RELATIONSHIP BETWEEN THE TROPICAL RAIN FOREST AND THE PEOPLE

(Final Report of Joint Research)

July 1984

Japan International Cooperation Agency

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PREFACE

This Report on the Relationship between the Tropical Rain Forest and the People embodies the results of the Joint Research which was carried out from December 1979 to March 1981 by the Japanese researchers headed by Dr. Kawana, Professor, at Tokyo University of Agriculture and Technology, and those of Mulawarman University in Indonesia.

I sincerely hope that this report will be of great use as a basic reference for the research of tropical rain forests.

I would like to express my sincere appreciation to the authorities concerned of both countries for their close cooperation extended to the Joint Research.

July 1984

Kazuto NAKAZAWA
Executive Director
Japan International Cooperation Agency

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Introduction

Biological production in the tropical land varies considerably according to the regional factors, such as the distribution of the rainfall, and the tropical rain forest is one of the richest ecosystems in the world. It could be said that the activities of the biosphere of these are still continuing by accumulating coal and petrolium that had once changed the circumstances of the earth in the past, under higher temperature and humidity, just like in the past. There, the human being could live in the forest, so long as he had been a part of the ecosystem. But, once, when the civilization and the population flourished, like the civilization of Inca, the human being would receive the retaliation, such as the degradation of the soil, and was expelled from there. Now, the forests on earth still remain only in the unarable regions of sub-arctic climate, where the growing period is very short, the regions of steep slopes, or these tropical rain forests. Thus, these forests are playing an important role to keep the balance between the human being and the biosphere. But, because of the development of the means of production and transportation, and the progress and diffusion of medical treatment, the human population increased rapidly, and, so long as it is consistent with the economic principal, man began to move and settle to the regions where he could not live in the past. This exerted a significant influence on the resources and circumstances and arose a certain anxiety for the future. Then, the human wisdom is making great efforts toward the population control while, on the other hand, we began to feel concern for the development and reproduction of resources, and ecological preservations.

In consideration of these backgrounds, the UNESCO and other organizations started to do the researches on the relations between the human being and the biosphere. In this context, the request for the joint research on "The relationship between the tropical rain forest and people, an assessment of interrelationship", made by Mulawarman University in Indonesia, could be said to have quite an actual meaning. The acceptance by the Japanese government (JICA) to cooperate with this project, also, shows our recognition of this fact.

Thus, the joint research group of JICA and Mulawalman University has engaged in the realization of this project. Objectives are: the policy of the natural resource preservation and emigrations for the distribution of the people and movement to merchandise economy from self-sufficiency by the Indonesian

Authority, the analysis of several conditions in the tropical rain forest, which is now under devastation because of the transformation of the shifting cultivation and above all, finding the necessary approach to coordinate them in the harmonious way with the human being.

While East Kalimantan has, in its vast land, one of the best forests in the world, including the tropical rain forest, it is here that Japanese forest industry has a long history of its activity, taking advantage of the short distance from Japan. But, recently, all the advanced industrial countries of Europe, the U.S. and Japan, have joined in its development, because of the drain of the wood resources in Africa and the decrease of resources in Asia. But, still, Japan holds on the greatest influence in this region. And, although the recent Indonesian policy of the preservation of the wood resources and the encouragement of the development of the national industry has made the situation rather uncertain, and there will be a possible change from log to lumber. Moreover, Indonesia is the country which has a very strong relationship with Japan as partners in trade both of import and export, such as agricultural products and oil. The production of wood increased from 1,490,000 m^3 in 1950 to 23,280,000 m^3 in 1974.[(1)] And it decreased from the peak of 28,900,000 m^3 in 1979 to 22,400,000 m^3 in 1982.[(2)] According to the report of Kompas,[(2)] the numbers of the playwood mills are 74 in operation, 46 under construction, and 30 were given permission to operate. According to the forecast of increasing consumption, for sawing, making playwood etc., the policy of export logs changed so as to limit the amount until exportation eases in the near future.

Looking at the figures above and the necessity of land for agricultural use, the importance of tropical rain forest should be up-held as it keeps the environment for humankind. Therefore, our aim of the cooperation in this research project is to find out how to aproach these problems.

To add to this, the Japanese government has offered a grant aid for the buildings and facilities of the Center for reforestation studies in the Tropical Rain Forest at the request of the Indonesian government, which is expected to contribute a lot to the study of the tropical rain forest, and for which many other countries have deep concerns.

The research on the tropical rain forest has a long history not only in the countries concerned but also in western countries, Japan, too, and has

(1) Shirohara Takeo : The Forestries in Southeast Asia and Oceania PP. 320 1981
(2) Kompas : 1983

been trying various approaches for many years, such as those by IUBS and MAB. But there have been few that were done from the broader viewpoint of the "relationship with the human being". In this respect, this research could analyze the relationship of the tropical rain forest and the people based on the actual conditions of them. In other words, this is done, not in the conservative approach of special departmental studies, but in the interdisciplinary group studies of both countries. In this context, we think, it is of great significance that this research was accomplished at this time when the development of the tropical rain forest and the utilization of its resources, together with the agricultural development, have been recognized as essential for the existence of the human being, with emphasis on the ecological and natural conservation, and especially when "A Decade of the Tropics" will arrive, following the researches of MAB by IUBS.

The type of technical cooperation of this research also belongs to quite a new that had ever been done by the Japanese government. Especially, in Indonesia, this was the first case of the kind. In spite of trial and error at the start of the project, we are satisfied with the unique results attained in the research that lasted for three years from 1979 to 1981. The research was done in the overlapping system by the members in 5 groups, which are listed below.

Finally, the following efforts are appreciated: those of the former Rector Sambas Wirakusumah who planned and requested this research, Dr. D.A. Tisna Amidjaja and Dr. Sidharta Pramoetadi of P & K (..inistry of Education and Culture), Rector Soetrisno Hadi of Mulawarman University, Mr. Numata, Mr. Nakano Mr. Shiraishi and other officers of JICA, as well as those of the officers of the government of East Kalimantan Province.

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* : Passed away, December,20, 1983.

Section 1

Land Use Classification Based on Geology, Physiography, Soil and Vegetation

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1. Preface

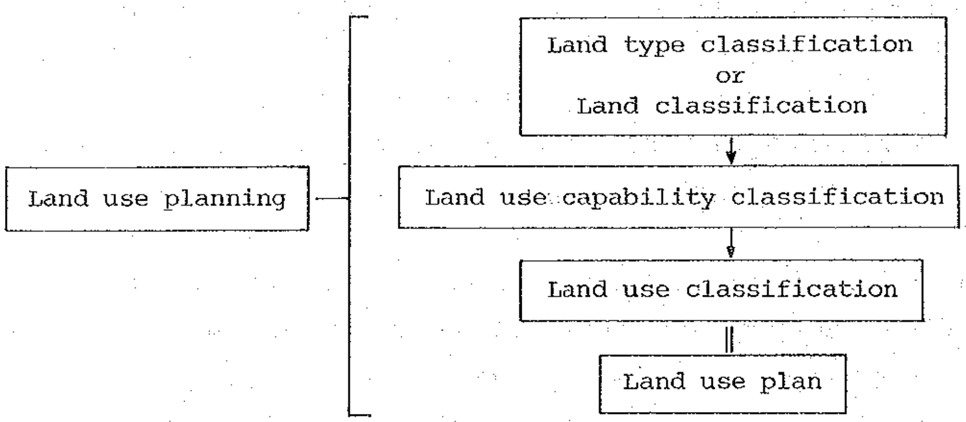
East Kalimantan Province, Republic of Indonesia, is one of the tropical rain forest area, producing timbers mainly consisting of Dipterocarps, the family of Depterocarpaceae. In addition to the conventional oil producing area, exploitation of the petroleum natural gas is under progress in recent years. Consequently, it is internationally assuming an important role.

It is, however, feared that owing to the remarkable increase in exploitation of forests, caused by the enlargement of timber production in this area, not only quicky exhaust of resources but also soil erosion and dicreasing of flood control function may ensue unless any efforts are taken in order to keep the forest resources.

On the other hand, if the Indonesian Government is progressing its plan on the exploitation of forests, it is feared that not only the loss of balance in the demand and supply of the Dipterocarpus timber will be occured dis-terbed the provincial economy and the development of this area that is expected to be a food producing region to bolster up the ever promptly in-creasing Indonesian Population.

Consequently, in order to solve these problems, the long term land use plann-ing must be made on in order to preserve forest area for continuous timber production is available, and various kinds of eco-systems as well along with the proper planning of the agricultural development must be contemplated so that harmony among them is made.

With a view to establish the land use planning, various methods are respec-tively taken according to the object of land use, however the land use must be made through the land use classification just as following chart.



This land use classification is completed through the land classification and the land use capability classification. The land classification is the classification of land according to the land properties, and the land properties are determined by various land characteristic items. Each land characteristic item consists of various kinds of categories and some of them have certain ranges occasionally.

The land use capability classification is one of the land evaluation according to the suitability value to be graded with potential or permanent plants productive capacity, classified based on land classification, hardness and easiness of land utilization, etc.

The land use classification is to grade land by the land use capability classification to adjust the graded land in accordance with the suitability for purpose of usage.

Therefore, the problem of whether it is possible or not to carry out the land use grading for fitting sufficiently with the purpose of the land use planning with ease, quickness and certainty depends upon the following: firstly, how to choose minimum land characteristic items concerning the land classification and how to finally divide these constituent elements, and secondly, how to simplify the land grading and dividing of grades concerning the classification of land.

2. Reasearch objective

Objects of the research to be performed are as the following items.

(1) It is to study the methodology of performing with ease, quickness and certainty the land use classification in order to contribute the continuous production of timber, the protection of forests and various kinds of eco-systems and to establish the land use planning of tropical rain forest area without any modern technologies such as computer photographic decipher with Satellite and so on in consideration of harmony with those agricultural developments.

(2) To try to divide the land use classification of tropical rain forest area of East Kalimantan on the basis of the studied methology and to add assessment to that result.

3. Methods of Research

(1) To collect characteristic items as the land properties which are necessary for land classification of the tropical area and of documents on their components and various kinds of observed data and information.

(2) To take place an image training relating to the land classification of the low land tropical rain forests on the Lemake experimental forest and Bukit Soeharto research forest of Mulawarman University to perform a preparatory survey on land classification from the ground and from the low sky by helicopter.

(3) The survey on the climatic features of East Kalimantan, geological features, topography, soil and vegetation with the objects in some of Muarakaman district along the Mahakam River, its delta zone of Sebulu area and mouth of the river and Samboja district along the seashore will be carried out. Also important land characteristic items of the land classification of East Kalimantan and the component of the land characteristic items will be studied to provide a survey table of land classification.

(4) In order to ascertain the accuracy of the provided land classification survey, the vegetation and land types shall be sellected on the Sebubu area. The representative of the low land tropical rain forest in East Kalimantan, by the previous air photograph interpretation. In addition, each survey area will be observed from the air by low flight helicopter and that from the river side by speed boat shall be made.

(5) By assuming the degree of difficulty and easiness on farmland development and the latent plant productivity due to land properties, the study on the land use capability classification shall be taken place and the land classification-land use capability classification survey table shall be provided.

(6) The land use classification of each survey area, graded and degree-classified by the land classification and land use capability classification survey table from the view point of land conservation, timber continuous production, protection of various ecological systems and development of farmland shall be taken place.

4. General description of East Kalimantan

The general description of East Kalimantan and viewed from the Republic of Indonesia, are as folllows:

The Republic of Indonesia lies, as shown in Fig. 1, between the Sabang Island that is located at six degrees north latitude and down southward via the equator to 11 degrees south latitude where the Roti island, belonging to the Timor island is situated, and lies midway between the Asian Continent and Australian Continents that extends between 95 degrees east longitude and 141 east longitude of West Irian. The Republic consists of about 13,000 islands in all, large and small.

Fig. 1 Location map of East Kalimantan

These groups of islands are divided into islands on the stable zone and those on the unstable zone, based on the structure of the geological features and topography also reflects as a whole both of the features. The stabilized zone has the Sunda continental shelf that is the extension of the Asian Continental shelf and the Sahul land shelf that is the extension of the stable zone of the Australian Continent. The stabilized zone is the stable land mass from the time of old geological features as compared with the unstable zone and suffered little new crustal activity, while the unstable zone had remarkable crust activity in as late as the 4th period like the Sulawesi Island.

The Indonesian archipelagoes are scattered at the equator and belong to the tropical high rain belt. It has generally oceanic climate of high temperature, high rain and high humidity. The wind is weak, but there occur local differences, caused by sizes of islands, height or lowness of a land, wind on land and sea, rainfall, etc. The biggest factor that governs the climate in this zone is the air mass of the Asian and Australian Continents and the trade wind blow near the equator. There are zones those are affected by and those not affected by the monsoon. Not only the plant growing changes subject to whether being affected by the monsoon or not, but the industry is also transformed.

Kalimantan is located slight westward from the central part of the Indonesian Archipelago, situating approximately extent between seven degrees north latitude to five degrees south latitude and from 109 degrees to 119 degrees east longitude. It is the third largest island in the world, and the equator crosses almost the center part of the island.

Kalimantan belongs to the stable zone based on the geological features, which are old and have many topography that suffered erosion for a long period, but it is said that after the final end of ice period, major zones of the low land sunk to be the sea bottom as the sea surface rose, the higher land remained as islands.

Therefore, the central portion of the same island is almost occupied by the mountain zone. As shown by Fig. 2, a number of mountain chains spread radially from here. The Iban mountain chain runs toward the northern end part together with mountains of 1,600 - 2,000m in height. They are followed westward by the Kapuas Hulu mountain chain west-northward by the Kapuas Hilir. Folllowing this, Schwaner mountain chain extends with the Meratus mountain chain sinuously reaching down southward up to the Selatan Cape. The Iban mountain chain, Kapuas Hilir and Kapuas Hulu mountain chain among them are the main border between the Malaysian territory. Kalimantan of the Indonesian territory has, as shown by Fig. 3, administrative districts of four states of East Kalimantan, South Kalimantan, Central Kalimantan and West Kalimantan.

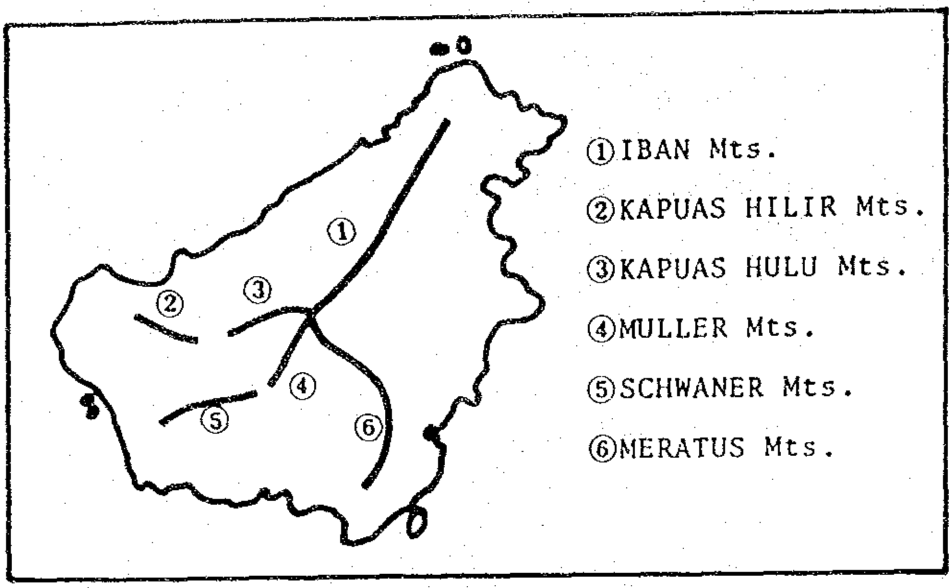


Fig. 2 Mountain chains in Kalimantan

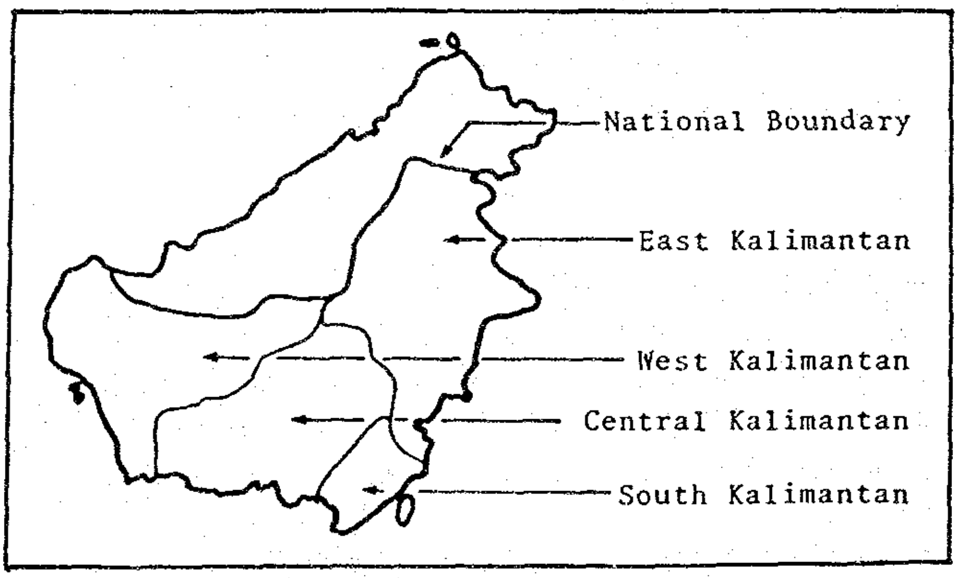


Fig. 3 Administrative area in Kalimantan

The area of East Kalimantan is 21,440,000 ha. which occupies 11% of the whole country and is said to be the most important tropical rain forest zone. From the mountain range behind the Sesagap River, River Kayan, Marinau River, Keki River, Mahakam River, etc. flow eastward. The rivers including these tributaries became important traffic route to the inland zone. The Mahakam River particularly is over 10,000 km in length, forming at the mouth of the river a large-scale delta that is a feature of a shoaling beach. At about 50 km upper reaches of the mouth of the river Samarinda, capital of the province, is located.

Since 1967, in East Kalimantan, logging work has been quickly progressed, and subsequently the social and economic change have been remarkable. As the results, not only the deforestation, but also the induction of forest and timber hauling laborers caused increase of population which became 960,000 in 1976 from 725,000 in 1971. 1) In addition agricultural immigrants have been positively made under the administrative guidance along with the opening of the highway between Balikpapan and Samarinda. The current present land use is approximately as shown in Table 1 and Fig. 4, and it is considered that considerable agricultural exploitation is being advanced.

Table 1 Present land use in East Kalimantan 2)

Kind	Area (ha)
Forest land	17,292,000
Farmland, plant garden	129,000
Lake, river surface	2,593,000
Others	1,426,000
Total	21,440,000

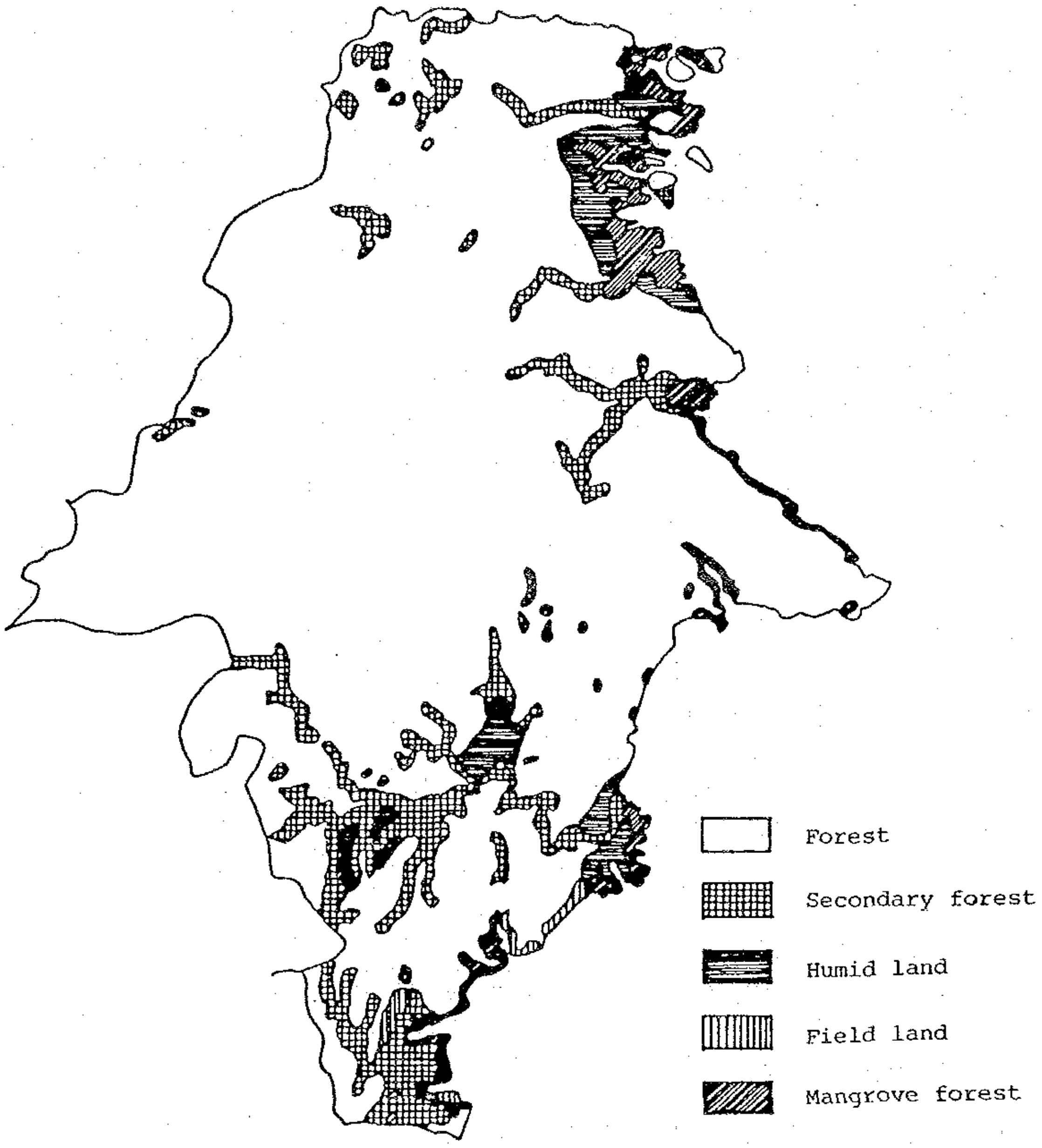


Fig. 4 Present land use in East Kalimantan

5. The Result and Discussion of the Land Use Classification in East Kalimantan

Results of the research on climate, geological features, topography, soil and vegetation and are as follows:

(1) Climate

East Kalimantan, located approximately between four degrees north latitude to two degrees south latitude is a tropical zone just under the equator. Annual temperature difference is small, i.g. at Balikpapan, it is 26.4°C in the hottest month and 25.6°C in the coolest month. The annual difference is only 0.8°C. The daily temperature difference, however, is as around 10°C, and based on observation value at Samarinda in 1979, there was no day with minimum temperature over 25°C at night, i.e., the tropical night, provided that the relative humidity was over 86% throughout the year. In Jakarta where the rainy season and dry season are clear as compared with Samarinda the average humidity is 76%. Similarly the climates of Sebulu near Samarinda and Surabaya in Java Island, Fig. 5 as indicated by the climate diagram that is the measurement by bodily sensation are shown as Fig. 5. The low land of East Kalimantan belongs to the tropical zone that is generally of high relative humidity.

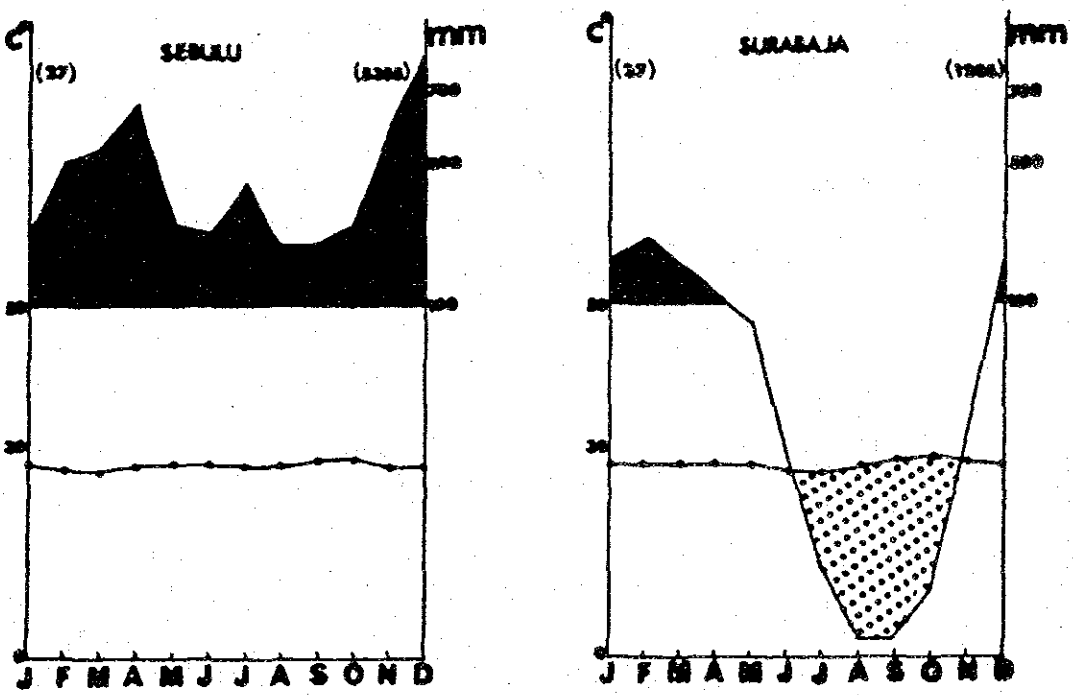


Fig. 5 Climatic diagram of Sebulu and Surabaya

Table 2 Recent years climatic data (1971-1979) in East Kalimantan

No.	Location	Number of years	Annual mean precipitation	No. of rainy days	Annual mean rainfall intensity	Fluctuation ratio
			mm	day	mm/day	%
1	Samboja	7	2,556	118.9	21.5	24.1
2	Tanahgrogot	6	1,890	91.0	20.8	29.2
3	Seppinggan	6	2,512	173.3	14.5	7.9
4	Sanga-Sanga	6	2,383	111.5	21.4	8.9
5	Balikpapan	6	2,356	146.7	16.1	15.1
6	Long Iram	7	2,749	108.1	25.4	22.7
7	Melak	7	3,291	126.4	26.0	16.5
8	Muara Pahu	7	2,236	111.1	20.1	28.9
9	Muara Muntai	9	2,328	91.8	25.4	17.9
10	Muara Kaman	5	1,869	137.0	13.6	12.9
11	Bontang	8	1,816	99.6	18.2	17.3
12	Tenggarong	7	1,903	124.6	15.3	23.7
13	Muara Ancalong	6	2,095	70.0	29.9	24.9
14	Muara Wahau	7	2,276	96.3	23.6	15.0
15	Muaralisan	5	2,122	108.4	19.6	32.2
16	Loa Kulu	6	1,945	70.7	27.5	23.8
17	Sangkulirang	6	1,836	118.7	15.5	13.1
18	Malinau	7	4,660	139.9	33.3	22.3
19	Sesayap	6	2,862	140.0	20.4	18.6
20	Tanjungredeb	7	1,805	105.6	17.1	14.6
21	Nunukan	8	2,064	99.4	20.8	13.5
22	Barongtongkok	6	3,597	107.2	33.6	40.6
23	Sungai Kunjang	7	1,683	105.3	16.0	5.4

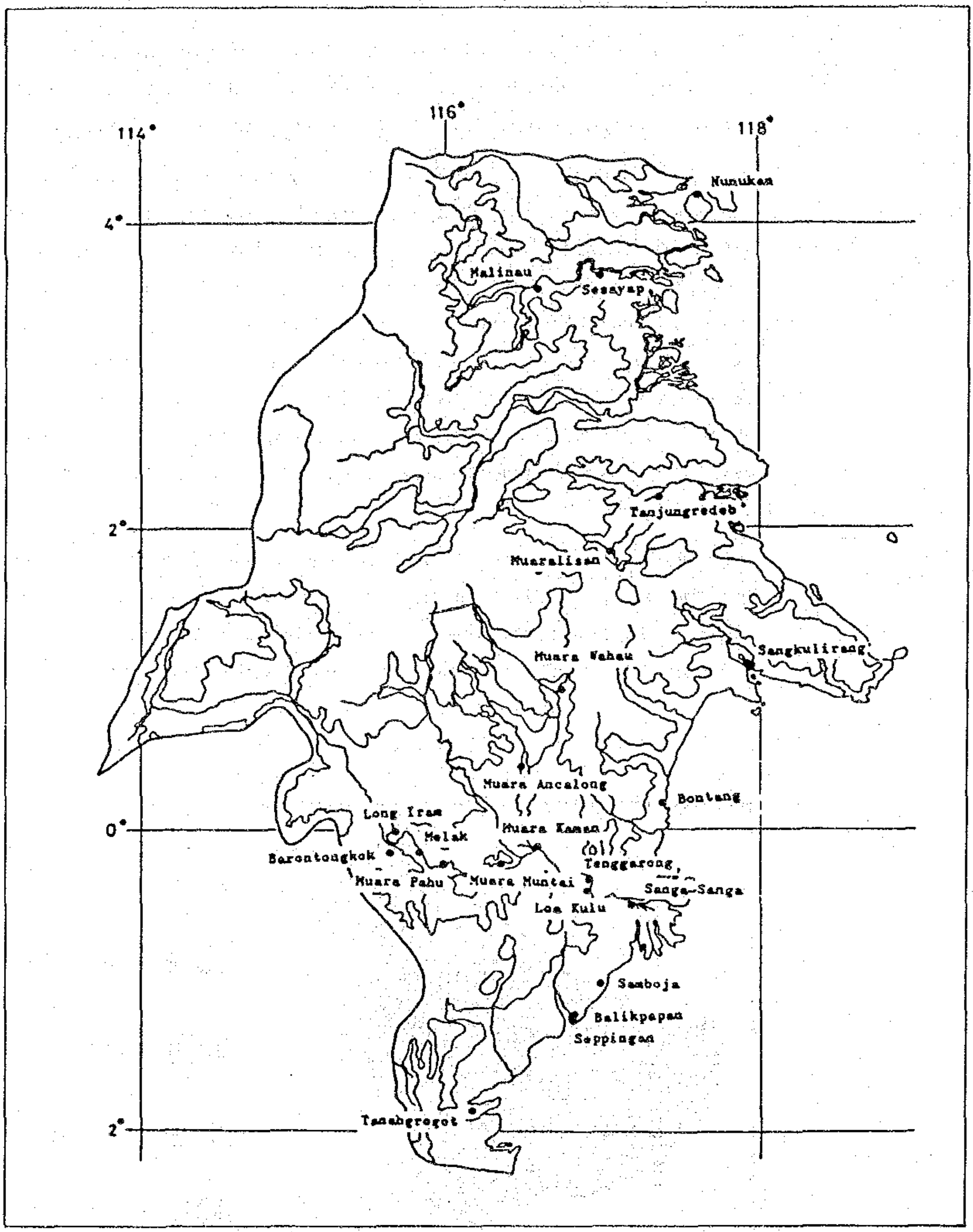


Fig. 6 Location of climate observation

i. Precipitation

° Annual Precipitation:

Table 2 shows the annual precipitation, etc. in East Kalimantan from 1971 through 1979 at 23 locations with less than four observation lacking years. Fig. 6 indicates the observation points.

The maximum annual precipitation is 4,660mm at Malinau and the minimum is 1,683 mm at Sungai Kunjang. Among 23 location there are three location which belong to much rain with the annual precipitation of over 3,000 mm shown by Fig. 6, while those have are relatively low annual precipitation below 2,000 mm are locating among 23 location. But regards the monthly average precipitation at these 8 points were always over 60 mm in the driest month (least rainy month) at each point, being the tropical rainfall forest climate (Af) according to Köppen's climatic classification[3].

Then whole districts of East Kalimantan are of this Af climate, but the district differences are much as to the annual precipitation. By the influence of topography such the distance from seashore, foot of a mountain, basin, humid inland zone, seashore hill, mouth of river zone, etc. the rainfall changes.

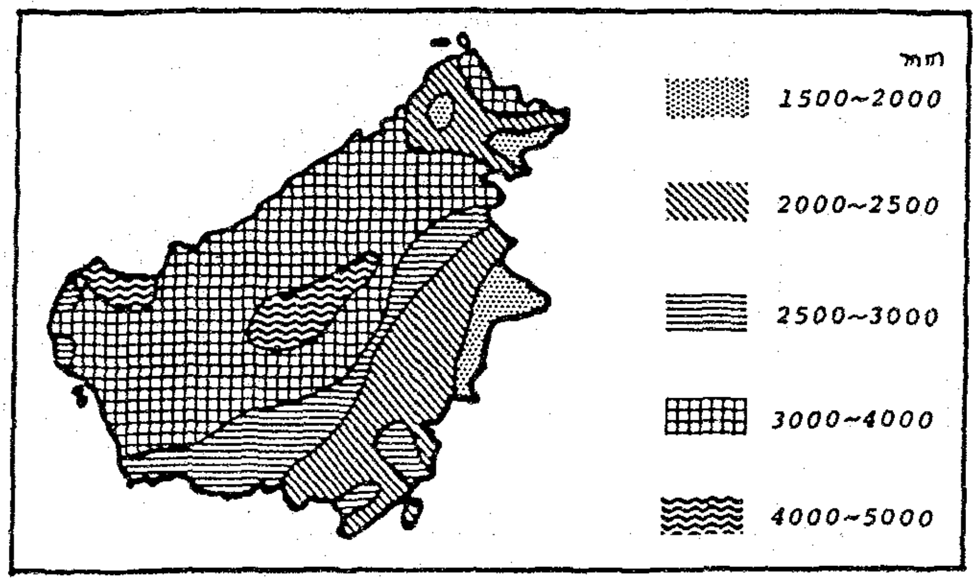


Fig. 7 Distribution of precipitation in Kalimantan

Fig. 7 is the distribution of precipitation in Kalimantan. This shows the above quite well, and to be concrete, the precipitation concretely shows the following order of seashore <hill <inland humid zone <basin foot of a mountain.

As regards the number of rainy days, at Sappinggan (Balikpapan Airport) is the largest, i.e., 173.3 days and the minimum number is 70.0 days at Muara Ancalong. Being affected by the topography the number of rainy days are over 140 days at Seppinggan and Balikpapan on the hill zone at Seashore and at Sesayap near seashore with a mountain (G. Sendang, 1,050 m) behind it. At the same seashore, however, the number of rainy days on the flat land and Tanahgrogot, Bontang and Nunukan creeks never reach 100 days. Even at the mouth zones of big rivers, there are large difference in the rainfall days owing to the difference in the circumferential topographies. At Tenggarong, the rainy days is 124.6 days, while at Loakulu, they are only 70.0 days. At the humid inland zone, each of 91.8 days at Muara Muntai and 70.0 days at Muara Ancalong is few, excluding 137.0 days at Muara Kaman.

° Mean Daily Rainfall:

To find mean daily rainfall, it is necessary to have the observation data of hourly rainfall, and if it is impossible to have such data, the mean daily rainfall can be estimated from mean daily rainfall is found by (annual rainfall/number of rainy day). According to this method, Barongtongkok 33.6 mm, Malinau 33.3 mm, etc. are relatively higher, whereas the mean daily rainfall at the seashore is lower. It does not reach 20 mm respectively at Sappingan, Balikpapan, Bontang, Tanjungredeb, etc.

° High Rainy Season and slight Rainy Season (Wet Season and Dry Season):

There is rainy season in an area that corresponds to the tropical rainfall forest climate (Af) according to the Köppen's climatic classification.

Also in East Kalimantan, wet season and dry season of twice a year are found at most locations as show when we see the histogram of the monthly rainfall. Fig. 8 precipitation of 13 locations in East Kalimantan and shows the high rainfall month over 200 mm per month based on data of the period of 1971 - 1979. It is the wet season throughout a year at Malinau where the annual rainfall is 4660 mm, and there is no distinct dry season.

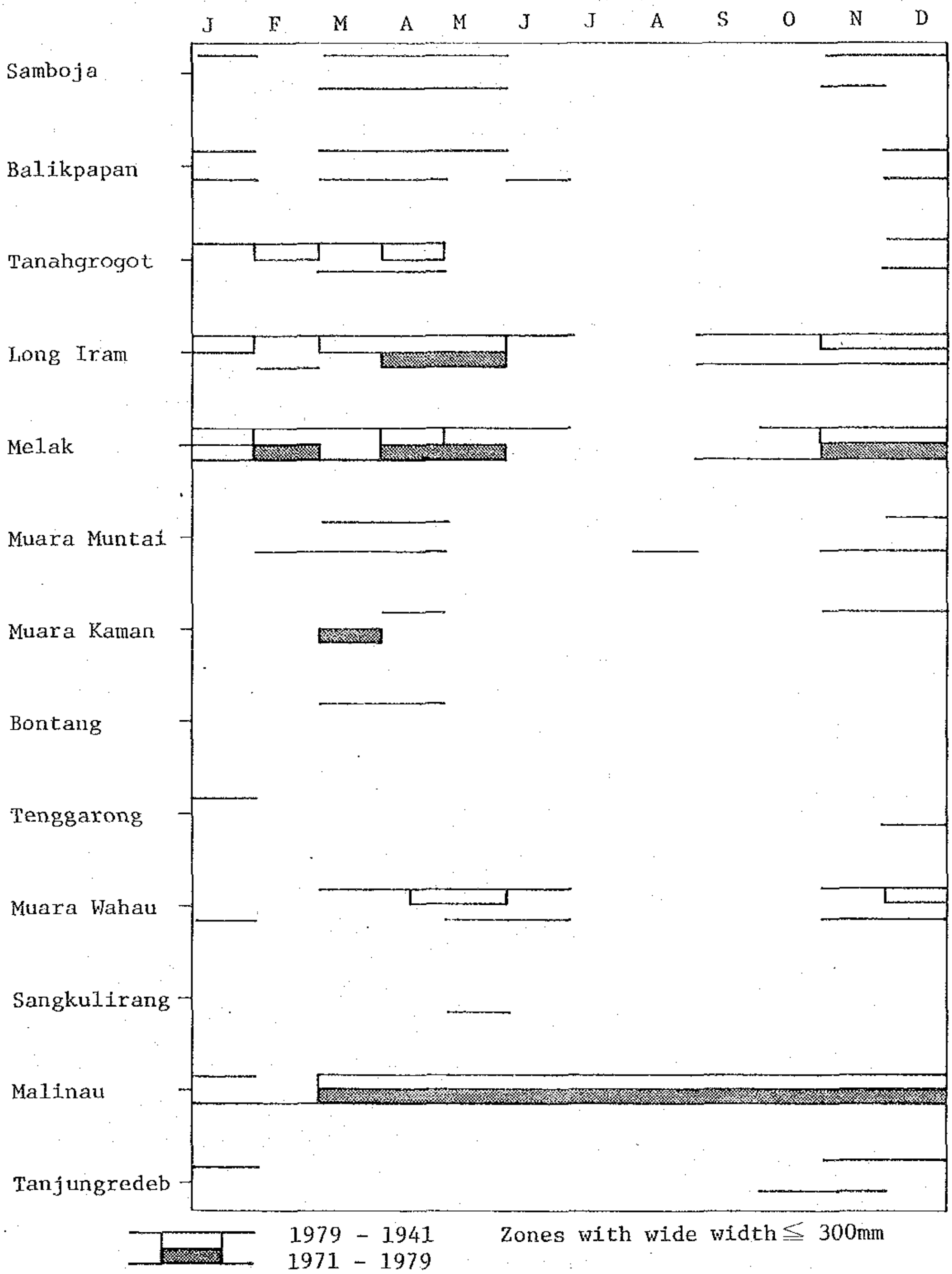


Fig. 8 Distribution of the wet season in East Kalimantan (≧200 mm)

At Bontang, however, the annual rainfall does not reach 2,000 mm, there may not be the wet season. At the other point once - three times wet season can be recognized. The reason why three times wet seasons appear per year is considered to be the cause that the statistical periods are short. Consequently, Fig. 9 shows the wet season also found with the same method from the data from 1879 - 1941. As a result there is the wet season of once or twice a year and three times thereof has not appeared.

The result of summing up the features of appearance of the wet season is as follows:

Once wet season
The clear dry month (monthly rainfall <200 mm) does not appear --- at Malinau
The wet month is once a year and very short --- Tenggarong

Twice wet season
The dry season appearas twice a year, i.e., in February and from July to October. The reason of dry season in February being short is that, as ITC moves northward in the summer of northern hemisphere, it does not move down southward in the southern hemisphere. It is indicated that in March ITC comes northward again to the neighbourhood of Kalimantan.

No wet season:
Even in the rainy season the monthly rainfall does not reach 200 mm --- at Bontang

Fig. 5, thick lines show the months with higher monthly rainfall increased as compared with the previous month and if the increase ratio was over 30% by finding the increase ratio with the formula of relative increase ratio of the rainfall by Minoru Yoshimura (1973).

$$Pr = \frac{Pn - Pn\text{-}1}{Pmax\text{-}Pmin} \times 100$$, where n shows month.

Yoshimura's formula:

Pmax: Rainfall of the wettest month
Pmin: Rainfall of the least wet month
Pr : Increase ratio of the rainfall

When entering the rainy season with the increase ratio of over 30% as Yoshimura mentions, the first entering in the rainy season is in February to April at many points in East Kalimantan. The second setting-in of the wet season is concentrated in October - December. Against this, it clearly appears that June - July are the dry season.

ii. Recent Climatic Fluctuation

East Kalimantan belongs to the Af climate, but fluctuation in its annual climate was not yet so far discussed. It is considered important for the agriculture in East Kalimantan which mostly in shifting cultivation. Table 3 shows heavy rain year (wet year) as W and slight rain year (dry year) as D of nine years from 1971 to 1979 in several points. Heavy or slight rain year of each point was estimated by mean rainfall of nine years, i.e., wet year in a certain location denotes over 120% of the mean rainfall value of nine years at that location and slight rainfall denotes under 80% of the mean rainfall value.

Though severe comparison cannot be made owing to many lacking measurement years, a general trend can be known. As there were only four locations in 1971, a secular change from 1972 to 1979 is noticed. The years of 1972 and 1973 were the slight rain or dry years, while years of 1975, 1976, 1977 and 1978 were the wet years.

As seen from the number of extraordinary slight rain point and heavy rain point, the years of 1972, 1973, 1974, 1977 and 1978 were those of large fluctuation.

There were 19 dry locations in 21 locations during 1972, and the extraordinary dry location appeared as much as seven points. The year of 1972 was that of the most extraordinary climate, and in Japan, its extensive location was attacked by the torrential rain in July.

In the world except China that suffered from drought owing to a dry season, even in the southeast Asian countries as India, Burma, Thailand, etc. had dry seasons owing to the late starting of monsoon. The granary areas of Soviet Union and Australia were also covered with large, high atmospheric pressure with long duration of fine weather and were attacked by a drought. Also in the Saheel

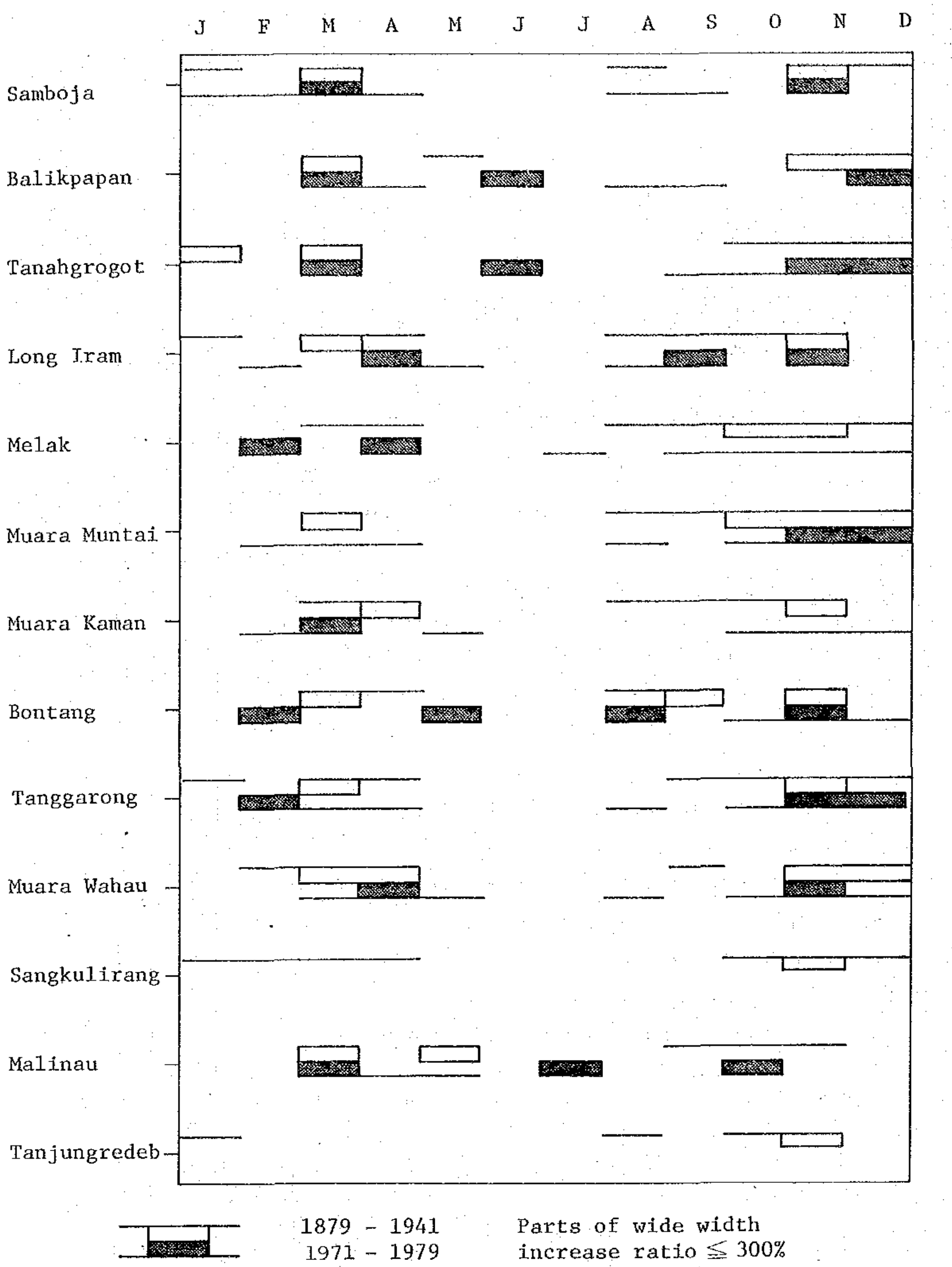


Fig. 9 Distribution of the rainy season (Increase ratio of rainfall in East Kalimantan)

Table 3 The secular change of the dry season at East Kalimantan

Location	"71	'72	'73	'74	'75	'76	'77	'78	'79	Number of years	Wet year	Dry year	Extraordinary years
Samboja	d	d	d	d	D	w	–	–	w	7	2(1)	5(1)	2
Tanahgrogot	–	D	W	D	d	–	w	w	–	6	3(1)	3(2)	3
Sappinggan	w	w	d	d	d	w	–	–	–	6	3(0)	3(0)	0
Sanga-Sanga	–	d	d	d	w	w	–	d	–	6	2(0)	4(0)	0
Balikpapan	–	–	w	d	w	–	D	w	W	6	4(1)	2(1)	2
Long Iram	–	d	d	d	d	D	–	w	W	7	2(1)	5(1)	2
Melak	–	d	w	d	–	d	w	w	w	7	4(0)	3(1)	1
Muara Pahu	–	D	w	–	w	w	D	w	W	7	5(2)	2(2)	4
Muara Muntai	d	d	d	W	w	d	d	w	d	9	3(1)	6(0)	1
Muara Kaman	–	d	d	d	W	w	–	–	–	5	2(1)	3(0)	1
Bontang	–	d	d	w	W	W	w	d	D	8	4(2)	4(2)	4
Tenggarong	–	d	D	W	w	w	W	–	D	7	4(2)	3(2)	4
Muara Ancalong	w	D	W	w	–	W	D	–	–	6	4(2)	2(2)	4
Muara Wahau	–	d	d	w	w	w	w	–	D	7	4(0)	3(1)	1
Muaralisan	–	D	D	W	–	–	W	d	–	5	2(2)	3(2)	4
Loa Kulu	–	w	W	–	w	D	–	w	d	6	4(1)	2(1)	2
Sangkulirang	–	d	d	w	w	d	–	d	–	6	2(0)	4(0)	0
Malinau	–	D	d	d	W	w	W	–	D	7	3(2)	4(2)	4
Sesayap	–	–	D	D	w	w	W	w	–	6	4(1)	2(2)	3
Tanjungredeb	–	d	d	W	w	d	w	–	w	7	4(1)	3(0)	1
Nunukan	–	d	d	w	w	d	w	w	w	8	5(0)	3(0)	0
Barongtongkok	–	D	d	D	–	–	D	W	W	6	2(2)	4(3)	5
Sungai Kunjang	–	d	d	w	d	w	d	d	–	7	2(0)	5(0)	0
Number of location	4	21	23	21	19	19	16	15	14				
Number of wet location	2(0)	2(0)	6(4)	10(4)	14(3)	12(3)	10(4)	10(1)	8(4)	74(23)			
Number of dry location	2(0)	19(7)	17(3)	11(3)	5(1)	7(2)	6(4)	5(0)	6(4)	75(24)			

Remarks: (1) The value in the normalyear as 100.0 D ≦ 80.0 W ≧ 120.0

(2) 80.0 < d < 100.0 100.0 < w < 120.0

(3) The value of ( ) os the number of wet locations and dry locations indicates the number of the extraordinary little rainy locations and extraordinary heavy rain location *D or W.*

Table 4 Climatic type in East Kalimantan

Location	'71	'72	'73	'74	'75	'76	'77	'78	'79	Number of years	Af	Am	Aw	Lacking number of years
Samboja	Af	Aw	Aw	Am	Af	Af	-	-	Af	7	4	1	2	2
Tanahgrogot	-	Aw	Am	Aw	Am	-	Aw	Af	-	6	1	2	3	3
Sappinggan (Meuc)	Af	Am	Am	Af	Af	Af	-	-	-	6	4	2	0	3
Sanga-Sanga	-	Am	Am	Am	Am	Af	-	Af	-	6	2	4	0	3
Balikpapan	-	-	Am	Af	Af	-	Aw	Af	Am	6	3	2	1	3
Long Iram	-	Af	Am	Am	Af	Am	-	Af	Af	7	4	3	0	2
Melak	-	Am	Am	Am	-	Af	Am	Af	Af	7	3	4	0	2
Muara Pahu	-	Aw	Af	-	Am	Af	Aw	Am	Am	7	2	3	2	2
Muara Muntai	Am	Aw	Am	Af	Af	Am	Am	Af	Af	9	4	4	1	0
Muara Kaman	-	Aw	Aw	Am	Af	Aw	-	-	-	5	1	1	3	4
Bontang	-	Aw	Aw	Af	Af	Am	Am	Aw	Af	8	3	2	3	1
Tenggarong	-	Aw	Aw	Am	Af	Am	Am	-	Aw	7	1	3	3	2
Muara Ancalong	Am	Aw	Am	Am	-	Am	Aw	-	-	6	0	4	2	3
Muara Wahau	-	Aw	Am	Af	Am	Am	Af	-	Aw	7	2	3	2	2
Muaralisan	-	Aw	Aw	Af	-	-	Af	Am	-	5	2	2	1	4
Loa Kulu	-	Af	Af	-	Af	Aw	-	Am	Am	6	3	2	1	3
Sangkulirang	-	Am	Am	Af	Af	Am	-	Aw	-	6	2	3	1	3
Malinau	-	Am	Af	Am	Af	Af	Af	-	Af	7	5	2	0	2
Sesayap	-	-	Af	Am	Af	Am	Af	Am	-	6	3	3	0	3
Tanjungredeb	-	Aw	Aw	Am	Af	Af	Am	-	Af	7	3	2	2	2
Nunukan	-	Aw	Aw	Am	Af	Aw	Am	Am	Am	8	1	4	3	1
Barongtongkok	-	Am	Af	Am	-	-	Af	Af	Af	6	4	2	0	3
Sungai Kunjang	-	Aw	Aw	Af	Am	Af	Aw	Am	-	7	2	2	3	2
Number of points	4	21	23	21	19	19	16	15	14					
Af	2	2	5	8	14	8	5	7	8	59				
Am	2	7	10	12	5	8	6	6	4	60				
Aw	0	12	8	1	0	3	5	2	2	33				
Number of location with lacking measurement	19	2	0	2	4	4	7	8	9	55				

district, the southern fringe of the Sahara Desert, North Africa, a drought continued. In this way, droughts occurred simultaneously at many points in 1972, causing to be the year when supply and demand of food in the world was even affected.

There were in 1979 rather more wet location than the dry location, but as much as eight points in 14 points showed the extraordinary value. It was the year when a drought occurred in India and that when, in America, there was a consecutive cold winter of three years.

According to th e most investigation in 1974 - 1977 by Tadashi Asakura (1981), the ratio of extraordinary heavy rain and extraordinary slight rain is 50:26, and extraordinary much rain emerged more, but such a trend was not found in East Kalimantan. Appearances of extraordinary value, according to the district, are found on many points that are located at inland zone or at the foot of mountains.

Table 4 shows the annual climate with types of climate based on Köppen's climatic classification method. The Köppen's climatic classification method has originally an object to divide by the mean value with a long duration of years, but it can be used in order to know a secular change of the annual climate. Each at the 23 locations in East Kalimantan is respectively Af by using mean value of 1971 - 1979, but if the annual climate is classified with the same method,

Af is only 38.8% of the whole, Am being 39.5% and Aw emerging as much as 21.7%. Firstly, when the secular change is observed into, 1972 is the year of slight rain year. Only two points among 21 points are Af and Aw appears as much as 12 points, while in 1975 of the wet year 14 points among 19 points were Af and Aw appears at no point.

As to differences according to area, over half of the statistical period had Af points that are the hilly zone along the coast of Malinau and Barongtongkok, etc., whereas points where Af does not utterly appear or only appear below 1/3 are Muara Ancalong, Muarakaman, Muara Wahau, Muara Pahu, etc. of the inland humid belt and Numukan on the seashore.

iii. Climates of recent and in the First 1900s

Table 5 shows that, on the 13 points which has recorded yearly rainfall of comparatively a long period (from 11 years to 41 years), the comparison was made with the recent (1971 - 1979) record. At seven points among 13 points, the rainfall decreased recently. The rainfall at 13 points fell from 2,341 mm to 2,247 mm later, showing a decrease of about 100 mm in the rainfall, i.e., a decrease of about 4%, whereas, as regards, rainy days (Fig. 10) and mean daily rainfall (Fig. 11) not only the quantitative change of rainfall, but also the qualitative change appeared remarkably. As to the number of rainfall days at 10 points among 13 points the number of rainy days decreased, and at Samboja and Tanahgrogot, etc. the number of rainy days decreased to about 2/3 of the former days.

The mean daily rainfall increased at the 11 point among the 13 point contrary to the above. To sum up the above features, the recent rainfall has a slight decreasing trend, and the number of rainy days decreased remarkably (decrease of 14%), while the mean daily rainfall seems increase.

Table 5. The annual precipitation in East Kalimantan

Location	Altitude	Period	I Number of years	Rainfall	Period	II Number of years	Rainfall
	m			mm			mm
Samboja	24.5	1928-41	13	2,347	1971-79	7	2,556
Tanahgrogot	±25	1917-41	24	2,325	1972-79	6	1,890
Long Iram	30	1900-41	41	3,463	1972-79	7	2,749
Melak	±20	1929-41	13	2,871	1972-79	7	3,291
Muara Muntai	±15	1910-41	26	1,833	1971-79	9	2,328
Muara Kaman	±3	1929-41	13	1,877	1872-76	5	1,869
Bontan	-	1929-41	11	1,874	1972-79	8	1,816
Tenggarong	0	1914-41	27	1,862	1972-79	7	1,903
Muara Ancalong	-	1922-41	19	2,218	1971-77	6	2,095
Muara Wahau	±40	1929-41	13	2,580	1972-79	7	2,276
Sangkulirang	-	1922-41	19	1,625	1972-78	6	1,836
Malinau	-	1922-41	19	3,543	1972-79	7	4,660
Tanjungredeb	±15	1908-41	29	2,015	1972-79	7	1,805
Average				2,341			2,247

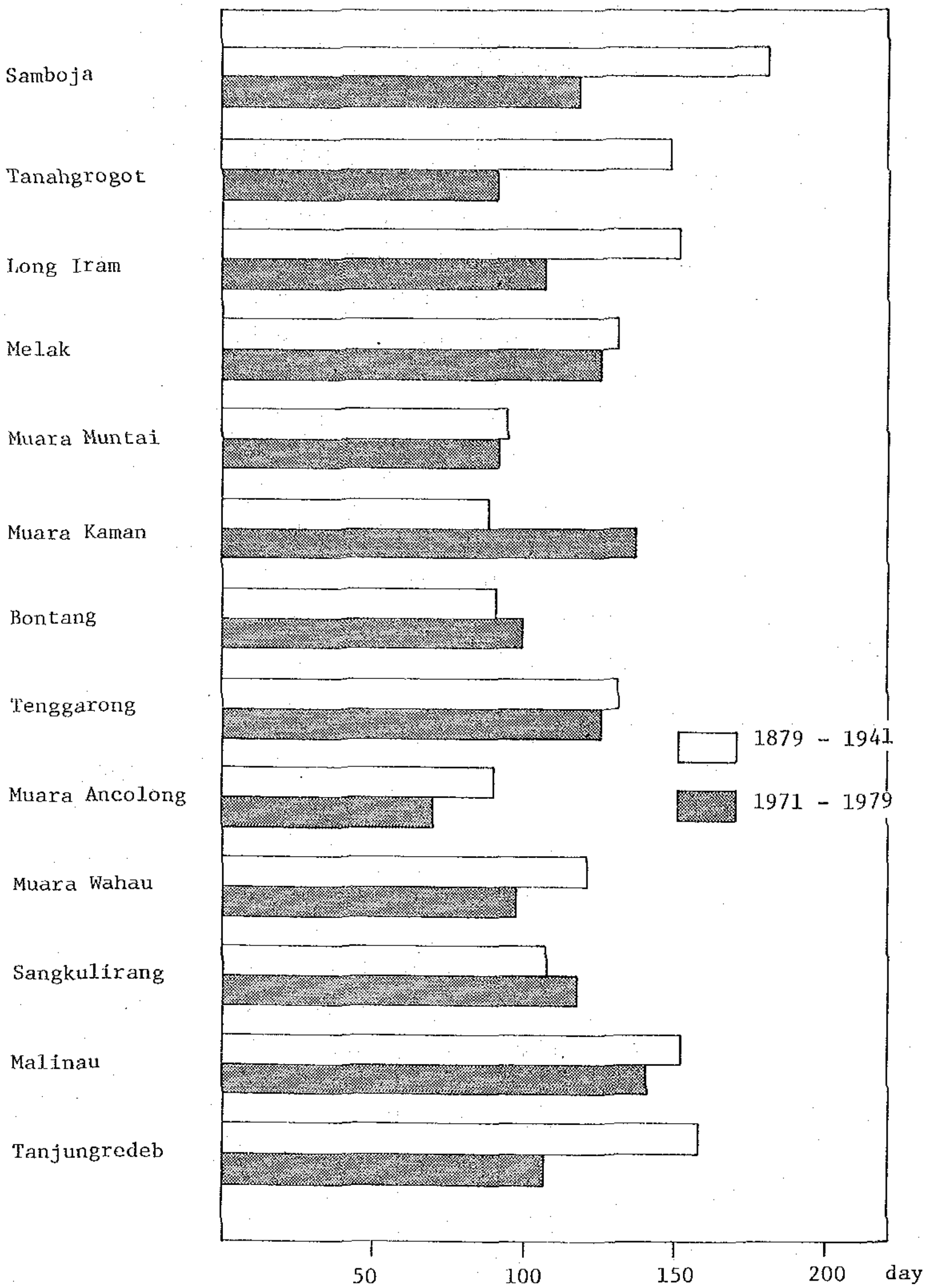


Fig. 10 Number of rainy days at East Kalimantan

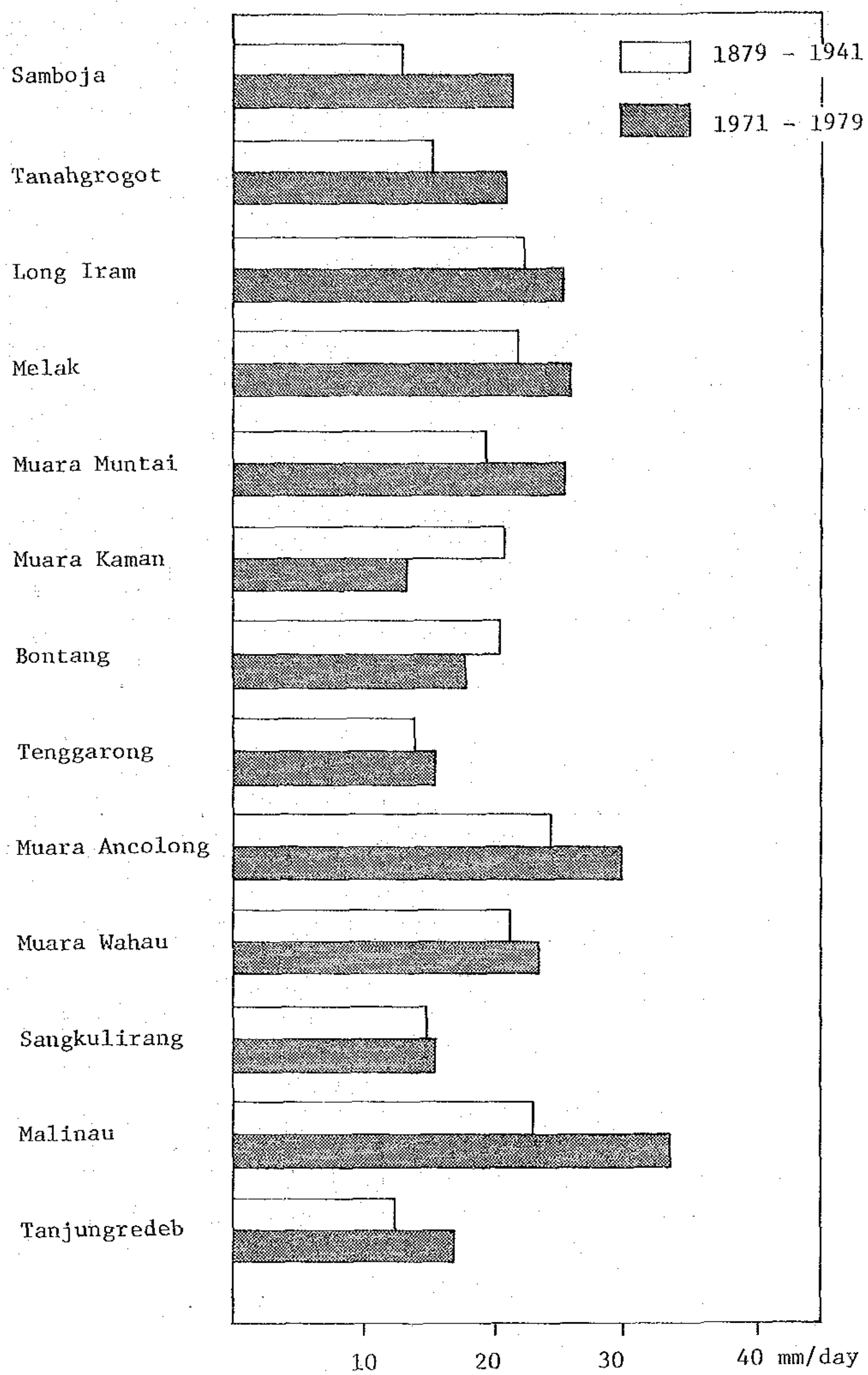


Fig. 11 The mean daily precipitation in East Kalimantan (mm/day)

Table 6 Classification of climate based on the wet and dry ratio in in East Kalimantan

Period / Location	Ann. Precipitation		Köppen's Type		No. of Dry Months <60mm		No. of Wet Months >100mm		Q		Schmidt's Type	
	I	II	I	II	I	II	I	II	I	II	I	II
	mm	mm										
Samboja	2,347	2,556	Af	Af	0.5	1.0	11.2	9.7	4.4	10.3	A	A
Tanahgrogot	2,325	1,890	Af	Af	0.9	2.2	9.1	8.5	9.8	25.5	A	B
Long Iram	3,463	2,749	Af	Af	0.3	1.2	11.1	10.0	2.7	12.0	A	A
Melak	2,871	3,291	Af	Af	0.9	0.7	9.7	10.7	9.2	6.5	A	A
Muara Muntai	1,833	2,328	Af	Af	1.6	1.4	8.8	9.3	18.1	15.4	B	B
Muara Kaman	1,877	1,869	Af	Af	1.9	1.6	8.3	8.8	22.8	18.2	B	B
Tenggarong	1,862	1,903	Af	Af	1.2	1.4	8.9	8.7	13.4	16.4	A	B
Muara Ancalong	2,218	2,095	Af	Af	1.3	2.0	9.0	8.5	14.4	23.5	B	B
Muara Wahau	2,580	2,276	Af	Af	1.1	1.1	9.6	9.4	11.4	12.1	A	A
Sangkulirang	1,625	1,836	Af	Af	1.4	1.0	8.4	9.2	16.6	10.9	B	A
Malinau	3,543	4,660	Af	Af	0.1	0.3	11.3	11.1	0.8	2.6	A	A
Tanjungredeb	2,015	1,805	Af	Af	1.0	0.9	9.5	8.0	10.5	10.7	A	A
Total	28,559	29,258			12.2	14.8	114.9	111.0	134.1	164.1		

Remarks: I = 1921-1940 II = 1971 - 1979

Table 6 is a result of study that Schmidt et al (1951) made on the Köppen's climate differentiation method and studied by the newly considered Wet and Dry Ratio method. Schmidt et al made the month with monthly rainfall less than 60 mm to be the Dry Month, and the month with rainfall more than 100 mm to be the Wet Month. The mean value of Dry Month and Wet Month during the Period of research is found and the value expressed in ratio is "Q", i.e., Dry and Wet Ratio.

Schmidt et al classified the Q value further finely into A, B and C.

These respective values were divided to the I Period of 1921 - 1940 and the II Period of the recent 1971 - 1979, and the comparison was made. To sum up the result, the monthly rainfall at the 12 points of the II Period is more than that of the I Period, but only at the 6 points among 12 points, became wet recently. Recently, however, the dry month increased and the wet month decreased, i.e., the dry season is lengthened, and the wet month has a trend of getting shorter.

iv. Precipitation and Flood

As regards the relationship between the rainfall and flood, e.g., the confluent point of the Mahakam River that is the largest river in East Kalimantan and its tributaries that lie between Muara Kaman and Sebulu, it is said that the water level at the normal time is 6.7 m, the average dayly fluctuation is 5 - 15 cm in August - September, the water level goes up usually by 0.5 - 1.0 m in the very wet season, and with an interval of about three years, it rises to 1.5 - 3.0 m, and with an interval of 10 years, it rises to 4.0 - 5.0 m. Photo 1 shows the village which is on the natural levee of Muara Kaman. From stains on the wall surface of houses, it is presumed that, when the water level is extremely high, even the colony on the highest part of the natural levee is flooded by about 1 - 2 m.

Photo 1 Colony on the natural levee of Muara Kaman

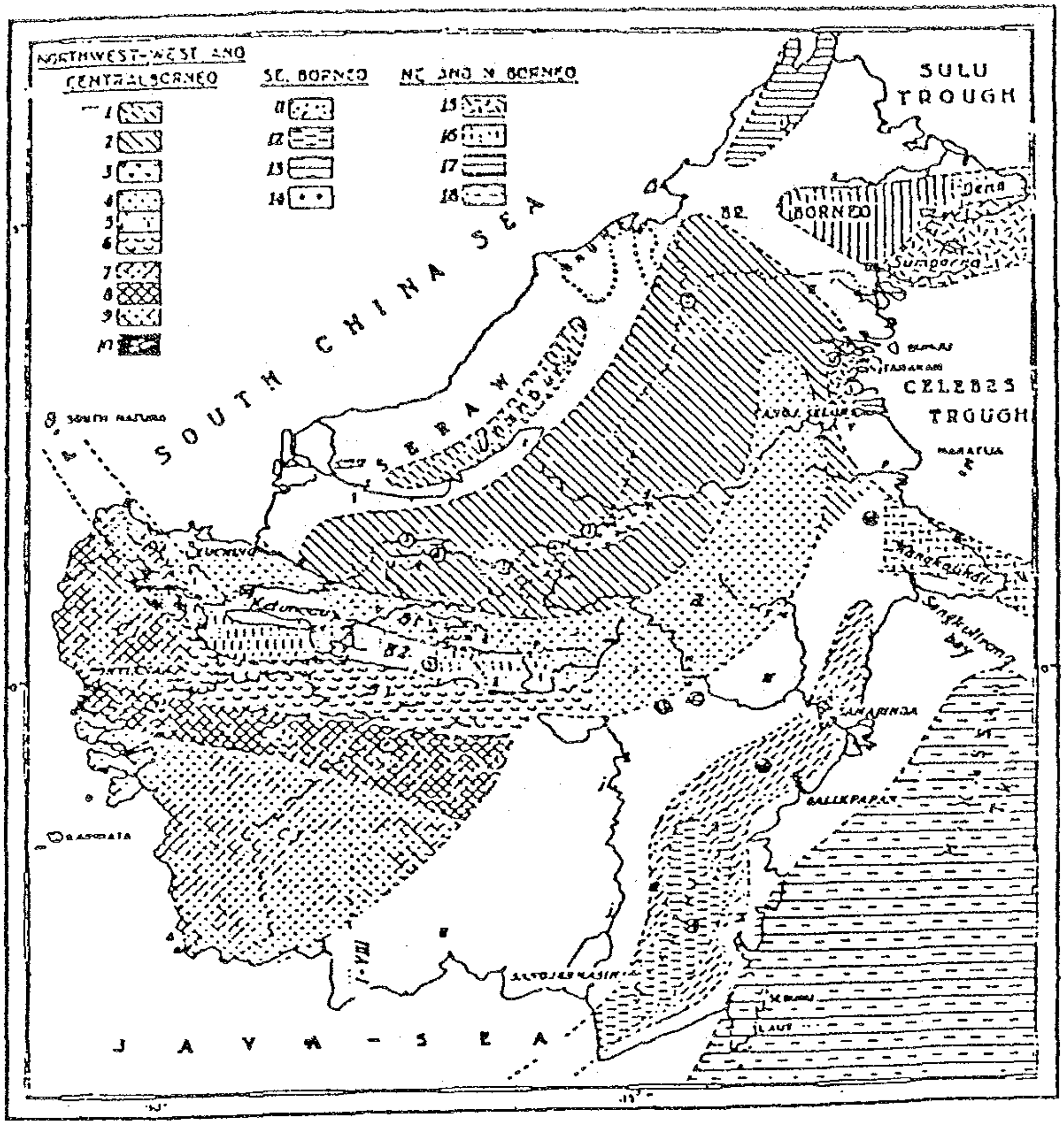
Further, the humid land behind the natural levee is the usually attacked zone to be flooded by water that flows up the natural levee, and as shown by Photo 2 of houses that are adjacent to the humid land, the water level of the humid plain seems to rise up to about 0.4 m below the floor. When the humid land is flooded, it occurs about two weeks before the water level starts lowering and the stagnant period is 1 - 2 months after the lowering started. In all of the former and the latter, the flood status continues for 2 - 3 months.

Photo 2 A house on natural levee and mud stains on the wall

(2) Geological Features

i. Structure of Geological structure

The geological structure of Kalimantan is concluded as the structural diagram (Fig. 12) by Van Bemmelen (1949)



Explanation of the signatures.

Northwest, West- and Central Borneo

1. Ularbulu ridge.
2. Embaluh Zone or Zone A.
3. Young volcanics of the Nieuwenhuis Mts and Apokajan.
4. Mandai Subzone = B_1 } Kuching Zone or Zone B
5. Semitau Median ridge = B_2
6. Melawi Subzone = B_3
7. North slope or Chinese Districts Area = C_1 } Basement complex or Zone C
8. Central Axis or Schwaner Zone = C_2
9. South slope or Ketapang Area = C_3
10. Quaternary basalts of Niut.

Southeast Borneo

11. Samarinda anticlinorium.
12. Meratus range.
13. Pulu Laut Area.
14. Suorescent volcanoes (Murai, Beluh).

Northeast and North Borneo

15. Young volcanic Sulu Zone.
16. End of the East Cordilleras of the Philippines.
17. End of the West Cordilleras of the Philippines.
18. Mangkalihat threshold.

Rivers

a. Sambas
k. Kapuas
l. Busang
m. Murung

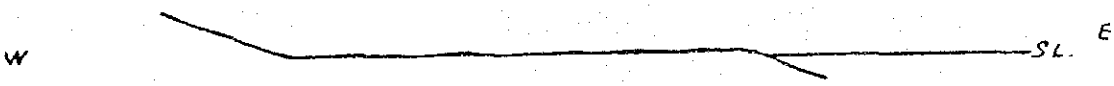
Fig. 12 Geological structure map of Kalimantan

When the basin of the Mahakam River is examined from this diagram, a large anticline is recognized near the seashore line, running parallel to the seashore line and from the north-northeast to the south-southwest and becomes the Samarinda anticlinorium that gathers a number of folds. Further, the western part of the present humid inland reaches the Mandai Subzone that is a part of the Kuching zone, and further, the central Borneo (central mountain area) at the up-river of the Mahakam River reaches the Embaluh belt.

Geological structure formation in the transition of ancient geography (geographical history) from the Tertiary to the Quatery period can be simplified as follows:

a. The End of the Cretaceous Period

Kalimantan became stabilized after the crustal movements at the end of the Cretaceous Period and is considered to be as in Fig. 13 by suffering the flattening (standardized) function with erosion.

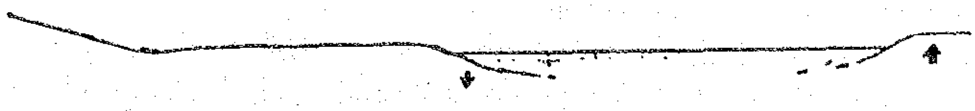


Comparatively flattened topography
by suffering the standardizing function

Fig. 13 The end of the Cretaceous Period

b. The First Half of the Lower Tertiary

On entering the tertiary, the Borneo Island became active in subsidance with transgression, witnessed in a wide extent. East Kalimantan with the north and the northwest parts of the Borneo Island is in the condition of the Idio geosynclinal state, i.e., being behind the geosynclinal belt and became an accumulated basin, generated after mountain-making movements. In this period, a thick stratum that covered the base unconformably and was mostly sea-generated was heaped with some degree of folding.



Subsidance were active with remarkable sinking in a wide sphere, activities of volcanos, and interpenetration of plutonic rocks.

Fig. 14 The first half of Lower Tertiary

c. The End o f the Lower Tertiary

The Kuching belt, that corresponds to the present central mountainous district and had a brisk upheaval, brought the magmas up to the surface of the earth by the internal force and gave rise to the volcanic activities. The volcanic nature, seen at present at the foot of mountain and highland, etc. in the upper basin of the Mahakam River is considered to be the heaped substance of volcanic nature such as erupted substances of volcanos which accumulated in this period. Most of the coal layers around the Meratus Mountain Range are the deposits in this period. The old Tertiary layer around the Meratus Mountain Range is rare with over 1,000 m of thickness of layer, but the thickness of layer increased in the north, reaching 2,600 m at South Kutai and 5,000 m at the Atan River.

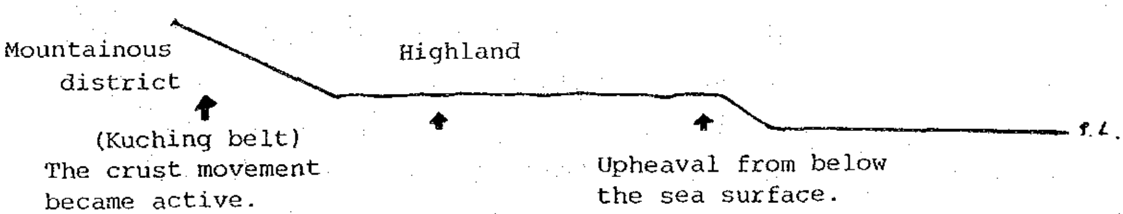


Fig. 15 The end of the first half of the Tertiary

In this period at the Kuching belt that is the geoanticline crustal movements, such as faulting movements and formation of troughs and others occurred actively. And also in the northeastern zone in the Borneo Island and in the northwestern zone of the Embaluh belt, various kinds of folds and fault movements much as folds, pushed-up faults, overthrust fault, etc. occurred actively.

d. The Upper Tertiary

This is the era when the Idio geosynclinal sinking movements continued and the transgression was observed. The new Tertiary layer is in the conforming relation with the upper old Tertiary and at South Kutai near the circumferential region of Pasir its thickness of layer amounts to 10,000 - 15,000 m, whereas the transition from the old Tertiary to the new Tertiary at North Kutai has features of heaped sedimentary substance of crude lime stone, brought about from the elevated zone.

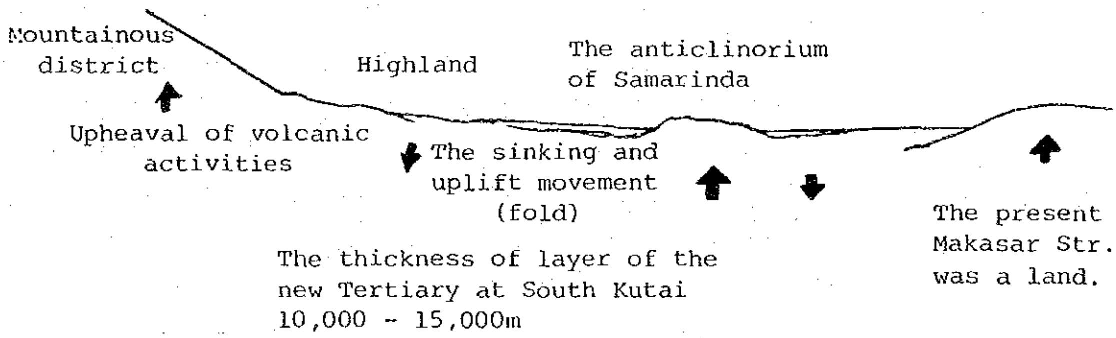


Fig. 16 The upper Tertiary

The upper zone of the Mahakam River in the eastern part of East Kalimantan corresponds to the elevated area that was the extension to the northeast from the Kuching belt, while its middle and lower zone corresponds to the settling down zone of the Idio geosynclinal zone, i.e., the back deep basin. Along with this sinking movement, prompt sedimentary function was taken place from the end of the old Tertiary, and the base of the present inland humid area was formed.

The lower new Tertiary that is distributed at the northern fringe of Lake District of Mahakam Basin and at the western border of the upper basin of the Barito River shows features of layer of volcanic nature. This indicates the fact that there were volcanic activities along with the geoanticlinal elevation early in the new Tertiary. The deepest part of the sunk area in East Kalimantan is located in East Kutai and West Pasir.

By the compression, followed by this sinking movement, on one hand, the Sumatra anticlinorium rose, causing the formation of hilly base, found near the mouth of the present Mahakam River.

With close observation, however, this uplift movement functioned strongly at the time of going inland from the seashore, causing to be an asymmetric anticline (e.g. Sanga-Sanga anticline is a good example.) when viewed closely the anticlinal structure.

The anticlinorium of Samarinda affected remarkably the formation of topography of the lower stream zone of the Mahakam River, assuming the shape of checking the Mahakam River and formed a large humid zone in the middle basin.

Whereas, the Makasar Str. that borders at present Kalimantan and Selawesi was located on a relatively high position at the end of the Tertiary, and it was the beginning of the 4th Period that the straight became the Makasar Trough as the present one.

e. The End of the Upper Tertiary

The characteristic event in this Period is that the Kinabalu Mountain Range, on the northern part of the Borneo Island, was upheaved from the geosyncline of the old Tertiary to become the present figure of the mountain.

Meanwhile, it was the era in East Kalimantan when rather plastic sedimentary substance of the new Tertiary heaped in a large quantity and caused to generate sinking in the deepest zone of the Idio geosynclinal basin, and to the east of it, parallel to the central axis of the basin the Meratus-Samarinda anticlinorium of the long folded belt was formed.

f. The 4th Period

Entering the 4th Period, the subsidance of the geosyncline was replaced by the elevating movement, the central axis of the anticlinorium was raised, and the central mountainous district was formed. The upheaval of the Meratus-Samarinda zone was most remarkable in the southern part of the Meratus Mountain Range, and already in the end of the Tertiary, the upheaval had begun to rise. Meanwhile, also in East Kalimantan, the Samarinda anticlinorium was meanderingly raised, the Peak of Balikpapan reached the height of 1,200 m above sea level, and the Mahakam River became, in the east, the preceding river that crosses the elevated anticlinorium.

In addition, by the elevation of this Meratus-Samarinda belt, the topographies of the eastern part of the present East Kalimantan, i.e., from the seashore to the inland zone, 1) seashore zone corresponding to the bendingly lowering area, 2) hilly zone corresponding to the Samarinda anticlinorium, and 3) the inland humid land, called as the Mahakam Lake District, were respectively formed.

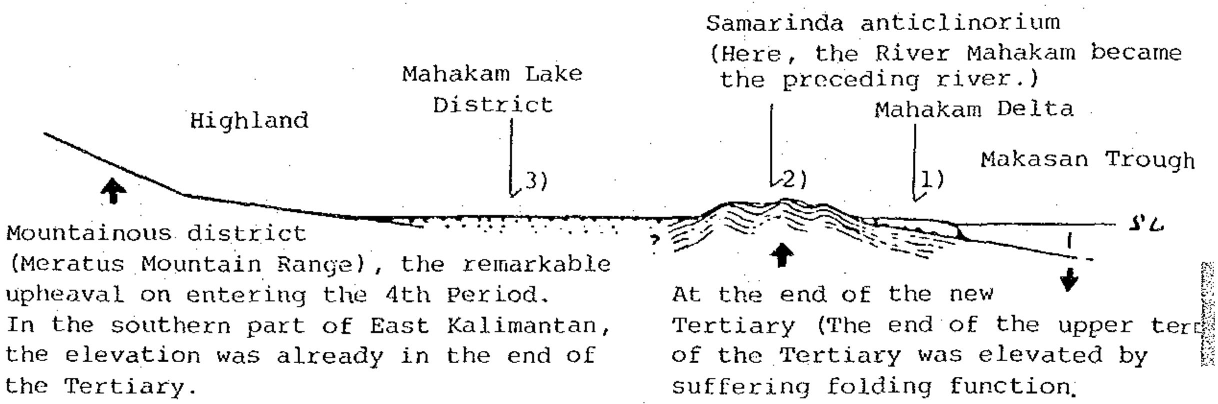


Fig. 17 The 4th Period

Meanwhile, in the east of the seashore district, the top of the Pulu Laut Dome of the new Tertiary was involved to form the Makasar Trough.

ii. The Relationship between the Geological Features and the Erosion by Rivers

The erosion by rivers effects, in relation to the geological features, the function, called as selective erosion and differential erosion. The first selective erosion is the function that eroses selectively such places of poor irresistibility as extension like the shape of lines or belts like a fault zone, forming valleys along them. The second differential erosion is the following topography: in the case where the adjacent areas are composed of rocks and layers that are remarkably different in the resisting power such as erosion and weathering,

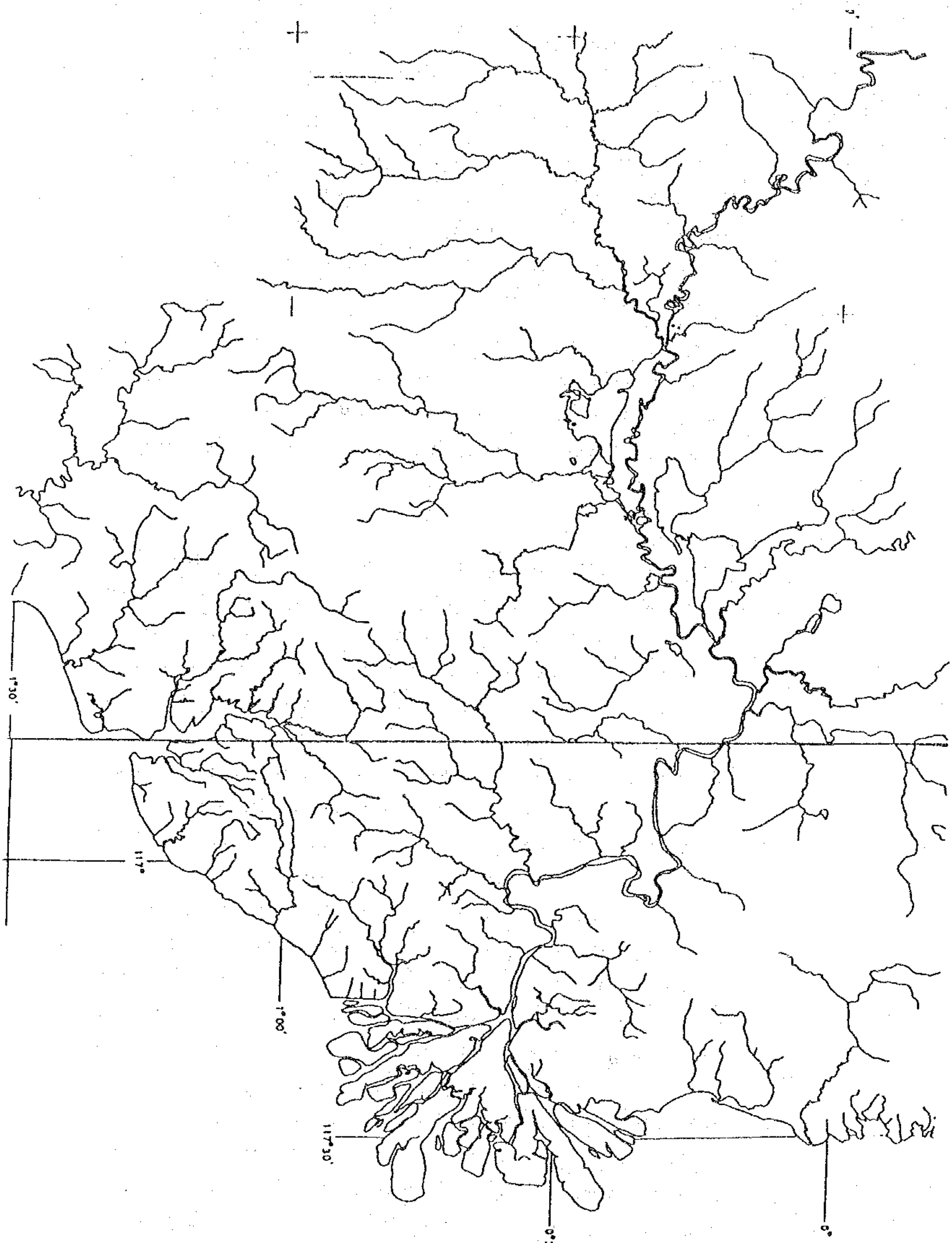


Fig. 18 Water system map

and as its reflection, one area is of further lower (low in height above the sea level) topography than the other. This topography is said to be formed by the different erosion.

East Kalimantan is the stable region with little crust change in the 4th Period, but in the Tertiary, as stated before, the change of folds were brisk, and from the end of the Tertiary to the 4th Period, hills that the Samarinda anticlinorium was up-heaved was formed at the lower zone of the Mahakam River.

As the hills that have the fold axes in the direction of this NNE-SSW are composed by such interrelated layers of sedimental rocks, which are differentiated by water permeability as sand-stone, marlstone, shale, slate, etc., the topography of in the form of Kesta, formed by the typical different erosion, have developed well.

The topography classified the direction of stream in the mutual relation with the slanting direction of the surface of the earth or in relation to the structure of geological features to the consequent stream, obsequent stream, subsequent stream and insequent stream. Then, with considering to know the influence of geological features for the topography formation of East Kalimantan, the water system map of East Kalimantan was made out of the topographical reduced map of one-five hundred thousandth (Fig. 18). When the water system map is considered, that which flows in the direction of the largest slant of the earth surface is the consequent stream, but the Mahakam River flows down, in a zigzag direction, the east slant surface of the Iban Mountain Range to the east or southeast as the consequent stream. When it reaches the foot of the hill with the slant becoming moderate, it flows to the N or NNE as an obsequent stream in the Mahakam Lake District, dammed up by the hill with the NNE-SSW directional fold axis and this hill. This is the largest humid zone in the middle stream of the Mahakam River. Thereafter, the Mahakam River changes its flowing way to the E - ESE, becomes a transverse valley, having a form of straight crossing of the hill of the Tertiary system to the fold axis, and enter the Makasar Str.

The hilly zone of the Tertiary system almost in parallel with the seashore line is the anticlinorium zone where a number of synclinal axes and anticlinal axes run in the direction of NNE-NE on the map of geological features, but the river flow is also reflected with this feature, and the development of subsequent stream that runs in the same direction with the fold axes is conspicuous.

iii. The Surface Bedrock

Seen from the old geographical and structure of geological features, the principal bedrock of the outer layer of East Kalimantan is the sedimentary rock of the alluvial epock of the inland basin, brought about from the igneous rock, concerned with the formation of mountain district of Meratus Mountain Range and others, and Idio geosyncline, uplifted from the sea bottom, sedimentary rocks of anticlinorium of Samarinda anticlinorium, upheaved in parallel with the seashore line.

When these bedrocks are finely divided with marks shown in the map of geological features, the result is as follows: The bedrocks of East Kalimantan, centered with the basin of the Mahakam River are mostly the sedimentary rocks.

In addition, the ages of generation of these rocks seem to be as Fig. 19.

1'	Qa	Alluvium	River and marine sediments, mud, clay, sand and gravels.
2'	Tpkb	Kampung Baru Beds (Fomation)	Quartz sand with limestone nodules and intercalated with young coal 1-3m thick.
3'	Tmbp	Balikpapan Beds (Fomation)	Quartz sandstone, clay and mud intercalated with coal 40-60cm thick, limestone 15-20 cm thick and thin layer of limestone.
4'	Tmw	Warukin Beds (Formation)	Quartz sandstone, loam and mud intercalated with limestone, coal and marl.
5'	Tmpb	Pulau Balang Beds (Formation)	Sandstone, schist and clay intercalated with limestone and coal, sometimes wood fossil.
6'	Tmbl	Babulu Beds (Fomation) Limestone families	Limestone contained higher foraminifera and gastropoda fossils. Lower part of limestone slightly clayed.

7'	Tml	Berai Beds (Fomation)	Massive limestone with high content of foraminifera fossil. At lower part found marl.
8'	Tmpm	Pamaluan Beds (Fomation)	Sandstone, clay and shist intercalated with limestone and marl contained foraminifera fossil and coal.
9'	Tmb	Berai Beds (Fomation)	Marl, loam and sandstone, Fossil was found in marl.
10'	Teotl	Tanjung Beds (Fomation) Limestone families (Complexes)	Slightly massive limestone, sometimes with high content of foraminifera fossil.
11'	Teotm	Tanjung Beds (Fomation) Marl families (complexes)	Marl intercalated with sandy clay and shist. Fossil was found sporadically.
12'	Teots	Tanjung Beds (Fomation) Sandstone families (complexes)	Sandstone slightly consolidated. Sometimes plant residues were found. (present)
13'	pTl	Limestone	Limestone, grey, red color, massive and crystalline.
14'	pTs	Consolidated sedimentary rocks	Consolidated sandstone, claystone, limestone, conglomerates composed of sandstone, limestone, claystone and volcanic rocks.
15'	pTv	Old volcanic rocks	Propylitized andesite laves and volcanic breccias components of andesite and propylitized basalt, compact.
16'	op	Ophiolite	Ophiolite group composed of ultorabasic and basic rocks. Ultorobasic rocks consists of (derived from) harzburgitte, wehrlite, pyraxenite, dunite and serpentinite.
17'	di	Diorite	
18'	gr	Granite	
19'	ToTs	Telake Beds (Fomation)	Loam and quartz sandy rock penetrated by coal and limestone.
20'	ToTm	Telake Beds (Fomation)	Marl.
21'	Tmv		Basalt and Agglomerate

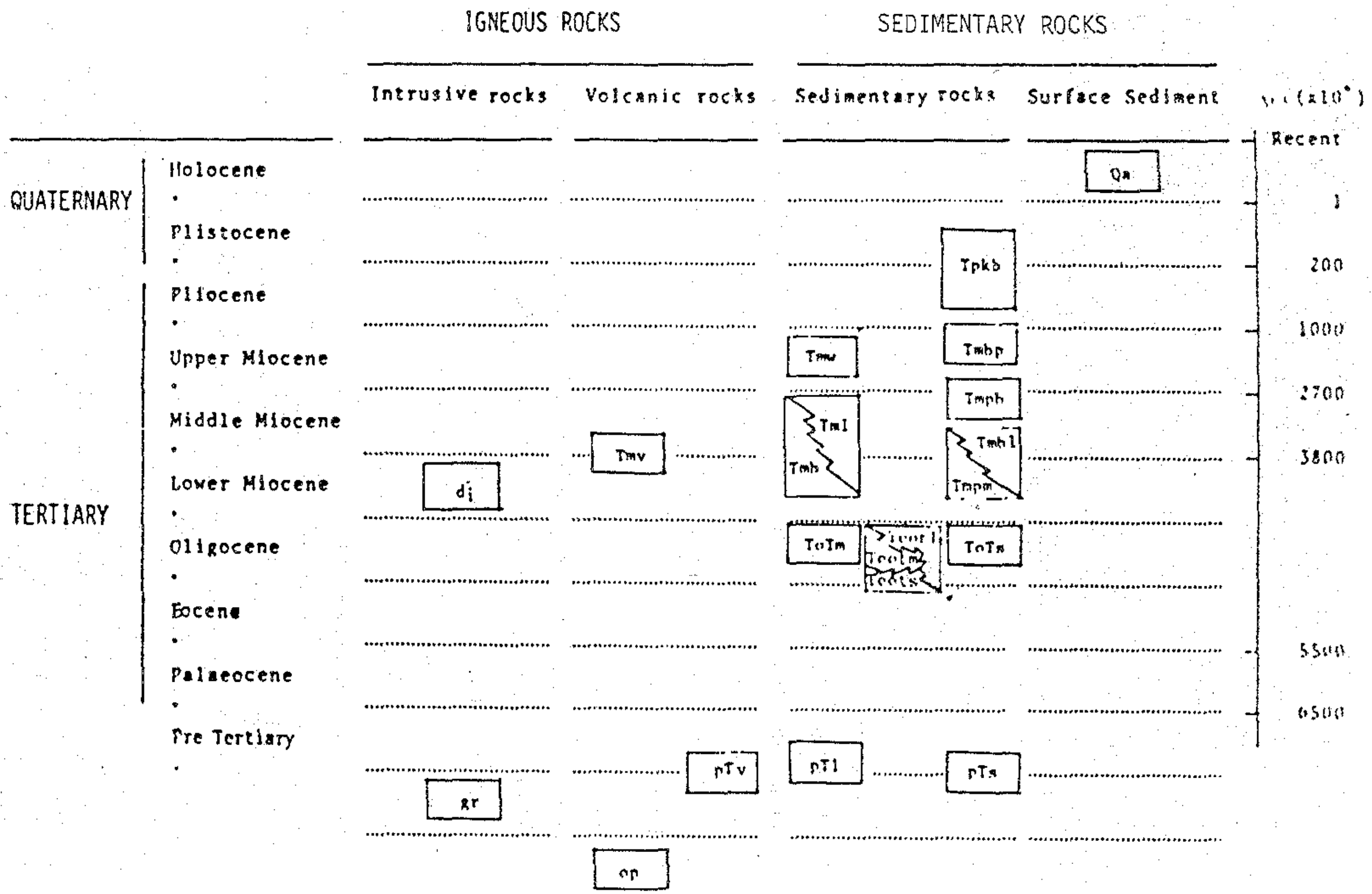


Fig. 19 Generative era of rocks and the like