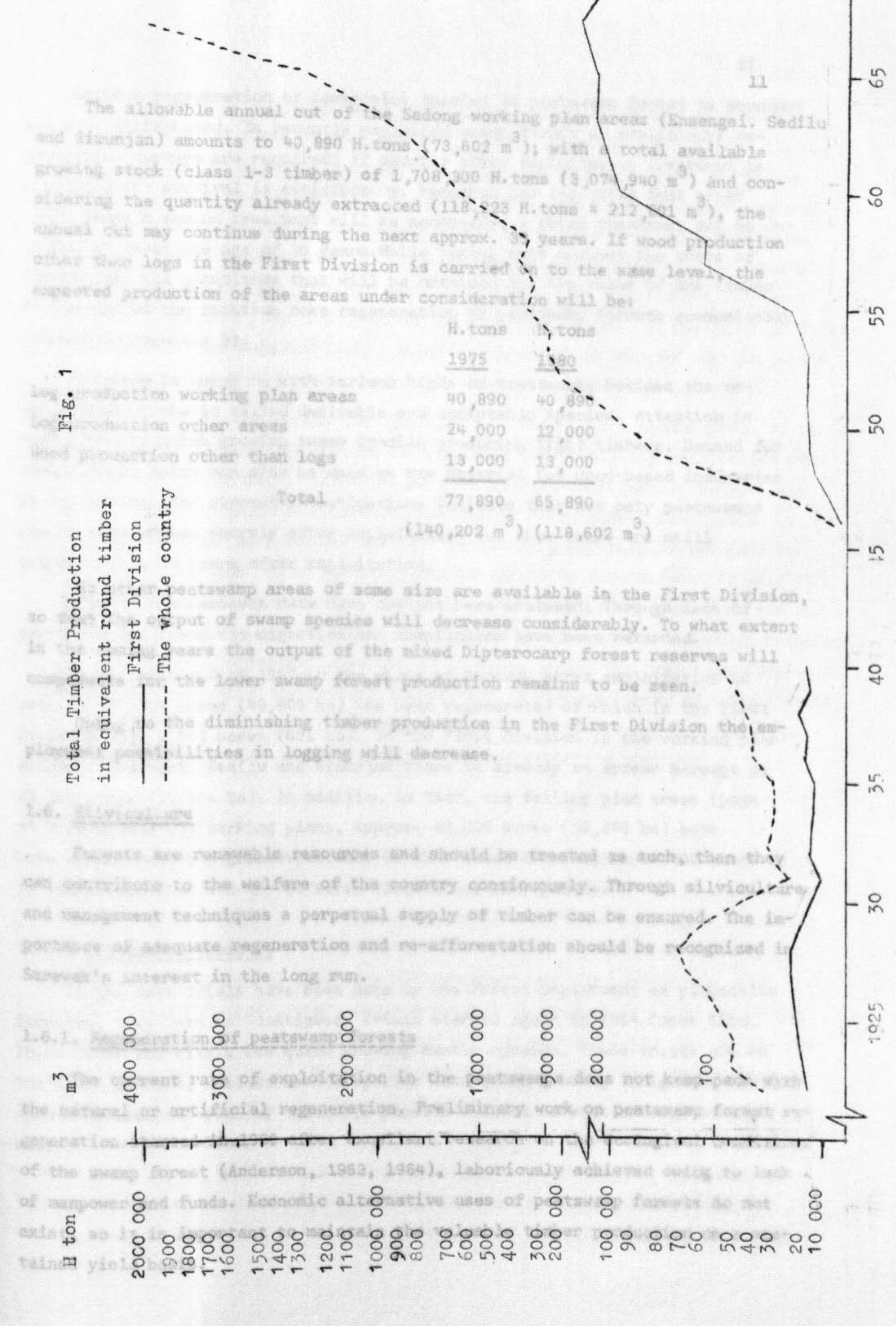

Fig. 1 Total Timber Production in equivalent round timber
—— First Division
----- The whole country

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	H.tons 1975	H.tons 1980
Log production working plan areas	40,890	40,890
Log production other areas	24,000	12,000
Wood production other than logs	13,000	13,000
Total	77,890	65,890
	(140,202 m^3)	(118,602 m^3)

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1.6.1. Regeneration of peatswamp forests

The current rate of exploitation in the peatswamps does not keep pace with the natural or artificial regeneration. Preliminary work on peatswamp forest regeneration started in 1960 after excellent research on the ecological conditions of the swamp forest (Anderson, 1963, 1964), laboriously achieved owing to lack of manpower and funds. Economic alternative uses of peatswamp forests do not exist, so it is important to maintain the valuable timber production on a sustained yield basis.

Natural regeneration of commercial species in peatswamp forest is abundant and well distributed. In recently exploited swamp forest no preliminary regeneration surveys are required; if shortly after exploitation treatment is practised the survival is satisfactory. Research has indicated that after 15-20 years a second treatment will be necessary, a third treatment may be required at about the age of 30 years. While taking into account the costs of treatments, the quantities that will be obtained and the value of the timber at the end of the rotation make regeneration of peatswamp forests economically justified (Appendix 3).

Research is going on with various kinds of treatment; besides the regeneration of the so called desirable and acceptable species, attention is also given to quick growing swamp species producing light timbers. Demand for such timber, which can also be used as raw material for wood-based industries is increasing. The current investigations indicate that not only peatswamps can be regenerated shortly after exploitation but that there are still possibilities 10 years after exploitation.

Many of the research data have not yet been analysed. Through lack of personnel and funds the digestion and compilation have been retarded.

Up till the end of 1967 in the whole of Sarawak after exploitation an area of 124,767 acres (49,906 ha) has been regenerated of which in the First Division only 1,553 acres (621 ha). In the First Division in the working plan areas of Ensengei, Sedilu and Simunjan there is already an arrear acreage of 35,260 acres (14,104 ha). In addition to that, the felling plan areas (page 8) surrounding the working plans, approx. 80,000 acres (32,376 ha) have been worked out to a greater extend. Of this total area may be 40,000 acres is fully exploited and 40,000 acres (16,188 ha) only partly.

1.6.2. Plantation forestry

In the past trials have been done by the Forest Department on plantation forestry, they were not continued. Trials started again in 1964 (near Sibu, Third Division) with a few quick growing exotic species. These trials are on too small a scale, besides exotic species also quick growing indigenous species should be included some of which are planted outside Sarawak already on a big scale.

The object of planting quick growing species is to produce wood as a raw material in short rotations for which the demand in South East Asia is rising, with Japan as the biggest consumer. As mentioned, the conditions of growing trees in Sarawak are favourable. The advantage of the First Division compared with the others is that it is already opened up by a major road system which will be improved considerably in the near future. The distances from several upland areas to Kuching port are relatively short with modern handling- and transport equipment, the costs can be kept reasonably low. In the First Division soil surveys have been completed, which is essential in determining the extend of land suitable for plantation establishment of selected species.

The limiting conditions for agricultural crops in the upland areas of the First Division, where agriculture is practised under shifting cultivation even on steep slopes in short fallow cycles (5-6 years), also justify such trials. In such short periods the soil fertility cannot be restored, thus yields of hill padi already low, are decreasing. The carrying capacity of the land is small, at the moment it is far too high, it should be reduced considerably. To obtain a somewhat reasonable yield the soil should be kept under forest for at least 15 to 20 years. In the meantime quick growing species in short rotations could be grown. The farmer could assist in establishing the tree plantations and in maintenance of the growing timber crop. A reduced number of people would get an additional regular income which will rise above the subsistance level, making differentiation in the activities of the community possible.

1.7. Timber industry

The total number of sawmills in the First Division is 18. Seven of these mills have a small capacity and are irregular in operation. Of the others 5 are circular sawmills with a capacity of 12,000 H.tons a year (2 Lundu-, 2 Kuching rural-, 1 Simunjan district), these also are usually not working to capacity. The last 6 mills are all operating with bandsaws and have capacities from 12,000 - 18,000 H.tons a year. Two are located in Kuching, 4 along the Sadong river. The total employment of the mills will be approx. 1,100 men. At the saw-mills large quantities of sawdust and other waste (slabs) must be disposed of, The way in which it is done should be improved.

With log production going down, the employment of the mills will decrease. One of the mills in Kuching that has arrangements with logging operators in the peatswamp area, is specializing in mouldings and is sawing in addition to ramin 3 or 4 other light hardwood species (sepetir and meranti's). The other bandsawmills are practically only converting ramin, they are well equiped, mostly overpowered and working in one shift only. The ramin is properly sawn, the quality is fair, dryed for shipping. In the whole of Sarawak mainly ramin is sawn for export, only small quantities of other species are exported as sawn timber.

Only for the years 1955-1957 in the whole country a bigger quantity of sawn timber was exported than logs. After that year the export rise of logs was more spectacular than that of sawn timber.

In the First Division approx. 89,000 H.tons of ramin logs were produced in 1967 and exported as sawn timber; 70,000 H.tons of other species were exported as logs. This could have easily been converted at the 6 mills without a substantial investment.

As the only one in South and East Asia the Forest Department's "Timber Training and Research Institute" gives the possibility of training sawmill workers and teaching the technique of sawing other timbers than ramin. In the near future several courses will be given including saw-doctering and killn-drying techniques through which the output of the mill and the quality of the produce can be improved.

2. FUTURE DEVELOPMENT

A. INITIAL FOREST DEVELOPMENT

2.1. Forest policy

In the interest of agriculture forest on steep slopes should be reserved. In the Forest Ordinance (1953, Cap. 126) no provisions were made to install protective forest reserves. The reservation of forests on steep slopes should not be postponed till the Forest Ordinance is altered. In view of the urgency reservation should start already as "Forest Reserve" or as "Protected Forest", which is already a long winding way.

Some steep slopes covered with forest are already reserved or are parts of permanent forests. Special precautions are to be laid down when in such areas logging operations are allowed under working plan regulations; precautions are to be made regarding the way of opening up those areas while fellings on steep slopes are to be restricted.

On map no. IX the main areas which are not yet reserved but should be reserved because of protective reasons, are indicated with a broken line. The exact boundaries should be fixed in the field. The marking of the boundaries in the field, when approximately 200 miles are to be extended, will amount to an expenditure of M$ 8,000.- with 6 men doing one mile per day, each.

2.2. Forest production

As has been explained in the part on the present situation the expected timber production in the First Division, particularly from the peatswamps, will decrease considerably (page 10). Log production is expected to be 64,890 H.tons (116,802 m^3) in 1975, in 1980 52,890 H.tons (95,202 m^3). With no other peatswamp areas available the mixed Dipterocarp forest reserves could come into operation. To develop logging operations in the upland areas, however, considerable investments will be needed. This can be justified if a sufficient quantity and quality of merchantable timber can be obtained and when the operations are not to be carried out under too severe terrain conditions. This taken into consideration the possibilities are expected to be limited in the First Division.

The potential areas to be considered are:

1. Gunung Pueh F.R. nearly half of the area is on steep terrain or of poor quality kerangas forest. During the low-intensity survey only visible defects could be noticed, the actual defectiveness should be expected to be much higher. For this reason the estimated growing stock of 503.036 H.tons (905,465 m^3) on 37,580 acres (15,209 ha) (page 7) may be too high. In the area only one circular sawmill is in operation. Logs or sawn timber ought to be transported by barques along the coast to Kuching.
2. Pasir-Jangkar F.R. 4,000 acres, mainly kerangas type forest, no inventory.
3. Sampadi F.R. 80,000 acres, poor lowland Dipterocarp forest alternating with kerangas, no inventory. Part of the area, joining the Matang Reservoir catchment area, is proposed as National Park.

The combined working plan of the Sabal F.R. and Balai Ringing P.F. (page 7) encloses part of the upper catchment area of the Btg.Krang. On the steeper slopes fellings should be restricted. When logging comes in operation an annual extraction of approx. 9,000 H.tons (16,200 m^3) can be expected.

The other reserved forest areas in the First Division cover mountainous areas with steep to very steep slopes, they should be treated as protective forest reserves. Moreover they are of small size (with the exception of Gunong Gading which is rightly proposed as National Park).

Owing to the diminishing timber production in the First Division the employment possibilities in logging will decrease. Under swamp conditions the average production per man per day is 0.56 H.ton (1 m^3) or per year (200 efficient working days) 110 H.tons (200 m^3). The employment in 1967 of an ample 1500 decreased to 1000 in 1969, and can be estimated for 1975 at 700, for 1980 600. When in the meantime logging in the mixed Dipterocarp forest comes into operation only an additional number of approx. 30 men will be needed because in the upland areas the skidding operation must be done with machinery.

2.3. Silviculture

Although forestry has contributed already considerably to the welfare of the country as employment and industrialization possibility, and earner of foreign exchange, not much has been done to ensure these advantages continuously. To attain continuous production the exploited forest must be regenerated.

2.3.1. Regeneration of peatswamp forests

On basis of the research already carried out (page 12) peatswamp forests can be regenerated by treating the exploited forest so that the natural advance growth which is available - abundant and well distributed - can develop from the seedlings to the pole stage.

As already mentioned many of the research data obtained have not yet been analysed; digestion and compilation should be sped up. Moreover the research should be continued to study different kinds of treatment. For instance to study the possibilities of regeneration of some of the quick growing swamp species so as to obtain an intermediate yield of these species and a final yield of less fast growing species. Also studies are to be made to rationalize treatment methods (Appendix 3).

The costs of the continued research in the next 5 years will be per year M$ 46,550.- (Appendix 3).

Besides regeneration research the growing characteristics of some of the faster growing swamp species should be studied in plots. At least 8 species should be tested in plots of 98 ft. 5 inches (30 x 30 m) with 121 trees spacing 8 ft. 3 inches (2.5 x 2.5 m), in three replications and three different localities. In total an area will be needed of 18 ¾ acres (7.5 ha), costs involved M$ 20,000.- (Appendix 3).

The regeneration of the peatswamps according to the system as it has been practised up till now, is economically feasible.

Depending on the quantity and the quality of timber the benefit/cost relation (calculated at 10% interest) varies from 0.76 to 10 and the rate of return from 9.2 to 10.(Appendix 3).

In the First Division only 1,553 acres (621 ha) of the peatswamp forest have been given a first treatment. There is already an arrear acreage of 36.260 acres (14,104 ha) in the working plan areas which have not been treated at all. (page 12). The felling plan areas in the Sadong river basin surrounding the working plans are worked out, part of it fully, part of it half. It should be worthwhile to re-examen the latter area for making another inventory, followed by a working plan for a renewed logging operation if sufficient quantities of commercial species (12 H.tons per acre) are still available. It is estimated that for approx. 20,000 acres (8,094 ha) a working plan could be drafted.

If the research results confirm that swamp forest which has been exploited for 10 years already can still be regenerated, these felling plan areas should be reserved as permanent forest and treated for regeneration. Peatswamp forest with peat of 6 feet (1.83 m) or more is unsuitable for any other use, as forest-land however, it is most promising, as by treatment sustained yield can be obtained. The fully exploited felling plan areas in the Sadong basin are to be re-examined first; recruitment sampling and mapping should be done, followed by treatment.

It is estimated that owing to poor regeneration conditions approx. 20,000 acres will to be left out. Including the arrear areas of the working plans, in total treatment should be carried out on 35,260 + 40,000 = 75,260 acres (30,292 ha). The costs of re-examination, treatment of the arrear areas, of the annual felling areas of the working plans are summarized in table 6.

Table 6: Costs of re-examination and treatment of the peatswamp forest per year for the next 5 years in the Sadong basin

Items	First year M$	Second year M$	Third year M$	Fourth year M$	Fifth year M$
I Yearly treatment of 1859 acres working plan area, per acre M$ 7.--	13,013	13,013	13,013	13,013	13,013
II Re-examination of the arrear areas; 75,260 acres à M$ 0.50 per acre in 3 years time	12,545	12,545	12,545	--	--
III Treatment of the arrear areas to be finished in 10 years, per year 7,526 acres, M$ 7.-- per acre	--	52,682	52,682	52,682	52,682
IV Treatment of the new working plan area of 20,000 acres; per year 333 à M$ 7.--/acre	--	--	2,331	2,331	2,331
Total	25,558	78,240	80,571	68,026	68,026
Research regeneration	46,550	46,550	46,550	46,550	46,550
Trial plots	4,000	4,000	4,000	4,000	4,000
Total	76,108	128,790	131,121	118,576	118,576

2.3.2. Financing peatswamp forest regeneration

The treatment of the swamp forests, including that of the arrear areas, and the research could be financed from additional receipts if royalties were brought up to date. Since 1957 the rates of the royalties have not been changed; the f.o.b. value of logs went up from M$ 44.54 to M$ 62.80 per H.ton in 1967, the f.o.b. value of sawn timber from M$ 136.91 to M$ 186.48 per cub.ton. In Sabah the royalties for most of the same species are considerably higher, every three months the royalty rates are fixed at 20% of the f.o.b. selling prices of the last three months (Appendix 4).

The log production in the First Division will be (page 11) up till 1975: 64,890 H.tons with an additional royalty rate of only M$ 3.-- per H.ton the additional receipt would be M$ 194,670. If royalty rates were gradually increased till 20% of the f.o.b. selling prices the additional receipt would be in the First Division only amount to approx. M$ 300,000 per year.

2.3.3. Plantation forestry

The favourable conditions in the First Division for growing trees should be used to establish plantations for producing wood.

The advantages of plantation forestry are that by uniform and adequate planting, certainty of regulating the composition of the stands a product can be obtained of more regular size, uniform quality and wood characteristics, with in addition higher yields than with natural regeneration. When trees are grown as an agricultural crop one must be aware of insects and other pests, precautions are to be taken in time.

Wood as a raw material can be exported as such or be converted for wood-based industries (pannel,pulp,paper) and exported as semi-finished or finished products. The demand for industrial wood in South and East Asia, with the increasing population and limited supplies, is growing fast, especially that for pulp and paper. Since 1964 Japan has been importing from the west coast of the United States in specially built ships large quantities of a semi-finished product "woodchips" (transport costs U.S.$ 8 à 9 per ton), in West Malaysia (Port Settenham) Japan has a factory producing woodchips (last year 300,000 tons were exported), Indonesia is exporting to Japan pine pulpwood (f.o.b. value U.S.$ 11.-- per m^3 or M$ 59.4 per H.ton), experiments are conducted in the Third Division by the Sarawak Woodchip Company Sendirian Berhad, a joint venture with Japanese interest, converting mangrove species into woodchips, which is already exporting 12,000 tons each month.

Planting fast growing species which can be used for varying purposes is the normal practise in temperate regions. Some decades ago similar species were planted in subtropical regions; former timber importing countries are now exporters of wood-based products (1966, Chili US$ 20.4 mln., South Africa US$ 37.7 mln., New Zealand US$ 35 mln). In several tropical countries planting schemes of quick growing species are under way; in South East Asia e.g. Indonesia has in central Java only already 177,100 acres (71,700 ha) pine and 132,900 acres (53,800 ha) Agathis plantations.

From several species under tropical conditions growth characteristics and ecological conditions are already known (Appendix 5); in 15 to 25 years yields can be obtained from 143-286 cub ft per acre per year (10-20 m^3 per ha) for pulpwood or on longer rotations (30-35 years) for sawn timber 214-314 cub ft per acre per year (15-22 m^3 per ha). In order to explore the possibilities and to obtain experience in plantation forestry, trials have to be set up. These trials should be statistically designed, of sufficient size, both indigenous species and exotics should be used. The latter are to be of good provenance and from regions comparable to the conditions in Sarawak. Results have been obtained already with quick growing species in regions with conditions similar to Sarawak as e.g. parts of Sabah and Indonesia.

Two types of trials will be necessary. In the first place trials with a large number of species and provenances of which little is known under the Sarawak conditions. They ought, however, to be species from regions with climatic conditions similar to Sarawak. The primary object is to eliminate species which under the existing conditions do not thrive and do not show promise of reasonable rate of growth. Small plots should be established, 25 trees of a species per plot. Approximately 12 species should be taken into consideration in random blocks with 3 replications in 8 different locations (including two in kerangas areas); the acreage needed will be approx. 17.5 acres (7 ha). Secondly, at least 6 species should be tested on a bigger scale in plots of 121 trees.It concerns species which are considered promising under existing conditions. In random blocks with 3 replications on 6 different locations an area of 25 acres (10 ha) will be needed (Appendix 6). The costs for these elimination and testing experiments during the (next) coming 5 years will amount to per year M$ 65,000.

These experiments are also fully justified as economic feasibility studies show, based on yields obtained under comparable conditions and which can be expected also on sandy-loamy soils with good to moderately drainage in the First Division; different alternatives regarding to establishment and management are also economically feasible (Appendix 6).

The proposed investigations should also be seen, as was mentioned already, as employment possibilities for part of the population which are practicing shifting cultivation (page 13). A justified fallow cycle can be restored. A system of growing agricultural crops during 1 or 2 years together with planted tree-seedlings can be applied. A system known as taungya which has already been practiced in South East Asia for over a hundred years.

2.4. <u>Timber industry</u>

The bandsawmills in the First Division have, as explained (page 14), an overcapacity. Converting the timber which now is exported as logs, will be far more profitable to the country. Finding a market for new species demands a long introduction time. Here the species are already known on the market, the technique of sawing the other species, however, can be different from ramin. The timber should be converted to such dimensions as fits the buyers overseas and the quality should be stable, graded to international standards. The best would be to follow the world wide known "Malayan Grading Rules" and the grading should as is the case in West Malaysia, be supervised by an independent organisation.

The possibilities should be considered of using part of the waste of the sawmills, especially the slabs.

An expert should be invited to make a study of using some of the waste, mostly the slabs, and part of the sawdust for the manufacturing of particle board. The investment needed for such a plant is relatively low compared to hard- or softboard installations. A product could be obtained, mainly for export, that in the South East Asia area should meet the demands. Particle board is a product less expensive than plywood, but it can be used for much the same purposes.

A plant of 20 tons per day (40 m^3) manufacturing 3-layer board should need an investment of approx. US $ 800,000.

2 Sawmills each converting per day 50 H.tons ramin for export, together obtain approx. 25 H.tons (=45 m^3) low grade material and slabs which can be used in the particle board plant. With a return of 0.7 an additional quantity of 4.7 H.tons (8.5 m^3) is needed, which, if sawdust cannot be used, can be supplied by logs of light species. The power requirement is approximately 180 kilowatt-hours per ton, labour only 15 man-hours per ton.

B. SUCCESSIVE FOREST DEVELOPMENT

2.5. <u>Protection of catchment areas in the uplands</u>

In the upland areas the development has been proposed of 9,000 acres of interior valley land for the cultivation of wet padi (Annex 7 Agriculture chapter 8). To a certain extent wet padi cultivation is already practised in interior valleys. During periods of heavy rainfall in the upper catchments of the rivers, however, heavy losses occur because of flooding. Under the existing system of shifting cultivation with a short fallow cycle of only 4 or 5 years the original forest vegetation has been removed in a considerable part of the area. One of the major effects of the virgin forests is the prevention of overland flow and run-off of rain water through infiltration of the rain water into the soil.

Interior valley land is mainly to be found in the geographic units 10, 12 and 13 where 69% of the total Land Dayak population of the First Division is living. These geographic units are rather dissected with steep sided valleys (Annex 3. Soils, part I, 2.1.). Owing to the deforestation overflow and runn-off of rainwater is increasing. To prevent losses of cultivated padi fields in the valleys the forest vegetation must be restored and the upper catchments are to be protected. The watersheds where valley land will be used for growing padi are to be explored regarding the form of the catchment, type and depth of the soil, kind of vegetation to consider the size of the area to be protected and the precaution to be made to recover the original vegetation. Only a rough estimate of the costs involved can be made, approx. M$ 20,000 during 3 years.

2.6. Continued regeneration of the peatswamp forests

The research recommended (2.3.1., Appendix 3) and maintenance of the trial plots is to be carried on, but the costs will be progressively less. On the basis of the results obtained modified regeneration treatment will become possible. By 1981 the first treatment of the arrear areas can be completed the expenditure of which are summarized in table 7 column 4. In table 7 all expenditures regarding the Forest Reserves are summarized including the cost of the continued research (column 6) and the treatment costs of the annual felled areas under working plan (column 5) according to table 6 (2.3.1.); from 1987 on a second regeneration treatment will be needed.

2.7. Plantation forestry according to taungya system

At the end of the initial phase the results of the series of trial plantations (Appendix 6) are to be evaluated. Depending the performance of the quick species sites can be chosen to establish plantations according to the taungya system on a regular scale.

Full advantage can be obtained of the taungya system under the existing conditions by starting operations in 8 units located in different regions after three years 1400 farmer-families can be employed. In Appendix 7 the set-up of such plantation project is further explained. Each unit will cover after 15 years 10,500 acres. In tabel 7 a time and cost scheme of a unit is represented. The income of the farmer will be M$ 2,680 (Appendix 6) from the 16th year after planting.

Table 9 gives a summary of the expenditure of the whole project (8 units) including research and overhead. At the 16th year the first planted compartments will be harvested. In three years the quantity to be obtained from the whole project will amount to 11,760,000 cub.ft. on a sustained basis. By that time the annual expenditure will be M$ 1,621,000, the annual revenue (f.o.b. value of the pulpwood minus costs of felling and transport) M$ 5,040,000. The quantity of pulpwood to be obtained from the 8 units will be sufficient to supply a pulpmill of 150,000 tons capacity.

Table 7.

Expenditure Forest Reserves

Year	Cost M$ 1,000						Revenue from For. Res. M$1,000*)
	Marking boundaries Prot. For.	SWAMP-FORESTS				Total Cost	
		Re-examination arrear areas	Treatment arrear areas	Treatment working plans	Research trial plots		
1	2	3	4	5	6	7	8
1971	6	12.6		13	50.6	82.2	600
72		12.6	52.7	13	50.6	128.9	580
73		12.6	52.7	15.3	50.6	131.2	560
74			52.7	15.3	50.6	118.6	540
75			52.7	15.3	50.6	118.6	520
sub.tot.	6	37.8	210.8	71.9	253.0	579.5	2800
1976	20		52.7	15.3	45	133.0	500
77	20		52.7	15.3	40	128.0	480
78	20		52.7	15.3	30	118.0	460
79			52.7	15.3	30	98.0	440
1980			52.7	15.3	25	93.0	430
81			52.7	15.3	25	93.0	420
82				15.3	25	40.3	420
83				15.3	25	40.3	420
84				15.3	15	30.3	420
85				15.3	15	30.3	420
86				15.3	15	30.3	420
87				28.3	15	43.3	410
88				28.3	15	43.3	410
89				28.3	15	43.3	410
1990				28.3	15	43.3	410
sub.tot.	60		316.2	281.5	350	1,007.7	6,470
Total	66	37.8	527.0	353.4	603	1,587.2	9,270

*) If royalties are brought up to date the revenue will be 20% higher.

Table 8 Time and cost scheme for one unit (10,500 acres, 4,200 ha)

Year	Establishment acres 1	Maintenance acres 2	3	4	5	6	7	8	9	10	11	12	13	14	15	Yield 1000 cub.ft. 16	Nr. fam.	Nr. 4 acres parcels	Total net-ares acres	Cost of establ. + maintenance M$
1	60																15	15	60	5,727
2	240	60															75	75	300	23,563
3	400	240	60														175	175	700	41,964
4	700	400	240	60														350	1,400	77,382
5		700	400	240	60													525	2,100	89,717
6			700	400	240	60												700	2,800	105,309
7				700	400	240	60											875	3,500	121,953
8					700	400	240	60										1,050	4,200	134,098
9						700	400	240	60									1,225	4,900	144,338
10							700	400	240	60								1,400	5,600	148,408
11								700	400	240	60							1,575	6,300	151,227
12									700	400	240	60						1,750	7,000	156,206
13										700	400	240	60					1,925	7,700	157,677
14											700	400	240	60				2,100	8,400	159,810
15												700	400	240	60			2,275	9,100	160,524
16													700	400	240	126		2,435	9,740	161,177
17														700	400	504		2,550	10,200	161,646
18															700	840		2,625	10,500	161,952
19																1,470				
	95.45	10.92	19.39	25.75	22.03	28.17	5.38	1.02	12.40	1.02	5.75	1.02	1.02	1.02	1.02				(Cost according to (schedule I (1/3) and (schedule III (2/3) per (acre (Appendix 6)	

Table 9. Plantation Forestry Project

Year	Costs M$ 1,000					Revenue M$ 1000
	Elimination and test trials	Research	Overhead and Executive Board	Establishment and Maintenance	Total cost M$ 1000	
1	2	3	4	5	6	7
1971	65				65	
72	65				65	
73	65				65	
74	65				65	
75	65				65	
sub.tot.	325				325	
1976	55	10	36	46	147	
77	50	15	44	189	298	
78	40	20	68	336	464	
79	35	20	84	619	758	
1980	30	25	100	718	873	
81	20	25	116	843	1,004	
82	10	25	132	976	1,143	
83		25	148	1,073	1,246	
84		25	164	1,155	1,344	
1985		25	180	1,187	1,392	
86		25	196	1,210	1,431	
87		25	212	1,250	1,487	
88		25	228	1,261	1,514	
89		25	244	1,279	1,548	
1990		25	260	2,184	1,569	
sub.tot.	240	340	2,212	13,426	16,218	
Total	565	340	2,212	13,426	16,543	
1991		25	280	1,289	1,594	432
92		25	300	1,293	1,618	1,728
93		25	300	1,296	1,621	2,880
94		25	300	1,296	1,621	5,040
95		↓	↓	↓	↓	↓

Appendix 1: Conversion factors

1 inch	= 2.540 cm
1 yard	= 3 ft = 0.914 m
1 foot	= 0.3048 m
1 chain	= 22 yards = 20.117 m
1 mile	= 1.6093 km
1 acre	= 0.4047 ha
1 sq. mile	= 640 acres = 258.9 ha
1 Hoppus cub.ft.	= 1.273 cub.ft.
1 Hoppus cub.ft.	= 0.036 m^3 (true measure)
1 H.ton	= 50 H.ft. = 1.8 m^3
1 cubic foot	= 0.028 m^3
1 cubic ton	= 50 cub.ft. = 1.416 m^3
1 cubic foot (sawn)	= 2 Hoppus feet (round) = 0.072 m^3
1 H.ft. per acre	= 0.09 m^3 per ha
1 H.ton per acre	= 4.5 m^3 per ha
1 cub.ft. per acre	= 0.07 m^3 per ha
1 m^3 per ha	= 14.3 cub.ft. per acre
100 shingles	= 1 H.cub.ft.
2500 shingels	= 1 H. ton
30 pikuls firewood	= 1 H.ton
8 pikuls charcoal	= 1 H.ton

Appendix 2: Species by inventory classes

(Forest Survey and Inventory Code 1.9.4, 1961)

Class 1

Belian, Billian	Eusideroxylon zwageri T. et. B.
Bindang	Agathis alba (Lam.) Foxw.
Giam	Hopea nutans Ridl.
Malagangai	Eusideroxylon malagangai Sym.
Ramin telur	Gonystylus bancanus (Miq.) Kurz.
Ranggu	Melia excelsa Jack.
Selangan batu	Shorea spp.
Tolong	Agathis spp. (sub-montane and montane)

Class 2

Chengal paya	Hopea pentanervia Sym.
Engkabang	Shorea spp. (red Meranti class)
Jongkong	Dactylocladus stenostachys Oliv.
Kapor	Dryobalanops spp.
K. bukit	D. becarii Dyer.
K. empedu	D. fusca V. Sl.
K. paji	D. lanceolata Burck
K. paya	D. rappa Becc.
K. peringgi	D. aromatica Gaertn.f.
K. keladan	D. oblongifolia Dyer
Keruing	Dipterocarpus spp.
Landin	Podocarpus spp.
Lun	Shorea spp. (yellow Meranti)
Meranti	Red (Hill) Shorea spp.
Merbau	Intsia palembanica Miq.
Penyau	Upuna borneensis Sym.
Red selangan	(see also Alan, Semayor)
Peran	Parashorea macrophylla W.-S. (Msc.)
Seraya puteh	Parashorea spp.
Semayur	Shorea inaequilateralis Sym.
Sempilor	Dacrydium spp.
Sepetir	Copaifera palustris (Sym.) de Wit
Tampar hantu	Sindora spp., Pseudoindora spp.
Tembusu	Fragrea spp.

Class 3

Alan	Shorea albida Sym.
Benggang	Neesia spp.
Bintangor	Calophyllum spp.
Durian burong	Durio spp.
Geronggang	Cratoxylon spp.
Kerakup	Shorea pachyphylla Ridl.ex.Sym.
Medang	Litsea spp.
	Alseodaphne spp.
	Cryptocarya spp.
	Dehaasia spp.
	Nothaphoebe spp.
	Phoebe spp.
Medang tija	Cinnamomum spp.
Medang paya	Litsea palustris kost
Meranti	Red (Swamp) Shorea spp.
Meranti buaya	Shorea rugosa Heim.
	Var.uliginosa (Foxw) Heim.
Meranti lilin	Shorea teysmanniana Dyer
Meranti lop	Shorea scabrida Sym.
Meranti paya	Shorea platycarpa Heim.
Mersawa	Anisoptera spp.

Class 4

Binuang	Octomeles Sumatrana
Bawang hutan	Scorodocarpus borneensis (Baill.) Becc.
Bintawak	Artocarpus anisophylla Miq.
Biris	Sterculia spp.
Entuyut	Tetramerista glabra Miq.
Jangkar	Palaquium leiocarpum Boerl.
Jelutong	Dyera costulata Hook.f.
Jelutong Paya	Dyera lowii Hook.f.
Kedondong	Canarium spp., Dacryodes spp.
Kelampu	Sandoricum emarginatum Heim.
Kepayang babi	Mezzettia leptopoda (Hk.f. et Th.)

Keruntum	Combretocarpus rotundatus Dans.
Kumbang semangkok	Scaphium spp.
Medang limo	Aromadendron nutans Dandy.
Medang padang	Litsea palustris Kost.
Medang tija	Cinnamomum spp.
Mengris	Koompassia spp.
Minggi	Parartocarpus spp.
Nyatoh	Palaquium spp., Ponteria spp.
Plajau	Pentaspadon spp.
Pulai	Alstonia spp.
Ramin batu	Gonystylus spp.
Rambutan hutan	Nephelium spp.
Rengas	Melanorrhoea spp., Gluta spp.
Resak	Vatica spp., Cotylelobium spp.
Selangan	Hopea spp.
Simpoh	Dillenia spp.
Sireh-sireh	Pternandra spp.
Terentang	Campnosperma spp.
Tui	Dolichandrone (L.F.) K. Sch.
Tundun biawak	Xerospermum muricatum
Upi	Parishia spp.

<u>Class 5</u>

Arauh	Cephalomappa spp.
Akau	Xylopia coriifolia Ridl.
Bajan	Lophopetalum spp. (hard timber)
Baru baran	Pentace spp.
Bantas	Neoscortechninia spp.
Balek angin	Elaeocarpus spp.
Benua	Macaranga spp.
Brangan	Castanopsis spp.
Buah pesa kanan	Chisocheton brachyantus Merr.
Buah raba	Mangitera spp.
Dilleh	Polyalthia spp.
Empenit	Quercus spp., Pasania spp.

Ipil	Intsia bijuga (Colebr.)O.K.
Ipoh	Antiaris toxicaria Lesch.
Jadam	Alangium spp.
Janang	Canthium didymum Gaert.
Jelungan sasak	Amoora rubiginosa Heim.
Jengkai	Nauclea spp.
Jering	Pithecellobium spp.
Kandis	Garcinia spp., Kayae spp.
Karai	Polyalthia spp.
Kasai	Pometia pinnata Forest.
Kayu malam	Diospyros spp.
Kayu pahit	Parishia spp.
Kawi	Whiteodendron moultanianum van Steenis
Kedaung	Parkia javanica Merr.
Keranji	Dialium spp.
Kerdam	Ilex.spp.
Ketiau	Ganua spp.
Kumpang	Gymnacanthera spp., Horsfieldia spp.
	Knema spp., Myristica spp.
Lemak manok	Blumeodendron spp.
Litoh	Ctenolophon spp.
Malo	Gardenia spp.
Manggis hutan	Garcinia spp.
Merbulan	Blumeodendron tokbrai (Blume) Sym.
Merambang	Androtium astylum Stapf.
Merpinang	Diospyros evenis Bakh.
Ngilas	Parastemon spp.
Nyalin	Xanthophyllum spp.
Porah	Elasteriospermum spp.
Perupok	Lophopetalum spp. (soft timber)
Petai	Parkia spp.
Pudau	Artocarpus spp.
Petoh	Swintonia glauca Engl., Swintonia spp.
Rabong	Carallia spp.

Rawang	Tetractomia spp.
Rentap	Timonius spp.
Ru	Casuarina spp.
Seledah	Santiria spp.
Selemo	Cyathocalyx spp.
Selumar	Jackia ornata Wall.
Selunsur	Tristania spp.
Semburok	Stemonurus spp.
Sengkurat	Elaeocarpus obtusifolins Merr.
Serait	Nephelium melanomiscum Radlk.
Serbah	Goniothalamus spp.
Somah	Ploiarium alternifolium (Vahl.) Melch.
Saga	Adenanthera spp., Abarema spp.
Serunai	Bhesa paniculata Arn. et Buch.
Simpoh laki	Ternstroemia spp.
Tampoi	Baccaurea spp., Antidesma spp.
Tapang	Koompassia excelsa (Becc.) Taub.
Terap	Artocarpus elasticus Reinw.
Tulang ular	Canthium umbellatum Wight
Ubah	Eugenia spp.

Appendix 3: Regeneration of peatswamp forests

1. Research

A series of special treatments are under investigation. Among other things, this involves a comparison of the standard treatment with treatments in which more species (also quick growers) are included, and the species-classes (Ramin and Jongkong, other desirable and acceptable species, augmented desirable species, undesirable species) to be removed, vary in diameter. "Other desirable and acceptable species" include: Kapor, Meranti, Semayur, Sepetir, Bintagor, Engkabang bungkus, Kerukup, Perupok, Durian barong, Kelompu, Menggris, Kepayang babi, Geronggan, Terantang. The "augmented desirable species" comprise moreover: Rangas, Keruntum, Nyatoh babi, Nyatoh jongkar, Medang, Akau, Benuah, Minggi, Pulai.

The "standard treatment" shortly after exploitation involves the removal (by girdling and poisening with sodium arsenite, 2 lbs per gallon of water) of:

1. all unsound, damaged and badly shaped trees;
2. all undesirable species over 12" diameter at breast height;
3. desirable and acceptable species with a diameter at breast height of 16" and more.

The trial treatments are allocated in 5 logging blocks with random plots. There are 5 replicates of each treatment.

These trials ought to be continued like the other established postwar trials (Clarke, 1964, Research Pamphlet no. 45) and the digestion and compilation of research data already obtained should be sped up. Moreove the regeneration research should be expanded in order to study the possibilities of obtaining 1) an intermediate yield of quick growing species in combination with a final yield after 60 years of less fast growing species, 2) a final yield of quick growers at the age of approx. 30 years with treatments at 0, 10, 20 years, 3) a final yield of quick growers at the age of approx. 30 years with two treatments only, at 10 and 20 years. Further more the possibilities of rationalising treatment methods should be studied.

The costs of the natural regeneration research during the next 5 years will be per year:

Research Forest Officer	M$ 18,000.-
Assistent	M$ 9,600.-
Clerk, typist	M$ 4,000.-
Workers and equipment	M$ 14,950.-
Per year total	M$ 46,550.-

In addition to the regeneration research the growing characteristics of some of the faster growing swamp species should be studied in plots. At least 8 species should be tested as e.g.: Geronggan (Cratoxylon sp.), Terentang (Campnosperma sp.), Medang (Litsea sp.) Pulai (Alstonia sp.), Yelutong (Dyera lowii), Kapor paja (Dryobalanops rappa), Jongkong (Dactylocladus stenostachys), Kelampu (Sandoricum sp.).

For each species, plots should be established of 98', 5" square, (30x30 m) with 121 trees, spacing 8', 3" (2.5 x 2.5 m). By omitting two surrounding rows an assessment plot of 49 trees is left. With a distance between the plots of 8',3" (2.50 m) and random blocks for 8 species with 3 replications, an area is needed of approx. 6¼ acres (2.5 ha); for three different locations the total area will be 18¾ acres (7.5 ha).

Supervision can be done by the staff in charge of the regeneration research. The costs of the test plots of swamp species involve:

establishing and equipment	M$ 10,000.-
wildlings, planting	M$ 2,000.-
maintenance and enumeration	M$ 8,000.-
Total costs	M$ 20,000.-

2. Economic feasibility of natural regeneration

2.1 Cost of regeneration

a. First treatment according to the standard practice per acre:

wages and poison	M$ 5.-
supervision and tools	M$ 2.-
	M$ 7.-

b. Second treatment after approx. 17 years (15-20 years), when the regenerated species are in the pole stage, will consist of giving more space to the individual trees;

cost per acre:

wages and poison	M$ 7.50
supervision and tools	M$ 2.50
	M$ 10.--

c. A third treatment may be required after approx. 30 years to thin the stands; cost per acre:

wages and poison	M$ 9.--
supervision and tools	M$ 3.--
	M$ 12.--

d. Other cost items

Felling, extraction, transport up to mill site (average distance 10 miles), depreciation of investment on logging equipment, inventory and management M$ 20.-- per H.ton

2.2. Benefits

a. Yield to be obtained with a 60 year rotation, depending on composition of the stand and site quality 50-60 H.tons/acre

b. Value of the produced timber at mill site - with f.o.b. value of pulpwood now already M$ 59.40 per H.ton (Ann.For.page 23) - will vary between M$ 60-70/H.ton depending on quality and species.

On the basis of these costs and the expected yields the following benefit/cost ratio's (10 percent interest) and rate of return can be obtained (schedule I):

					B/C	Rate of Return
With a yield of	50	H.tons/acre and value of the timber	M$ 60/H.ton		0.76	9.2
,,	50	,,	,, 70	,,	0.89	9.7
,,	60	,,	,, 60	,,	0.87	9.6
,,	60	,,	,, 70	,,	1.01	10.0

If the proposed treatment trials result in obtaining an intermediate harvest of quick growing species at the age of approx. 30 years, a third treatment will not be necessary. With an intermediate yield of 20 H.tons per acre (by which yield a logging operation is justified) and a value of the timber of M$ 50.-/H.ton, this system would be economically feasible (schedule II). As would be the system with a final yield of quick growers at the age of approx. 30 years and treatment shortly after exploitation, at the 10th and 20th year (schedule III).

If the proposed research shows that exploited forest can be regenerated with a first treatment 10 years after logging, followed by a second treatment at the age of approx. 20 years, and final yields of the quick growing species of 30 of 40 H.tons/acre could be obtained after 30 years, this system would also be justified (schedule IV).

Summary of alternatives

System	B/C 10%	Rate of Return
Schedule I 3 treatments yield 60 years	0.76 - 1.01	9.2 - 10
Schedule II 2 treatments yield 30 years yield 60 years	1.87 - 1.93	15.7
Schedule III 3 treatments yield 30 years	1.97 - 2.06	17.6 - 18.5
Schedule IV 2 treatments yield 30 years	2.16 - 2.24	24.6 - 26.5

Schedule I Natural regeneration peatswamp forests.
Cost-benefit analysis on a 60 year rotation:
3 treatments

Year	Costs	Benefits	Disconted 10% Costs	Disconted 10% Benefits	B/C	Rate of Return
0	7.-		7.--			
17	10.-		1.98			
30	12.-		0.69			
60 a	1,000.-	3,000.-	3.28	9.85		
60 b	1,000.-	3,500.-	3.28	11.49		
60 c	1,200.-	3,600.-	3.94	11.82		
60 d	1,200.-	4,200.-	3.94	13.79		
a	Yield 50 H.tons/acre	Value timber M$ 60/H.ton	12.95	9.85	0.76	9.2
b	" 50 "	" " 70 "	12.95	11.49	0.89	9.7
c	" 60 "	" " 60 "	13.61	11.82	0.87	9.6
d	" 60 "	" " 70 "	13.61	13.79	1.01	10.0

Schedule II Natural regeneration peatswamp forests.
Cost-benefit analysis on a 60 year rotation
with an intermediate yield at 30 years:
2 treatments

Year	Costs	Benefits	Disconted 10% Costs	Disconted 10% Benefit	B/C	Rate of Return
0	7.-		7.-			
17	10.-		1.98			
30	400.-	1,000.-+	22.92	57.31		
60 a	600.-	1,800.-	1.97	5.91		
60 b	600.-	2,100.-	1.97	6.90		
60 c	800.-	2,400.-	2.63	7.88		
60 d	800.-	2,800.-	2.63	9.20		
a	Yield 30 H.tons/acre	Value timber M$ 60 H.ton	33.87	63.22	1.87	15.7
b	" 30 "	" " " 70 "	33.87	64.21	1.90	15.7
c	" 40 "	" " " 60 "	34.53	65.19	1.89	15.7
d	" 40 "	" " " 70 "	34.53	66.51	1.93	15.7

+ intermediate yield after 30 years
of 20 H.tons/acre value timber M$ 50/H.ton.

Schedule III Natural regeneration peatswamp forests.
Cost-benefit analysis on a 30 year rotation:
3 treatments

Year	Costs	Benefits	Disconted 10% Costs	Disconted 10% Benefits	B/C	Rate of Return
0	7.-		7.-			
10	10.-		3.86			
20	10.-		1.49			
30 a	800.-	2000.-	45.85	114.62		
30 b	1000.-	2500.-	57.31	143.27		
a	Yield 40 H.tons/acre	Value timber M$ 50/H.ton	58.20	114.62	1.97	17.6
b	" 50 "	" " " 50 "	69.66	143.27	2.06	18.5

Schedule IV Natural regeneration peatswamp forests.
Cost-benefit analysis on a 30 year rotation:
2 treatments, first treatment 10 years after exploitation

Year	Costs	Benefits	Disconted 10% Costs	Disconted 10% Benefit	B/C	Rate of Return
0	-		-			
10	10.-		3.86			
20	10.-		1.49			
30 a	600.-	1500.-	34.39	85.96		
30 b	800.-	2000.-	45.85	114.62		
a	Yield 30 H.tons/acre	Value timber M$ 50/H.ton	39.74	85.96	2.16	24.6
b	" 40 "	" " " 50 "	51.20	114.62	2.24	26.5

Appendix 4: Royalties

1. Rates of Royalties Sarawak since 1957

A.

Malagangai (Eusideroxylon malagangai), Belian, Tembusu, Ipil, Merbau, Teruntum (Lumnitzera spp.), Nyireh batu (Xylocarpus granatum).

Round per H.ton	M$ 15.--
Converted per H.ton	" 30.--

B.

Ramin (Gonystylus spp.)

Per H.ton	Round	Converted
1st, 2nd, 3rd Division	M$ 8.--	M$ 16.--
Rajang Drainage	" 10.--	" 20.--
Oya and Mukah Drainage		
Balingian Drainage and		
Bintulu, Miri and		
Baram District	" 6.50	" 13.--

C.

Bindang, Sepetir, Resak, Sempilor, Jongkong, Keruing, Kapur, Dungun, Medang, Ranggu, Semayur, Kerukup, Red Selangan, Meranti, Giam, Chengal, Selangan batu, Penyau.

Round per H.ton	M$ 6.--
Converted per H.ton	M$ 12.--

D.

All timbers not mentioned under A, B and C

Round per H.ton	M$ 2.--
Converted per H.ton	M$ 4.--

2. Rates of Royalties Sabah

A.

Malagangai (Eusideroxy malagangai), Belian, Merbau, Resak batu, Selangan batu

B.

Geriting (Lumnitzera littorea), Kembang (Tarrietia spp.), Oba suluk (Shorea pauciflora and its allied species), Seraya merah (Shorea leprosula, S.smithiana, S.parvifolia and other species of Shorea), Urat mata (Parashorea spp.)

C.

Gagil (Hopea sangal), Kapur (Dryobalanops spp.), Kapur paya (D. rappa), Keruing (Dipterocarpus spp.), Limpaja (Cedrela spp.), Melapi (Shorea bracteolata, S. symingtonii and other species of Shorea of the Anthoshorea group having whithish or ochre wood), Nyatoh (Palaquium spp., Payena spp.), Sepetir (Sindora spp.), Seraya Kuning (Shorea acuminatissima, S. symingtonii and other species of Shorea having a white-yellow wood), Serungan (Cratoxylon arborescens), Tembusu (Fagraea fragrans)

D.

Jongkong (Dactylocladus stenostachys)

E.

Ramin (Gonystylus bancanus)

O.T.

All timbers not mentioned under A, B, C, D and E.

2. Rates of Royalties Sabah

A.

Malagangai (Eusideroxy malagangai), Belian, Merbau, Resak batu, Selangan batu

B.

Geriting (Lumnitzera littorea), Kembang (Tarrietia spp.), Oba suluk (Shorea pauciflora and its allied species), Seraya merah (Shorea leprosula, S.smithiana, S.parvifolia and other species of Shorea), Urat mata (Parashorea spp.)

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D.

Jongkong (Dactylocladus stenostachys)

E.

Ramin (Gonystylus bancanus)

O.T.

All timbers not mentioned under A, B, C, D and E.

For the first quarter of 1970 the royalties were as follows:

Class	Round M$ per H.ton	Round for processing M$ per H.ton	Converted 2/3 recovery M$ per H.ton
A	10.62	10.62	10.41
B	31.25	15.00	15.00
C	19.37	11.87	12.08
D	9.37	9.37	9.17
E	5.62	5.62	5.82
O.T.	7.50	7.50	7.50

The royalties in Sabah are subject to change every 3 months; every quarter they are fixed at 20 percent of the f.o.b. value of the 3 proceeding months.

3. F.O.B. values of logs exported from Sarawak

Year	F.O.B. value M$ per H.ton
1956	44.54
1957	30.62
1958	44.54
1959	47.89
1960	51.81
1961	51.81
1962	48.67
1963	49.46
1964	49.46
1965	54.95
1966	60.45
1967	62.80

Appendix 5 : Main quick growing species

Species	Origin	Elevation m.	Rainfall mm.
1. Tropical lowland			
1.1. Dry period less than 2 months			
Agathis labilliardierii	West Irian	0-1500	3000-4000
A. borneënsis	Borneo	0	2000
A. loranthifolia	East Indonesia	500-1000	3000-4000
Anthocephalus cadamba	South East Asia	0- 400	2000-4000
Albizzia falcata	East Indonesia	0- 800	2000-2700
Eucalyptus deglupta	New Guinea	0- 500	3800-5000
Octomeles sumatrana	Indonesia	0- 600	2000-4000
1.2. Dry period 2 to 3-4 months			
Aucoumea klaineana	Gabon	0- 300	2000-2480
Musanga smithii	West Africa	0- 300	1500-2500
Terminalia superba	West Africa	0-1000	1300-2300
Ochroma lagopus	South America	300- 800	1500-3000
Pinus caribaea var. caribaea	Cuba	50- 300	1000-2000
P.c. var. hondurensis	Central America	0- 700	1250-3000
P. oocarpa	Central America	500-2500	900-2000
Albizzia falcata	East Indonesia	0-1500	2000-2700
Anthocephalus cadamba	South East Asia	0- 400	2000-4000
Araucaria cunninghamii	New Guinea	400-1500	1000-1500
A. hunsteinii	New Guinea	600-1500	1600-1850
Eucalyptus deglupta	New Guinea	0- 500	3800-5000
Gmelina arborea	India, Burma	0-1000	760-4600
1.3. Dry period 4 to 5-6 months			
Terminalia superba	West Africa	0-1000	1300-2300
Pinus caribaea var. bahamensis	Bahama Islands	0	1140-1270
P.c. var. hondurensis	Central America	0- 700	1250-3000
P.c. var. caribaea	Cuba	50- 300	1000-2000
Gmelina arborea	India, Burma	0-1000	760-4600
Tectona grandis	India, Thailand, Indonesia	0- 800	1000-2540

Species	Origin	Elevation m.	Rainfall mm.
2. Tropical highlands 700-1700 m elevation			
Maesopsis eminii	West and East Africa	1300-1700	1600-2500
Pinus patula	Mexico	1500-1800	1020-1520
Agathis loranthifolia	East Indonesia	500-1000	3000-4000
Pinus khasya	India, Thailand	1000-1700	1200-2000
Pinus insularis	Philippines	1000-1500	2500-5000
Pinus merkusii	Sumatra	800-1500	1200-2200
Pinus roxburghii	India	1000-2300	1000-2300

Appendix 6 : Plantation forestry

Most of the countries in South East Asia are already practising plantation forestry on a more or less larger scale. Sarawak is lagging behind; in the first place it has to find out which quick growing species under the favourable condition can be cultivated.

1. Research

A series of trial plantations ought to be established statistically designed both of suitable exotics and indigenous quick growing species. Two types of trials are necessary: elemination and test trials.

In elimination trials a large number of species and provenances should be used, mainly species of which little is known under Sarawak conditions. The primary object is to eliminate those species which do not thrive and show no promise of a reasonable rate of growth. The species are planted in small plots of 25 trees, spacing 8', 3" (2.5m), by omitting the outside row a plot of 9 trees is left for assessment; at least 12 different species should be used in random blocks with 3 replications, which need an acreage of approx. 2 1/4 acres (0.9 ha). For 8 different locations the total area comprises 18 acres (7.2 ha).

In the test plots species should be used of which there are already indications of a promising growth under the conditions in Sarawak. At least 6 species should be tried in plots of 121 trees, spacing 8', 3" (2.5 m), by omitting the two outside rows an assessment plot is left of 49 trees; with 3 replications in random blocks the acreage is 4.2 acres (1.7 ha); for 6 different locations 25 acres (10 ha).

The elimination trials are to be established in 8 different locations after a detailed soil survey of the areas concerned:

1. four locations in the hill country on red yellow podzolics with slopes of both less than 15° and more than 15°.

2. two locations in the area between Bau and Kpg. Stass on sandy soils in the more undulating terrain.

3. two locations in the kerangas area along the road to Lundu between Gunung Saibong and Kpg. Gelam. +)

For the hill country and the Bau area the following species are to be taken into consideration.

+) Especially soils with a soft humuspan in gently sloping terrain should be considered.

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3. two locations in the kerangas area along the road to Lundu between Gunung Saibong and Kpg. Gelam. +)

For the hill country and the Bau area the following species are to be taken into consideration.

+) Especially soils with a soft humuspan in gently sloping terrain should be considered.

Broadleaved species

Albizia falcata

Alstonia sp.

Anthocephalus cadamba

Azadirachta (Melia) excelsa

Campnosperma oriculata

Endospernum malcense

Eucalyptus deglupta

Gmelina arborea

Lophopetalum sp.

Macaranga sp.

Maesopsis eminii

Mezzettio sp.

Octomelus sumatrana

Pterospernum sp.

Conifers

Agathis alba (provenance Sarawak and Brunei)

Agathis borneënsis (provenance Kalimanten)

Agathis labilliardierii

Agathis loranthifolia (provenance Indonesia)

Araucaria cunninghamii

Araucaria hunsteinii

Pinus caribaea var. caribaea

Pinus caribaea var. hondurensis (provenance Belice and Mosquite Coast)

Pinus tropicalis

Species to be considered on kerangas soils:

Broadleaved

Calophyllum sp.

Dipterocarpus borneënsis

Dryobalanops fusca

Dryobalanops rappa

Gymnostoma nobile

Melaleuca leucodendron

Ploiariom alternifoliam

Shorea albida

Conifers

Agathis alba (provenance Sarawak and Brunei)

Agathis borneënsis (provenance Kalimanten)

Agathis labilliardierii

Pinus caribaea var. hondurensis (provenance Belice and Mosquite Coast)

Pinus tropicalis

The test plots should be established in 6 different locations after a detailed soil survey of the areas concerned:

1. four locations in the hill country on red yellow podzolics on slopes both less than 15° and more than 15°.

2. two locations in the Bau Kpg.Stass area on sandy soils in the more undulating terrain.

For the test plots in the hill country and the Bau area the following species are to be taken into consideration.

Broadleaved species

Anthocephalus cadamba

Eucalyptus deglupta

Macaranga sp.

Octumelus sumatrana

Conifers

Agathis borneënsis (provenance Kalimanten)

Araucaria hunsteinii

Pinus caribaea var. hondurensis

- provenance Belice
- provenance Mosquito Coast

The budget of the plantation forestry trials involves the following cost items:

First and second year

Clearing, raising nursery stock, planting etc. 43 acres	M$	25,000.-
Transport vehicle and equipment	"	20,000.-
Total	M$	45,000.-

Budget each year during 5 years

Research Forest Officer	M$ 18,000.-		
Assistants	" 19,200.-		
Guards	" 8,000.-		
Clerks, typist	" 5,000.-		
Maintenance and enumeration	" 5,800.-		
Total per year	M$ 56,000.-	5 years	M$ 280,000.-
	Total during 5 years		M$ 325,000.-

2. Economic feasibility of plantation forestry

As mentioned before, several advantages can be obtained with plantation forestry:

1. Higher yields can be expected than with natural regeneration.
2. Timber can be grown of more regular size and uniform quality.
3. Quick growing species can be grown in short rotations, producing raw material for wood based industries as e.g. pulpwood.
4. The demand for pulpwood is rising considerably, especially in the South East Asia area with Japan as largest consumer (Ann.For. page 19). In West Malaysia the consumption of pulp, paper and paper products has increased more than 6 times in 18 years.

Table 10 West Malaysian consumption of pulp, paper and paper products

Year	Quantity (tons)	Value M$ c.i.f.
1948	13,307	8,587,793
1955	26,779	21, 92,961
1960	45,132	34,393,934
1966	82,878	55,719,175

5. Prices to be obtained for pulpwood are reasonable. The f.o.b. value of pulpwood from countries which are exporting this commodity in larger quantities as e.g. Skandinavia, Russia, Canada were as follows:

Year	F.O.B. value US \$ per m^3
1960	10.7
1961	12.2
1962	11.8
1963	10.7
1964	10.3
1965	13.0
1966	11.4

6. Growing pulpwood in short rotations can be combined with an agriculture crop during plantation establishment to replace shifting cultivation with short fallow cycles. The increase in population in the hill country of the First Division caused a decrease of the fallow cycle and low yield of hill rice. To change conditions the fallow cycle should be at least 15 years, which gives possibilities for growing quick growing timber species in a short rotation. Tree seedlings can be planted together with hill rice; the additional work to be done in raising and maintenance of the trees and the exploitation of the stands will give the farmer an additional income, so that his total income will rise above the subsistance level.

7. Preliminary cost calculations for pulpwood production in the First Division with the taungya system also justify the proposed trials. The following calculations are based on an extensive afforestation operation with an experienced staff and trained workers.

2.1. Costs and benefits of plantation forestry

Into consideration have been taken only the costs of pulpwood production and the export of this commodity, not the converting for wood based industries or the export as semi-finished products (wood chips, pulp, paper).

Costs of establishing

Wages 1 manday M\$ 4.-, increase per year cumulative 2%; per year 300 working days.

Overhead field staff per year per ha M\$ 2.50.

Fertilizer M\$ 0.40 per kg.

Cost of opening up according to West Malaysian standards for forest roads in areas with slopes of 15 degrees or less (20 miles per 7500 acres, cost per mile M$ 8,000.-) per ha M$ 54.-, with slopes of more than 15 degrees M$ 80.- per ha (according to the "Report of the Special Committee on the Establishment of Quick Growing Species" Kuala Lumpur, April, 1968).

Costs of transportation M$ 40.- per ha.

Tools and equipment nursery M$ 5.- per 7500 seedlings.

Tools and equipment planting M$ 10.- per ha.

Cost of poison M$ 0.12 per liter.

Costs of maintenance

Depending on weed conditions and the species which have been planted -conifer or broadleaved- either scheme A or B has to be applied. Scheme B includes pruning. It is expected that with planting conifers the treatment will be according to scheme A, on which the calculations have been based.

Extraction costs

Felling, bucking, roadside piling M$ 4.50/m^3, average per day 1.5 m^3; in steep terrain 1 m^3/day; per m^3 M$ 6.75.

Transport costs over an average distance of 75 miles, M$ 7.50/m^3 (according to the report "Transport Development in Malaysia" by Covendale and Colpits, July, 1968; 1 ton = 0.71 m^3).

Benefits

Yields per ha 150 - 200 - 250 m^3

F.O.B. value of the timber M$ 30 (scheme A), M$ 32 (pruned, scheme B) per m^3.

Maintenance schemes

	Scheme A				Scheme B				
Yr.	Weeding	Poisoning		Thinning	Weeding	Poisoning		Thinning	Pruning
	md	md	lit.	md	md	md	lit.	md	md
1	5				5				
2	7	2	4		8	2	4		
3	12				15				
4	10				13				
5	-	4	250	3	-	3	200	3	1
6	2				2				2
7	-				-				
8	3			2	4	2	5		
9	-				-				
10	2				2				
11	-				-			4	4

Nursery cost per selected 7500 seedlings

Establishing beds, sowing and raising 10,000 seedlings of which 7500 are selected	50 md	M$ 200.--
Cost of seeds		" 10.--
Fertilizer		" 10.--
Tools and equipment		" 5.--
	Total	M$ 225.--

Cost per 1700 plants M$ 51.--

Planting cost per ha

Planting space 8 x 8 feet per ha		
1600 + 100 = 1700 plants		M$ 51.--
Preparation, planting etc.	12 md	" 48.--
Opening up per ha		" 54.--
Transport costs		" 40.--
Fertilizer		" 5.--
Tools and equipment		" 10.--
Total		M$ 208.--

Several alternatives can be taken into consideration:

Schedule I Areas with slopes of 15 degrees and less.

" II Areas with slopes of 15 degrees and less with an annual rent of the land of M$ 3.- per acre (7.50 per ha.)

" III Areas with slopes of more than 15 degrees; cost of opening up M$ 80.-- per mile; cost of preparation of planting site and planting M$ 15.-; extraction cost M$ 6.75 per m^3; maintenance cost 30% higher than schedule I.

" IV According to schedule III + annual rent of the land of M$ 3.- per acre (7.50 per ha.)

As alternative has been taken into consideration an annual rent during 15 years as compensation for customary rights on the land.

Summary of the alternatives taungya system

System	B/C interest 10%	Rate of Return
Schedule I Areas with slopes < 15°	1.29 - 1.60	14.0 - 18.4
" II Areas with slopes < 15° and rent of the land of M$ 3.- per acre	1.20 - 1.51	12.8 - 17.4
" III Areas with slopes > 15°	1.08 - 1.34	11.2 - 15.6
" IV Areas with slopes > 15° and rent of the land of M$ 3.- per acre	1.01 - 1.28	10.2 - 14.7

2.2. Income of the farmer

1. Under present conditions 1 family of 6 persons yearly needs 4 acres for growing hill rice.

   Labour requirement in mandays per acre:

		mandays	
	men	woman	
a. felling, clearing burning	20		
b. sowing	–	4	
c. weeding	–	22	
d. harvest	5	5	
	25	31	mandays
4 acres	100	124	"

2. To get a reasonable yield the fallow cycle should be at least 15 years. A femily than needs in total 60 acres (24 ha) of which 56 acres (22.4 ha) can be used for growing pulpwood.

3. After a period of 15 years the age of the timber crops varies from 0 to 14 years, the acreage of each age class being 4 acres (1.6 ha).

4. The labour requirement during 15 years for raising the timber crop will be per year:

		slopes < 15°	slopes > 15°		slopes < 15°	slopes > 15°
		md	md		md	md
nursery 15 md per 7500 plants						
per 1700 plants	1 ha	11.3	11.3	4 acres	18.1	18.1
planting	1 "	12	15	4 acres	19.2	24
maintenance	10 "	52	68	40 acres	83.2	108.8
felling (150 m^3/ha)		100	150	4 acres	160	240
		Total mandays			280.5	390.9

5. Income farmer

	slopes < 15° md	M$/md	total M$	slopes > 15° md	M$/md	total M$
nursery	18.1	4	72.40	18.1	4	72.40
planting	19.2	4	76.80	18	4	40.00
				14	4	71.40
maintenance	83.2	4	332.60	5	4	20.00
				103.8	5.10	529.38
felling	160	6.75	1,080.00	240	6.75	1,620.00
sub total			1,561.80			2,353.18
farming (Annex 7 Agric.)			600.00			600.00
total			2,161.80			2,953.18

Average income (1/3 slopes < 15°, 2/3 slopes > 15°) M$ 2,689.38 (with rent of land M$ 168 more).

Schedule I Cost-Benefit analysis taungya system
Areas with slopes < 15°

Year	Costs	Benifits	Disconted 10% Costs	Disconted 10% Benifits	B/C	Rate of Return
0	210.50		210.50			
1	22.90		20.82			
2	40.42		33.40			
3	53.43		40.14			
4	45.78		31.27			
5	63.41		39.36			
6	11.51		6.50			
7	2.50		1.28			
8	25.94		12.10			
9	2.50		1.06			
10	12.25		4.72			
11	2.50		0.88			
12	2.50		0.80			
13	2.50		0.72			
14	2.50		0.66			
15 a	1,800.--	4,500.--	430.93	1,077.33		
15 b	2,400.--	6,000.--	574.58	1,436.44		
15 c	3,000.--	7,500.--	718.22	1,795.55		
a	Yield 150 m^3/ha	Value timber M$ 30/m^3	835.14	1,077.33	1.29	14.0
b	" 200 "	" " " 30 "	978.79	1,436.44	1.47	16.5
c	" 250 "	" " 30 "	1,122.43	1,795.55	1.60	18.4

Schedule II Cost-Benefit analysis taungya system.

Areas with slopes < 15^o. Rent of land M$ 3.-- per acres

Year	Costs	Benefits	Disconted 10% Costs	Disconted 10% Benefits	B/C	Rate of Return
0	218.--		218.--			
1	30.40		27.64			
2	47.92		39.60			
3	60.93		45.78			
4	53.28		36.39			
5	70.91		44.02			
6	19.01		10.73			
7	10.--		5.13			
8	33.44		15.60			
9	10.--		4.24			
10	19.75		7.61			
11	10.--		3.51			
12	10.--		3.19			
13	10.--		2.90			
14	10.--		2.63			
15 a	1,800.--	4,500.--	430.93	1,077.33		
15 b	2,400.--	6,000.--	574.58	1,436.44		
15 c	3,000.--	7,500.--	718.22	1,795.55		

a	Yield 150 m^3/ha	Value timber M$ 30/m^3	897.90	1,077.33	1.20	12.8
b	" 200 "	" " " 30 "	1,041.55	1,436.44	1.38	15.4
c	" 250 "	" " " 30 "	1,185.19	1,795.55	1.51	17.4

Schedule III Cost-Benefit analysis taungya system.

Areas with slopes > 15^{o}

Year	Costs	Benefits	Disconted 10% Costs	Disconted 10% Benefits	B/C	Rate of Return
0	248.50		248.50			
1	29.02		26.38			
2	51.66		42.69			
3	68.71		51.62			
4	58.76		40.14			
5	72.68		45.11			
6	14.21		18.02			
7	2.50		1.28			
8	32.97		15.38			
9	2.50		1.06			
10	15.18		5.85			
11	2.50		0.88			
12	2.50		0.80			
13	2.50		0.72			
14	2.50		0.66			
15 a	2,137.50	4,500.--	511.73	1,077.33		
15 b	2,850.--	6,000.--	682.31	1,436.44		
15 c	3,562.50	7,500.--	852.88	1,795.55		
a Yield 150 m^3/ha	Value timber M$ 30/m^3		1,000.82	1,077.33	1.08	11.2
b " " 200 ""	" " " " " " 30 "		1,171.40	1,436.44	1.23	13.7
c " " 250 ""	" " " " " " 30 "		1,341.97	1,795.55	1.34	15.6

Schedule IV Cost-Benefit analysis taungya system.

Areas with slopes > 15°. Rent of land M$ 3,- per acre

Year	Costs	Benefits	Disconted 10% Costs	Disconted 10% Benefits	B/C	Rate of Return
0	256.--		256.--			
1	36.52		33.20			
2	59.16		48.89			
3	76.21		57.26			
4	66.26		45.26			
5	80.18		49.77			
6	21.71		12.25			
7	10.--		5.13			
8	40.47		18.88			
9	10.--		4.24			
10	22.68		8.74			
11	10.--		3.51			
12	10.--		3.19			
13	10.--		2.90			
14	10.--		2.63			
15 a	2,137.50	4,500.--	11.73	1,077.33		
15 b	2,850.--	6,000.--	628.31	1,436.44		
15 c	3,562.50	7,500.--	852.88	1,795.55		
a	Yield 150 m^3/ha	Value timber M$ 30/m^3	1,063.58	1,077.33	1.01	10.2
b	" 200	" " " 30 "	1,234.16	1,436.44	1.16	12.7
c	" 250	" " " 30 "	1,404.73	1,795.55	1.28	14.7

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x) Schedules I and III are calculated without rent of the land; with rent the additional investments will be M$ 3.-- per acre.

Appendix 7: Brief outline of the Plantation Project.

The quick growing species which are to be selected from the series of trial plantations (Appendix 6) can be grown in taungya system with mainly hill padi as an agricultural crop during the first year of establishment. The tree-seedlings, raised in nurseries, are planted at the same time as the hill padi will be sown; spacing the seedling 8 x 8 feet, along the tree-row space is left of one foot on both sides. When the trees are grown in a rotation of 15 years a proper fallow cycle will be restored and the farmer will get a substantial additional income, his total income can gradually amount to M$ 2680 from the 16th year (Appendix 6).

Each farmer-family has to contribute every year compartments of 4 acres to the scheme. The compartments of a couple of families should be united and planted in succession. On steep slopes, ravines and gullies the original vegetation is to be kept or restored. They should serve at the same time as a barrier for fire-protection and as refuge to the natural animal population, specially birds. At least blocks of approx. 1000 acres should be surrounded by barriers of natural vegetation of a width of 25 - 30 feet.

By setting up the project in units of restricted size, localized in different regions, in 3 years time a maximum of families can benifit from it. Starting in the first year with 15 families per unit in the 4th year 175 families can be employed; the area which will be established per unit is increased from 60 acres in the first year to 700 acres in the 4th year. When 8 different locations are chosen the total number of employed families from the 4th year on will be 1400 by that time 11200 acres will be planted.

The schedule of establishment and maintenance of a unit is represented in table 8 (2.7.). The cost of establishment and maintenance in the succeeding years is derived from the schedules I and III[x] (Appendix 6). As an average they are based on one third of the afforestation cost of areas with slopes of less than 15° and two third of areas more than 15°.

The first yield to be expected will be obt..ned in the 16th year. Three years later a harvest can be obtained each year from 700 acres which amount to a sustained yield of 1,470,000 cub.ft. (42,000 m^3), per unit. By that time the area in peration per unit will be 10,500 acres (4200 ha).

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x) Schedules I and III are calculated without rent of the land; with rent the additional investments will be M$ 3.-- per acre.

Before the project starts the Forest Department selects the sites and a committee has to be formed consisting of representatives of the group of kampongs concerned and the local authorities. This committee nominates an executive board under the guidance of the Forest Officer; the board is supported by an administrative officer. The board gives its assistance to a smooth development of the scheme, administers the parcels each family is contributing, serves as a clearing-house for the distribution of tools, fertilizers obtainable at costprice level, as well as -with the assistance of the Agricultural Department- seeds of high yielding varieties of agricultural crops. The members of the board will be rewarded for their efforts. The cost are estimated, including the payment of the administrative officer, at M$ 20,000 annually.

From the 4th year on each year per unit seedlings have to be raised to plant continued an area of 700 acres (280 ha), approx. half a million. Depending the location the nursery can be established supplying 2 or more units. Field staff needed for raising the seedlings, supervising planting activities and maintenance should be trained on the job. The expenditure cost for field staff is included in the plantation cost (schedule I - III Appendix 6). Overhead staff when the whole project is full operation will consist of 2 Senior Forest Officers, 4 Forest Officers, 8 Forest Rangers, 16 Forest Guards, the cost of which has been summarized, including the executive board, in table 9 column 4 (2.7.).

Research has to be continued. Regarding the trial plantations of the initial phase some of the species of the elemination trials have to be tested in bigger plots. Regular investigations are to be done to rationalize the raising of seedlings and the maintenance, to prevent loss and damage by diseases and insect attack. The expenditure is summarized in table 9 column 2 and 3 (2.7.).

The expenditure of the whole project are summarized in table 9 (2.7.). From the time the 8 units are fully stocked the annual expenditure of the project will be M$ 1,621,000, the annual revenue (calculated on a f.o.b. value of M$ 30 per m^3 pulpwood minus cost of felling and transport) will be M$ 5,040,000.-

In full operation the project can supply on a sustained basis a quantity of pulpwood sufficient for a 150,000 ton capacity pulpwood mill.

Appendix 8 : Literature

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A N N E X 6

M A R I N E F I S H E R I E S

CONTENTS

LIST OF TABLES

1. INTRODUCTION

This Annex on Marine Fisheries relies more than any of the other annexes on knowledge and information obtained from local experts, as no marine fisheries expert was included in the Sarawak Study Team.

Therefore the advice of Mr. K.H. Postuma, a marine fisheries expert of the Marine Fisheries Research Station in IJmuiden, The Netherlands, with experience in the West Malaysian State Trengganu is gratefully acknowledged. Mr. Postuma read through a first draft of this report and suggested many improvements.

Nevertheless, responsibility for the contents of this Annex remains entirely with the Sarawak Study Team.

2. NATURAL CONDITIONS

The coastal region of the First Division can be considered to be a productive fishing area. Its coast is part of a more or less protected bay, bordering on the gently sloping continental shelf. The coast contains large mangrove areas in which especially young prawns mature. The many large rivers carry minerals and other material, thus providing food for the micro organisms. The main fish types according to catches recorded in all of Sarawak in 1968 are listed in table 1. It should be noted that approximately 16% is pelagic in origin. In the total catch pelagic species amount to over 20%.

Table 1. Main species of landings in 1968

Common name	Scientific name	%
Praws and shrimp	Crustaceae	23
Spanish mackerel	Scomberomerus	9
Herrings	Clupea, Chirocentrus	7
Sharks	Galeorhinidae	4
Pomfrets	Pampus	4

Fishing operations are hampered during the landas season, large waves coming in from the South China Sea endangers the landing operations of the smaller vessels.

3. DEPARTMENT OF MARINE FISHERIES

The Marine Fisheries Department Sarawak is a branch office of the Fisheries Division of the Federal Ministry of Agriculture and Co-operatives (now Ministry of Agriculture and Lands) of Malaysia. In Sarawak it was established by the end of 1965 and the next year established itself throughout Sarawak.Contrary to West Malaysia, where inland and marine fisheries are in one department, in Sarawak inland fisheries is taken care of by the State Department of Agriculture.

Table 2. Landings of marine fish 1968/1969 in tons

Type of fish	Landed in Kuching: By fishermen from First Div.		By fishermen from Second Div.		Total		All of Sarawak	
	1968	1969	1968	1969	1968	1969	1968	1969
1 Crustaceae	1,110	1,894	1,910	721	3,020	2,615	3,230	5,864
Prawns	1,027	1,750	1,910	721	2,937	2,471	3,141	5,720
Crabs	82	144	-	-	82	144	89	144
2 Assorted fish	3,665	4,232	605	666	4,270	4,898	6,571	5,972
3 Mixed fish	623	566	1,179	144	1,802	710	2,579	982
4 Trash fish	327	28	842	13	1,169	41	1,303	823
Total	5,725	6,720	4,536	1,544	10,261	8,264	13,683	13,785

The recent establishment is the main reason why no earlier than in 1968 the first reliable and fairly complete statistics of marine fisheries could be produced.

The comparatively young department put up already quite an ambitious programme of development for Sarawak fisheries which is now being brought in line with the one for West Malaysia. The personnel of the department in Sarawak is listed in table 10.

4. THE FISHING INDUSTRY

4.1 Subsistence fishing

On a subsistence level fishing is practised by nearly all the people living along the coast; most of them are Malay and, outside the First Division, also Melanau. The number of people engaged in subsistence fishing and their catches are unknown and thus not included in any figure.

4.2 Catches

In 1968 almost 80% of all fish was caught by fishermen from the First and Second Divisions and landed in Kuching; details are given in table 2. Fishermen of the First Division accounted for over 40% of all catches in Sarawak. Total value for Sarawak amounted to nearly M$ 11,500,000 at landing with a retail value of M$ 18,000,000.

In 1969 catches in Sarawak did not rise, but emphasis was more on prawns than on other products. The total retail value remained at approximately the same level. In the First Division there apparently was an increase in production of 17% spread over all products. This increase, however, may be due to a change in statistics. In 1968 it was possible to divide the landings in Kuching into shares from fishermen from the First and from the Second Division. In 1969 the distinction is not clear in the statistics.

A comparison of monthly catches in all of Sarawak is given in table 3.

Table 3. Catches of marine fish by months; all kinds, in piculs
(16.8 picul = 1 ton)

Month	First Division		All of Sarawak	
	1968	1969	1968	1969
January	1,103	2,764	2,232	7,315
February	1,140	3,208	3,221	8,259
March	2,552	8,945	7,182	35,209
April	10,953	12,661	19,131	50,392
May	15,768	20,593	28,127	32,668
June	11,990	12,890	41,607	24,352
July	9,850	14,548	38,545	21,653
August	12,476	9,628	24,631	14,877
September	9,350	10,801	27,740	15,332
October	10,080	8,395	18,777	11,185
November	7,763	5,419	12,260	6,552
December	3,188	3,045	6,428	3,799
Total	96,213	112,897	229,881	231,593

The sharp increase in catches in the first months of 1969, mainly due to an increase in catches of prawns, was counterbalanced by a decrease in later months. It is also noted that in 1969 the landas season ended approximately one month earlier than in 1968.

4.3 Number of fishermen

The number of fishermen, divided into racial groups in 1968 and 1969 is given in table 4. In the First Division only Malay, Chinese and a few Iban are fishermen. The Malay and Iban live along the coast; the Chinese for the greater part come from Kuching.

Table 4. Recorded number of fishermen in 1968 and 1969

Race	First Division				Sarawak			
	Full time		Part time		Full time		Part time	
	1968	1969	1968	1969	1968	1969	1968	1969
Chinese	697	727	17	-	739	770	22	54
Malay	1,091	914	314	429	1,538	1,337	639	791
Melanau	-	-	-	-	740	738	296	686
Iban	1	-	25	5	1	6	25	233
Kedayan	-	-	-	-	7	2	28	28
Total	1,789	1,641	356	434	3,025	2,853	1,010	1,792

Registration of fishermen is a difficult task; the margin of error in this table is, therefore, supposed to be considerable. Nevertheless it may be assumed that approximately 60% of the full time fishermen and approximately 35% of the part time fishermen come from the First Division. Except with the Chinese who show some growth in number, both full time and part time, there is a decline in number of full time fishermen, accompanied by an increase in number of part time fishermen. This probably points to former full time fishermen taking additional jobs, which probably is correlated with better opportunities in other sectors of the economy.

4.4 Fishing craft

The fishing craft in operation in 1968 and 1969, as recorded in table 5, gives a good impression of the fact that fishing in still primitive. Approximately 50% of all fishing craft in Sarawak is stationed in the First Division.

Table 5. Type of fishing craft in 1968 and 1969

Type	First Division		All of Sarawak	
	1969	1968	1968	1969
with inboard	469	405	846	754
with outboard	271	310	935	1,009
non powered	1,736	626	2,330	1,115
fish carriers	29	24	92	80
trawlers	13	15	20	60
Total	2,518	1,380	4,223	3,018

The largest difference in number is found in the non-powered craft in the First Division. At least part of the variations found may be due to severe difficulties in collecting this statistical material. Especially the increase in number of trawlers is interesting. There is not always a clear difference between trawlers and fish carriers as both can be easily converted.

4.5 Gear

Table 6. Fish landings by gear groups

Gear group	1968 Landing in piculs	1969 Landing in piculs
trawl nets	5,952	10,127
gill nets	93,174	92,447
fishing stakes	28,716	33,961
seine nets	14,846	9,002
lift nets	11,352	9,408
bag nets	52,628	62,452
barrier nets	12,127	7,790
hooks/lines	1,607	365
traps	1,625	2,315
unsorted	7,854	3,726
Total	229,881	231,593

From table 6 an impression is gained concerning the importance of gear groups. The changy drift/gill nets head the list with approx. 40% of the catch together with the seine nets, with which most of the pelagic fish is caught. Bag net fishing is a good second with some 35%, mainly prawn. Third is the palisade type of gear with over 12%. It should be noted that the share of trawl nets increased from 2.6% in 1968 to 4.3% in 1969.

5. TRANSPORT, PRESERVATION, STORAGE AND MARKETING

5.1 Introduction

Besides the rather primitive techniques made clear by the large number of but part-time fishermen, the type of craft and the type of gear, transport preservation, storage and marketing form an important bottleneck in the development.

5.2 Ice

Ice for preservation is very expensive. It is cheapest around Kuching, at M$ 1,-- per 80 lbs and goes up to M$ 3,-- per 80 lbs in other parts of the country. This is mainly caused by an uneven distribution of ice producing factories. Fishermen thus are faced with the choice of either buying expensive ice or making only short trips in order to reach the market in time. Other conservation methods, such as salting and drying or smoking are practised only on a very small scale.

5.3 Marketing

Marketing usually is done with local fishmongers who take care of the retail on markets. Few fishermen are independent from the fish dealers which easily leads to exploitation. According to table 2., in 1968 some 35% of the retail value or 57% of the landing value was taken by the fish dealers. In the case of fishermen being dependent on the dealers the percentage could be even higher. At first glance this may seem rather high, but it should be realised that the middleman

(i) takes care of the troublesome transport to the retrail market,

(ii) takes all risks of spoilage,

(iii) in many cases even provides loans for the fishermen.

At present some middlemen go out with boats (carriers) with ice and buy the catch at sea. This system works especially in the First and Third Divisions, but it is insufficiently organized.

6. RECENT DEVELOPMENTS

In 1966 a larger private enterprise made a start in Sarawak, with the object of trawl fishing for prawns. Since 1967 this company, the Tropical Seafood (Sarawak) Sendirian Berhad, an 85% Japanese enterprise, has been fishing with a number of Japanese trawlers. Their catches are shown in table 7.

Table 7. Catches of Tropical Seafood in tons

Year	Fish	Prawn
1967	45.4	97.4
1968	8.4	116.3
1969	59.5	73.1

These Japanese trawlers, originally 7 and now 5 in number, have their own cold storage and can operate independently. The catch is processed at once and taken to Japan by fish carriers. Approximately four times the weight in prawns is caught in trash fish, which at the moment is discarded.

At first the trawling done by these vessels caused much disturbance among local fishermen because their drift nets were damaged and because local fishermen thought their potential would be endangered. This dispute was more or less settled by an agreement that the trawlers should stay outside the 6 fathom or 3 miles boundary. Nevertheless some tension is still apparent which could easily increase should more foreign trawlers appear.

In March 1969 at Goebilt a new ice plant cum cold storage was completed, built by the Goebilt Processing Berhad, a newly formed company, with 45% Tropical Seafood and 51% local capital. The plant has a deep-freezing capacity of 20 tons a day and coli storage for 350 tons, at a total cost of M$ 2,000,000. In addition a fish-meal plant may be built, so that trash fish can be processed. At the time of the completion of the plant there were plans to charter a fleet of about 65 Japanese trawlers. This fleet will later on be replaced by locally built and if possible locally manned smaller trawlers.

Ten 45-foot steel double-rigged trawlers have been built by the Sarawak Development Finance Corporation (SDFC) at the cost of about M$ 90,000 each. Four of these were constructed in Singapore, another four in Miri and two in Kuching. These vessels have no refrigerating equipment. The trawlers are powered by 100 B.H.P. Yanmar diesel engines. The trawlers will be handed over to local fishermen on a hire-purchase scheme arranged between the SDFC and Goebilt Seafood Processing Bhd.

7. POTENTIAL AND BOTTLENECKS

The potential for development of marine fisheries in Sarawak has not yet been assessed. Although such a determination of potential is still necessary, for the time being a comparison with Sabah may be useful. In Sabah marine fisheries is more intensive, as can be seen from table 8. However rough these figures are it may be concluded from this table that Sarawak's potential still is considerable. On the other hand it should be kept in mind that in Sabah overfishing has been reported.

Table 8. Comparison between Sabah, all of Sarawak and the First Division

	Sabah	Sarawak	First Division
miles shore line	180	500	130
number of fishermen	9,000	4,000	2,100
number of vessels	5,000	4,000	2,500
production in tons	30,000	13,500	5,700
production per vessel	6 tons	3.5 tons	2.3 tons
production per man	3.3 tons	3.5 tons	2.7 tons
production per mile shore line	166 tons	27 tons	43 tons

For all of Sarawak a considerable increase in fishing seems possible, even up to three times the present production. For the protected bay of which the First Division's coast forms part, prospects are somewhat less bright, especially if one realizes that the fishermen of the First and Second Divisions are fishing in that bay, but doubling seems possible.

With the increase of trawling, however, fishermen will be less tied to their own part of shore line, so that the potential will be tapped more regularly over the whole State. Moreover if trawlers really adhere to the rule of staying outside the 3 miles and 6 fathoms lines more areas of the sea will be harvested.

With respect to development of prawn fishing, it should be realized that large scale development of prawn farms (see Annex 7: Agricultural Development) will endanger the prawn fishing potential. If large parts of the mangrove area are turned into prawn farms, there will be less prawn in the sea.

8. DEVELOPMENT PROGRAMME AND PROJECTED RESULTS

8.1 Introduction

The whole programme for development of marine fisheries is being brought in line with the one for West Malaysia. A summary of the first and second Malaysia plans is given in table 9.

In general the ambitious proposals for the second Malaysia plan are quite sound. If really implemented they are considered sufficient for a rapid development.

8.2 Expansion of research facilities

In the first plan period a multi-purpose fishing vessel was built in West Malaysia. The vessel was expected to be completed early in 1970 and is intended for Sarawak and Sabah. A 36 feet trawler for trials and demonstrations is under construction and various nets for trials have been bought.

It is trusted that the multi-purpose vessel will conduct at least some surveys in Sarawak waters in the second plan period. Experiments in salting and smoking and research on various types of fishing units will be carried out by the technical staff.

8.3 Financial assistance to fishing industry

As it was not yet known how such assistance could be given, the provision under the first plan should be considered to be a token provision.

For the second plan period financial aid will be channeled either through co-operative societies or through the Sarawak Development Finance Corporation in the form of subsidised loans. It is expected that through such loans fishermen will be able to acquire better and larger boats with better engines and more efficient gear.

Table 9. Summary of first and second Malaysia plans for marine fisheries in Sarawak

		Title	M$ 000 expenses '66 -'70	% achievement	M$ 000 expenses '71-'75
I		Expansion of research facilities	272		475
	1	Survey of resources	46	100	50
	2	Experiments in fish handling and processing	20	100	25
	3	Fishing units for trials and demonstrations	206	59	400
II		Financial assistance to fishing industry	10	0	400
III		Fishing port development	484		1,200
	1	Ice production and cold storage	300	83	600
	2	Fish landing and marketing facilities	134	67	500
	3	Lights, buoys and navigational aids	50	80	100
IV		Training of fishermen	238		300
	1	Marine fisheries school	200	0	200
	2	Training in established methods of fishing	38	76	100
V		Adoption of modern fishing methods	120		390
	1	Fisheries enforcement and inspection vessels	120	100	390
VI		Administrative Services	105		570
	1	Fisheries headquarters and research facilities	5	100	300
	2	Offices and quarters at fisheries centres	15	100	250
	3	Speedboats for fisheries staff	85	47	20
		Total	1,459	69	3,335

8.4 Fishing port development

During the first plan period an ice plant cum cold storage was planned at Miri and landing jetties were built in Santubong and Sungei Apong. It was proposed to build landing jetties also in Belawai and Bintulu. A number of lights, buoys and other navigational aids were planned to be installed in 1970. Especially the provision of ice plant cum cold storage facilities will be increased considerably in the next plan period. It will be a waste of energy and finance if marketing is not simultaneously improved with the increase in production. It is proposed that the Federal Agricultural Marketing Authority begins a marketing scheme.

For solution of the problems connected with transport, storage and marketing there are two possibilities:

(i) cold storage and ice plants at selected spots along the coast,

(ii) mobile cold storage and ice plants with a fixed schedule of meeting fishermen at sea.

Both proposed methods are already in use; for future development one should be selected and adhered to. The Marine Fisheries Department is at present in favour of the second solution.

8.5 Training of fishermen

In the first plan period nothing was spent on a marine fisheries school but training of fishermen did receive attention as can be seen from table 10.

Table 10. Fishermen sent for training

	First Division							All of Sarawak						
Place of training	64	65	66	67	68	69	tot	64	65	66	67	68	69	tot
Penang	4	2	2	-	2	1	11	8	10	4	4	4	4	34
K. Trengganu	-	3	5	7	6	9	30	4	15	10	15	12	14	70
Sabah	-	-	-	8	12	6	26	-	-	-	8	12	10	30
Total	4	5	7	15	20	16	67	12	25	14	27	28	28	134

The training will be continued in the second plan period. Furthermore it is proposed to build a joint Sabah-Sarawak Marine Fisheries School on Labuan island. Assistance in setting up such a school has been sought from the Freedom From Hunger Campaign. The school will direct its teaching to:

(i) fishing techniques

(ii) navigation and ship maintenance

(iii) fish handling and preservation.

8.6 Adoption of modern fishing methods

A M$ 120,000 vessel, meant primarily for enforcement of fisheries law, is expected to be completed early in 1970. In the second plan period a provision is made for three vessels so that the entire 500 mile coastline of Sarawak can be covered. With the proposed extension of the Malaysian Fisheries Act to Sarawak there should be means of enforcement, especially when the rapidly increasing trawl fishing is taken into account.

8.7 Administrative services

As the department in Sarawak is relatively new, in most places adequate quarters have yet to be provided, including a simple research laboratory in Kuching.

The department personnel is expected to increase as shown in table 11.

Table 11. Staff requirements

	1969	1975	increase
Division I			
administrative	1	1	-
professional	-	4	4
technical	1	2	1
Division II			
fisheries asst's.S.G.	2	4	2
Division III			
fisheries asst's	10	22	12
clerks	3	4	1
crew	7	22	15
Division IV			
crew	5	11	6
office	2	5	3
Total	31	75	44

8.8 Production

If the development plan of the Department of Marine Fisheries is adhered to, and also if the expected development of trawl fishing becomes reality, the following increase in production may be expected:

Table 12. Estimated increase in production of marine fish (including Crustaceae)

	First Division		All of Sarawak	
Period	% growth per year	Production in tons	% growth per year	Production in tons
'68 / '69	reference year	6,300	reference year	13,700
till '75	7%	8,800	7%	19,200
till '80	5%	11,300	7%	26,900
till '90	(3%)	(15,000)	5%	44,000

If the projected growth is realised, the estimated potential of the protected bay, of which the coast of the First Division forms part, will be fully tapped in 1980.
In order to prevent overfishing, therefore, determination of the potential at short notice is of the utmost importance. Only after assessment of the potential it can be determined whether after 1980 a 3% growth in the First Division will be possible.

In this calculation it is left out of consideration that with an increase of fishing there will be a relative increase of short lived species.

It should be noted also that, however rapid the growth of marine fishing in the First Division, growth in the remainder of Sarawak will be more rapid still. The relative importance of the First Division in Sarawak's marine fishing will decrease from nearly 50% at present to approximately 35% in 1980.

8.9 Employment

Mainly due to the rapid development in trawl fishing the following estimated changes in employment in marine fishing are expected.

Table 13. Estimated employment possibilities for full time fishermen

Period	First Division % decrease per year	First Division Employment	All of Sarawak % decrease per year	All of Sarawak Employment
'68 / '69	reference year	1,700	reference year	2,900
till '75	3%	1,450	3%	2,450
till '80	2%	1,300	3%	2,100
till '90	1%	1,200	2%	1,700

The full time fishermen taking up other occupations will often first become part time fishermen. The number of full time fishermen becoming part time fishermen will more or less counterbalance the part time fishermen finding other more lucrative employment. Therefore, the number of part time fishermen is expected to remain at approximately its present level of:

for the First Division 400 persons,
for all of Sarawak 1,400 persons.

It is probable, however, that the necessary ice plant cum cold storage facilities will give a number of employment opportunities.

8.10 Gross Value Added

An estimate of the Gross Value Added is given in table 14.

Table 14. Gross Value Added 1968

		First Division	Sarawak
1.	Average value per ton of marine fish M$ 837,--		
2.	Gross Production Value	4,792,000	11,450,000
3.	Non factor input:		
	diesel fuel, cylinder oil	700,000	1,700,000
	ice	280,000	680,000
	insurance, repairs, misc.	285,000	700,000
	Total 3.	1,265,000	3,080,000
4.	Gross Value Added	3,527,000	8,370,000

Under the assumptions

(i) of a yearly growth of production as given in 8.8. table 12

(ii) of constant prices at the 1968/'69 level

(iii) of a yearly growth of the productivity of 1%,

the following estimates of the future development of the Gross Value Added can be made.

Table 15. Expected future development of the Gross Value Added in marine fisheries

	First Division M$ million	All of Sarawak M$ million
1968/'69	3.26	8.37
1975	5.17	13.28
1980	6.92	19.51
1990	(10.25)	34.92

It should be stressed again that, especially for development of marine fisheries in the First Division, full assessment of the potential before 1980 is urgently needed.

9. SOURCES OF INFORMATION

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