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No. 208

THE REPUBLIC OF KENYA

LAND USE MAPPING

(TOPOGRAPHIC MAPPING PROJECT)

IN

THE REPUBLIC OF KENYA

FINAL REPORT

MARCH 2004

JAPAN INTERNATIONAL COOPERATION AGENCY

THE REPUBLIC OF KENYA

LAND USE MAPPING

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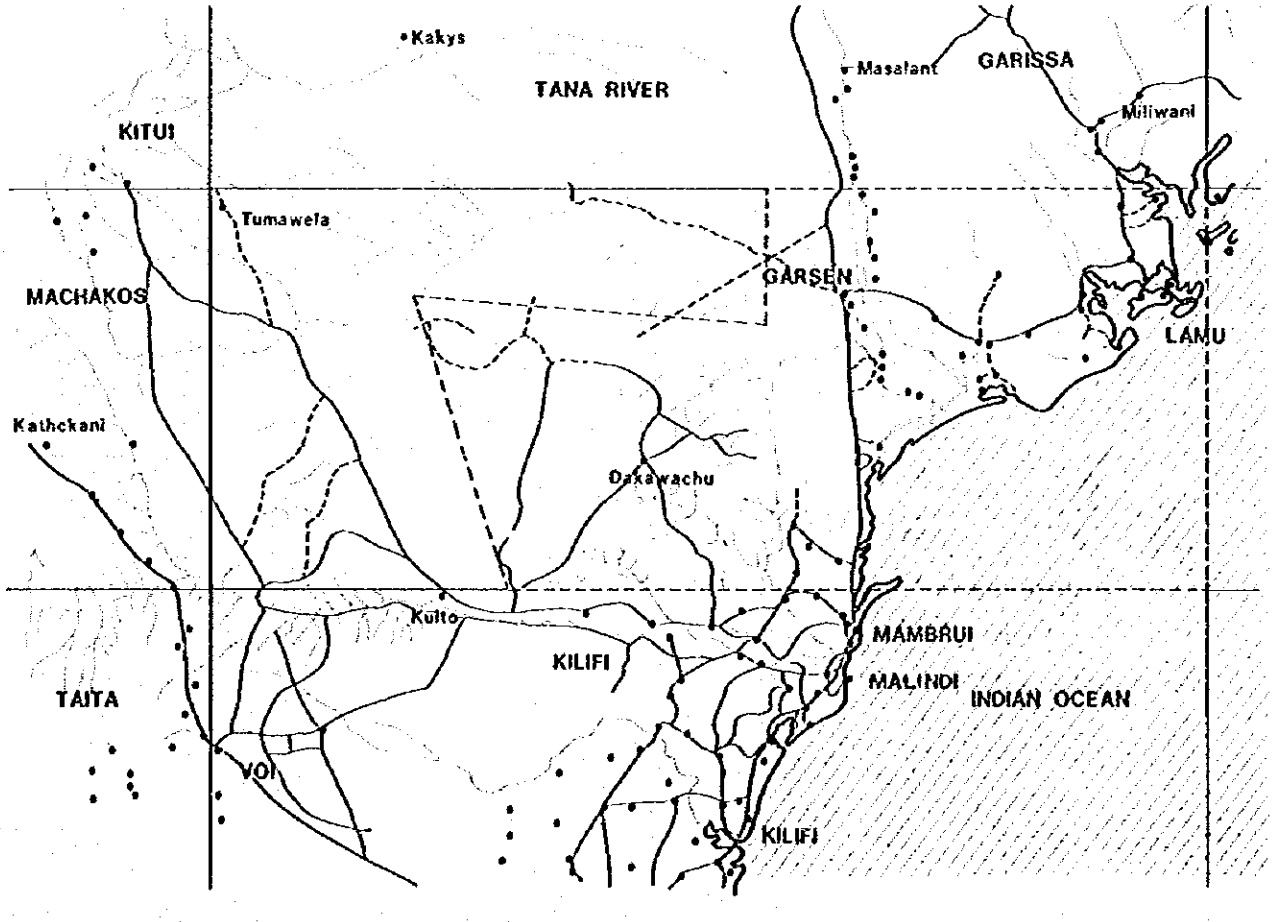
Location Map of Project Area



Road Sea and River Project area

PREFACE

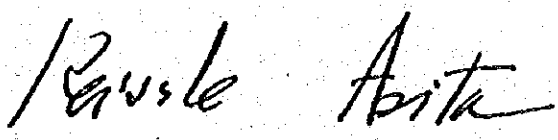
In response to the request of the Government of the Republic of Kenya, the Japanese Government decided to conduct a survey on the Land Use Mapping (coverage: approximately 14,700 km²) Project in East Kenya and entrusted the survey to the Japan International Cooperation Agency (JICA). The JICA sent to Kenya several times a survey team headed by Mr. Eiji Gojo from August 1981 to November 1983.

The team exchanged views with the officials concerned of the Government of Kenya on legend of thematic maps and conducted a field survey in the Project Area. After the team returned to Japan, further studies were made and the present report and maps have been prepared.

I hope that this report and maps will serve as a basic reference for the development of the Project Area and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Kenya, particularly those of the Survey of Kenya, for their close cooperation extended to the team.

March 1984

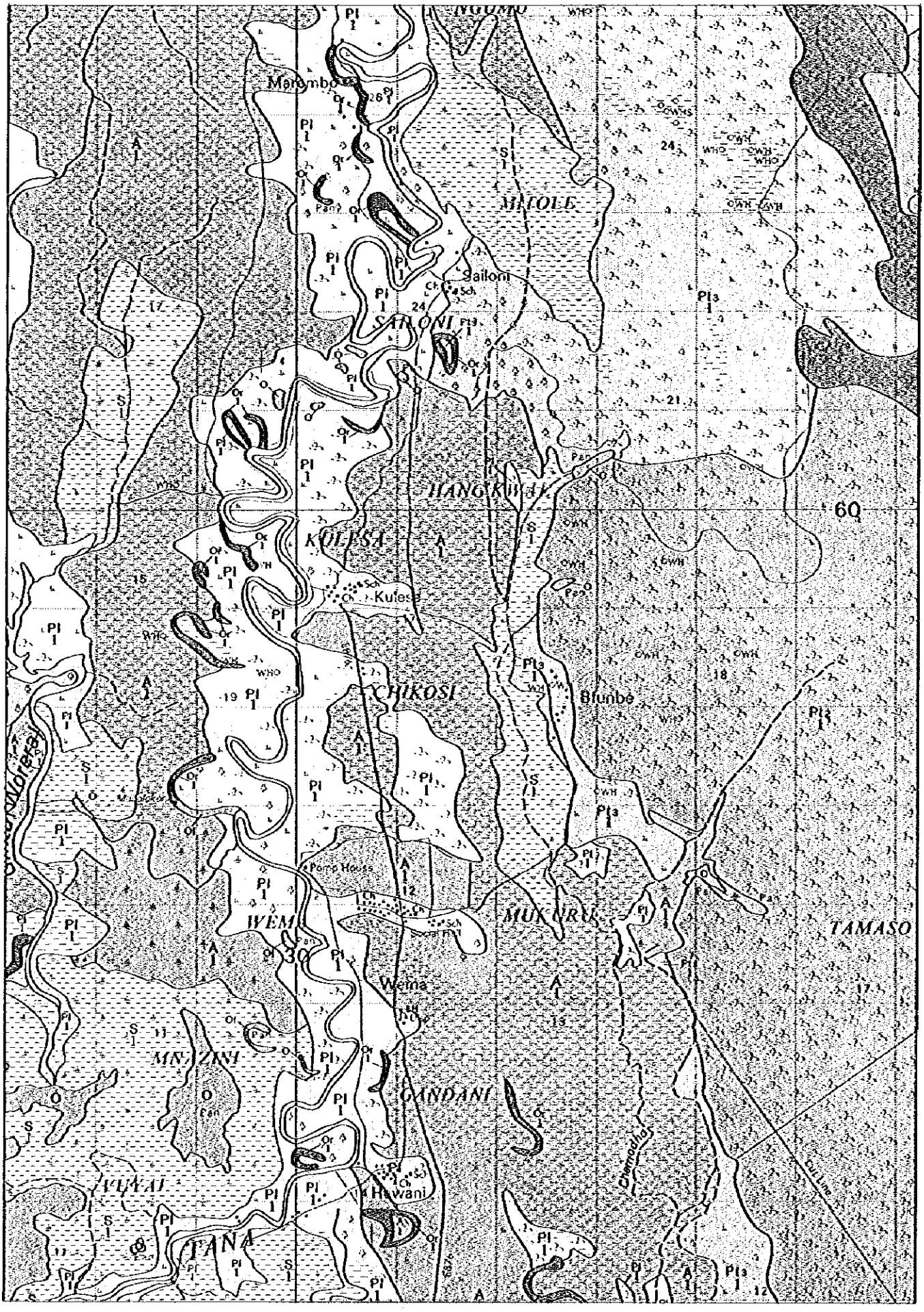


Keisuke Arita
President
Japan International Cooperation Agency

LANDFORM, SLOPE AND DRAINAGE MAP

WEMA

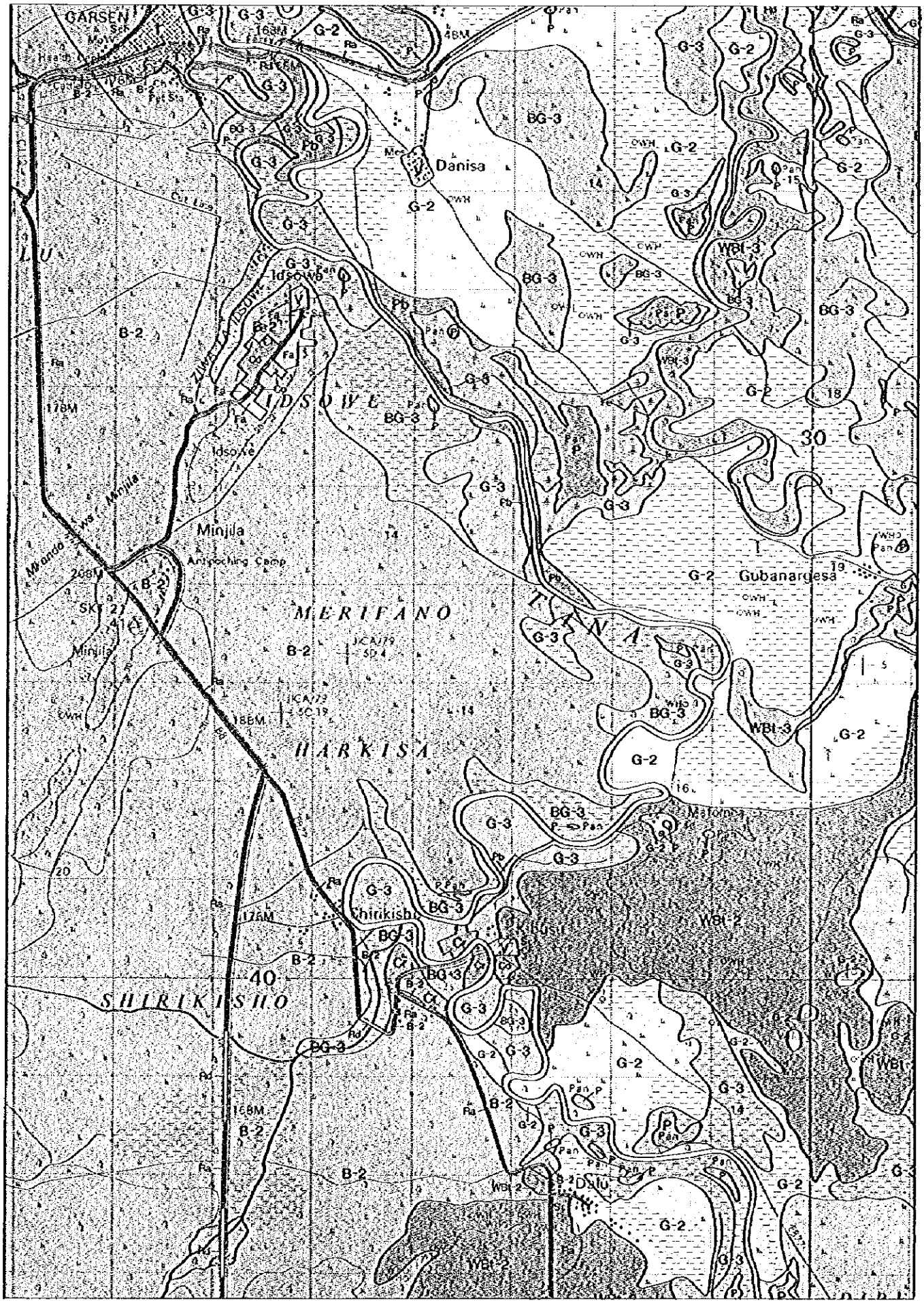
KENYA 1 : 50, 000



VEGETATION AND PRESENT LAND USE MAP

GARSEN

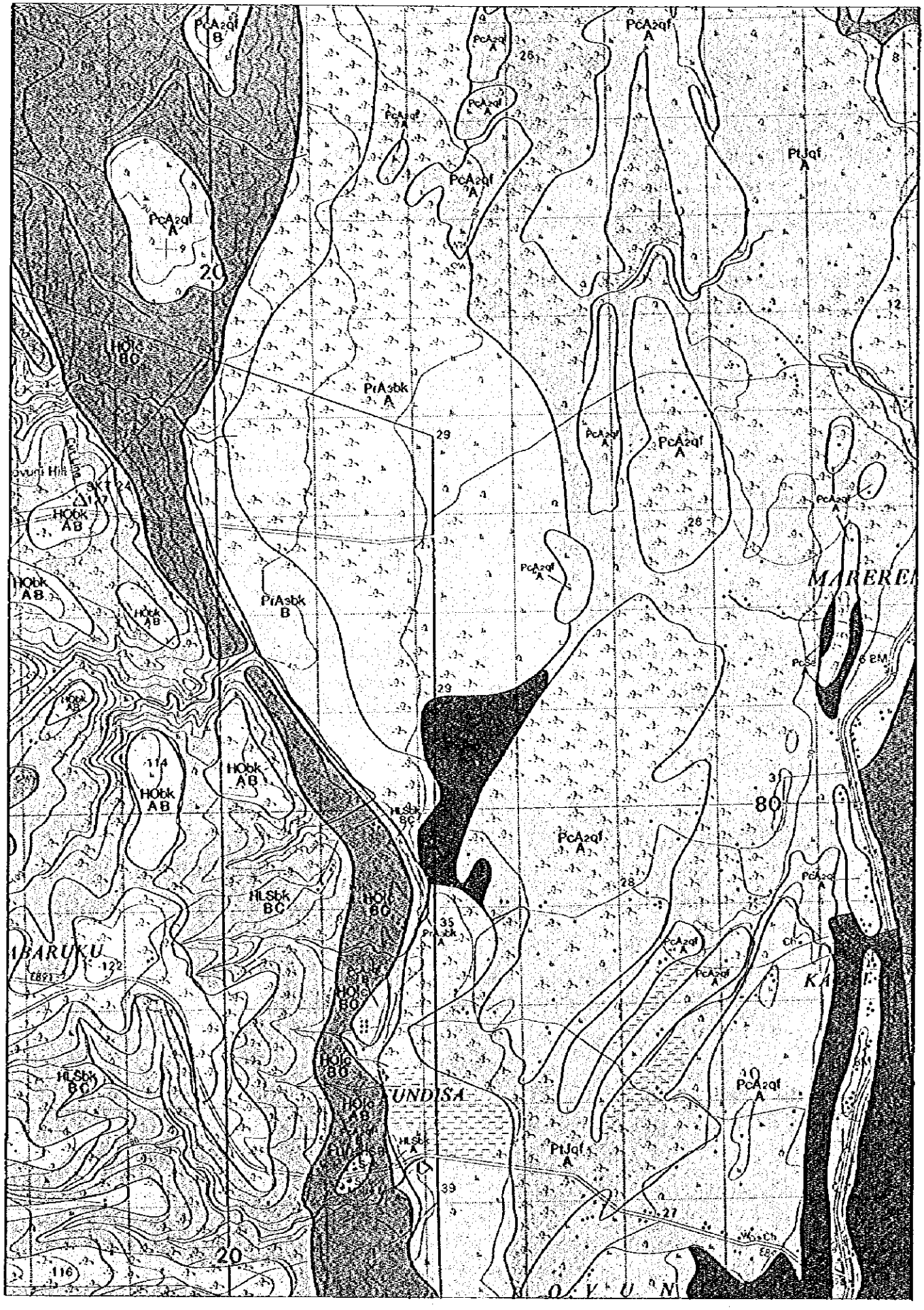
KENYA 1 : 50,000



SURFACE GEOLOGY AND SOIL MAP

FUNDISA

KENYA 1 : 50,000



FOREWORD

The Land Use Mapping Project in East Kenya was started in 1981 as a three year project and completed in March 1984. This project was undertaken following the completion of the Topographic Mapping Project conducted as a Japanese Government Technical Cooperation program taking six years from 1975 to 1981.

The purpose of this project was to produce 1/50,000 and 1/100,000 scale thematic maps and as one application of these maps to evaluate the land. The maps produced are as follows. (Refer to Fig. 1.)

Thematic Maps:

Tana River Delta Area –

Vegetation and Present Land Use Map	1/50,000	12 sheets
Landform, Slope and Drainage Map	1/50,000	12 sheets
Surface Geology and Soil Map	1/50,000	12 sheets

Ranching Project Area –

Vegetation and Present Land Use Map	1/100,000	4 sheets
Landform and Drainage Map	1/100,000	4 sheets

Land Evaluation Maps:

Tana River Delta Area –

Evaluation Map of Hazard of Soil Erosion	1/100,000	3 sheets
Suitability Map for Rainfed Agriculture	1/100,000	3 sheets
Suitability Map for Irrigated Agriculture	1/100,000	3 sheets

Ranching Project Area –

Current Suitability Map for Ranching	1/100,000	4 sheets
Potential Suitability Map for Ranching	1/100,000	4 sheets

This report describes the objectives, implementation procedure and methodology, study results, and utilization of the products. It is sincerely hoped that these products will find meaningful use as basic information for various development programs in East Kenya.

Sincere appreciation is expressed to the officials of the Survey of Kenya, the Kenya Soil Survey, the Tana and Athi Rivers Development Authority, the Kenya Rangeland Ecological Monitoring Unit and other Kenyan government agencies who kindly provided assistance and cooperation for the survey work.

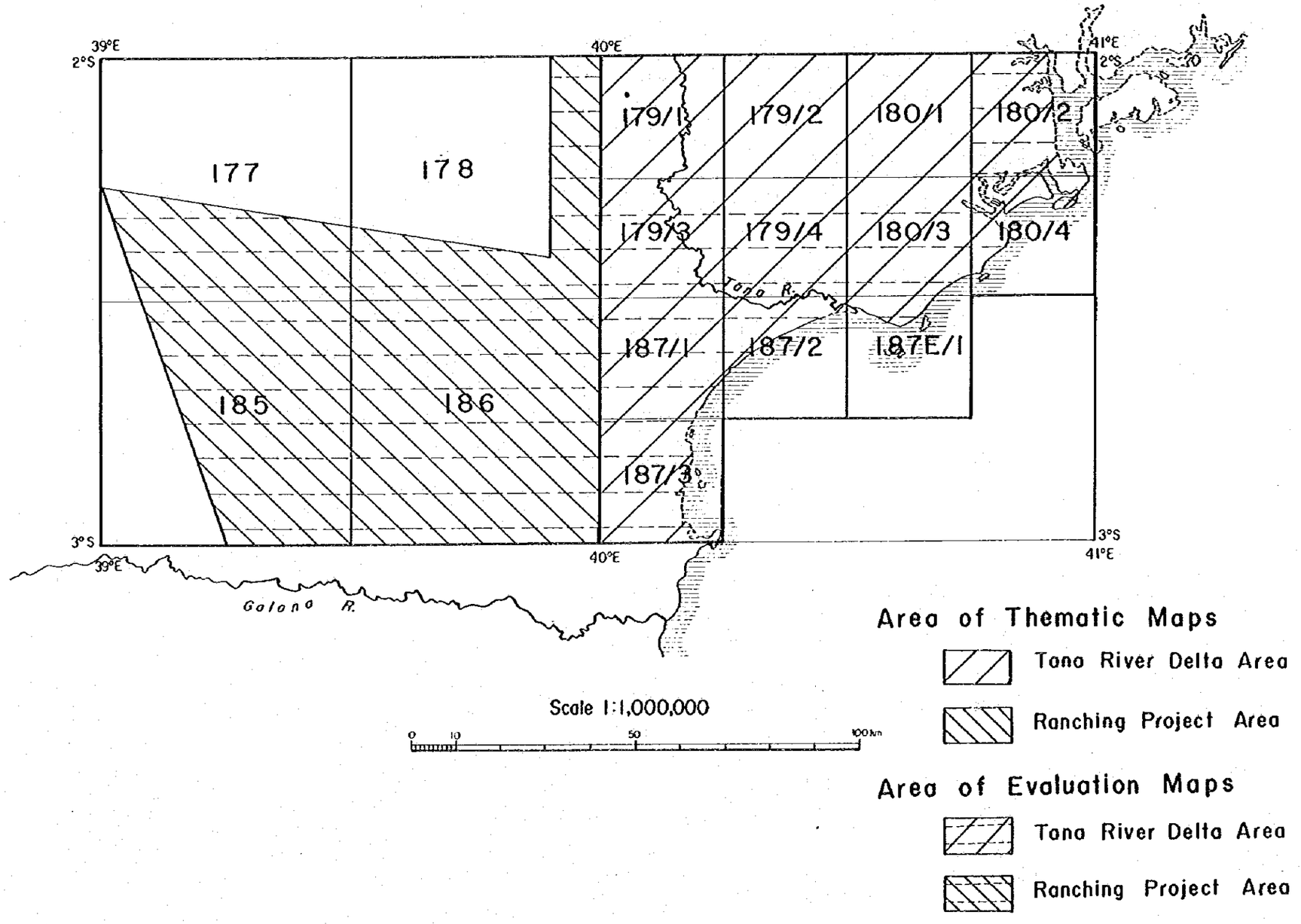


Fig. 1 Map index

REPORT ON LAND USE MAPPING (TOPOGRAPHIC MAPPING PROJECT) IN EAST KENYA

Contents

SUMMARY

SUMMARY

This was a project to survey with respect to East Kenya such basic elements of the land as vegetation, present land use, landform, surface geology, soil, and to produce thematic maps on the basis of the topographic maps which had been previously prepared. The survey results and the thematic maps thus developed were then studied for their applications, and as an example of such applications, land evaluation was made from them.

East Kenya as covered by this survey is divided into two areas along the 40° east longitude according to the objectives of major development plans, namely, the Tana River Delta Area (approx. 6,950 km^2) on the east (Indian Ocean side) where irrigated agriculture development is envisioned and the Ranching Project Area (approx. 7,700 km^2) on the west (Inland side) for which ranching is planned to be promoted.

As thematic maps, with respect to the Tana River Delta Area, Vegetation and Present Land Use Map, Landform, Slope and Drainage Map, and Surface Geology and Soil Map were prepared at 1/50,000 in scale, while for the Ranching Project Area, the Vegetation and Present Land Use Map and the Landform and Drainage Map, both 1/100,000 in scale, were produced.

The land evaluation dealt with the following subjects: soil erosion resistance, rainfed agriculture suitability, and irrigated agriculture suitability for the Tana River Delta Area (4,640 km^2 excluding a northern portion) and ranching suitability for the Ranching Project Area.

The results of this survey are summarized below.

(1) The Tana River Delta Area consists of natural levees running along the river and extensive flood plain spreading beyond these levees.

The natural levees are micro reliefs formed by sandy sediments and moderately well in drainage thus allowing Garsen and many other settlements to be located in this area. While there are observed banana plantations and small scale paddy fields and farms, the area is mostly Bushland, Bushed grassland or Wooded bushland. The area is considered suitable for small scale irrigation.

The flood plain is comprised by low and wet Grassland or Bushed grassland with relatively fertile soils to make the area suitable for large scale irrigation development.

(2) The area to the east of the Tana River Delta is of nearly flat or undulating terraces with Wooded bushland and Forest as vegetation with the former being dominant as forests have been reduced to Wooded bushland over years of cutting for timber and charcoal. The southern part of the area has an annual rainfall of 1,000 mm – 1,200 mm, the highest level of rainfall in the entire study area.

Plantations of coconuts, mangos, cashew nuts as well as large settlements are observed. The area contains relatively large settlements such as Witu and Mokewe. Lamu on Lamu Island to the east is an Arabic style town serving as a tourist place.

The area is relatively well conditioned for rainfed agriculture but there is the possibility of drought when there is not enough rainfall during the rainy season (April–June) thus necessitating development of irrigation even on a small scale.

(3) In the terrace area extending from west of the Tana River Delta to south, the land is flat with strongly calcareous and highly sodic soils distributing widely and vegetation being mainly Bushland. Settlements and cultivation are least developed except in the southern part and potentiality for agricultural development appears to be low.

(4) In the coastal area to the east of the Tana River Delta, dunes are developed continuously and swamps of poor drainage are formed behind them. Over the tidal flats of this area are mangroves and Grassland. The area to the south is used for sun-dry salt fields.

(5) The Fundisa Hill Area located in the southern central part of the survey area has gentle undulations at elevations ranging 100 m – 150 m. The land is of Tertiary limestones, calcareous sandstones and sandy clays covered mainly by forests. Soils originated from sandy clay among other types show good physical properties to make areas with such soils good for farming and ranching as actually done. Settlements including Fundisa are well developed.

(6) The area west of Fundisa Hill is an extensive plain formed on Triassic and Jurassic sandstones, ranging in elevation from 150 m to 200 m. The western half of the area is a flat peneplain whereas the southern and eastern parts are dissected by dendritic valleys forming gentle reliefs with plateaus, uplands and dissected peneplains.

The annual rainfall amounts to only 200 mm – 600 mm. Bushed grasland is a dominant vegetation. The valley bottom lowlands, which are flooded only during the rainy season, are

calcareous and poorly drained. By better utilization of water with bore holes and dams, ranching can be further promoted in the area.

(7) The results of the land suitability evaluation for the Tana River Delta Area (covering 4,640 km^2 excluding a northern portion) are as follows.

The area is generally free from soil erosion except there are some places with weak resistance to erosion classified under "Slight resistance" located on the slopes of dunes.

With respect to the rainfed agriculture suitability, which depends on climate and soil conditions, "Marginally suitable" places account for about 80% whereas "Unsuitable" places about 17%.

In terms of the irrigation suitability, most of the area has been found as "Unsuitable". "Moderately suitable" and "Marginally suitable" places combinedly represents less than 30% of the area.

(8) The results of the Ranching suitability evaluation made of the Ranching Project Area are as follows.

According to the current suitability evaluation, most of the area is rated as "Marginally suitable" or "Submarginally suitable" excepting forests, rocky places and places too remote for access to the existing water supply facilities.

According to the potential suitability evaluation, which assumes effective utilization of water and forest clearing, significantly large portions of those evaluated as "Unsuitable" under the current suitability are rated "Marginally suitable" or "Submarginally suitable". And there are some more of "Moderately suitable" places.

I. BACKGROUND AND OBJECTIVES

I. BACKGROUND AND OBJECTIVES

Located in East Africa right under the Equator, Kenya has a land space of 580,000 km² with highly developed high lands favoured by such natural elements as climate, soils, vegetation, in the south of the inland area having concentrations of industries and populations. Except for the coastal area on the Indian Ocean, arid land accounts for most of the nation's land space, even where there are more than 2 million people or about 20% of the total population living primarily on traditional cattle raising.

Since its independence in 1963, the government made investments of various kinds to economically develop the arid land in an attempt to ease regional disparities. With the establishment of the Tana River Development Authority in June 1974 with a view to comprehensive development of the Tana River (Kenya's longest river: approx. 700 km long and approx. 132,000 km² in catchment area) that flows into the Indian Ocean, comprehensive surveys and studies were started for effective utilization of water from the river and, with respect to the downstream regions, paddy field development by irrigating the delta area and intensive use of land for ranching.

These surveys and plans required high accuracy national base maps as basically essential information for their implementation. Recognizing this need, the Kenyan Government requested the Japanese Government to produce the national base maps of 1/50,000 in scale covering the downstream of the Tana River and surrounding areas. In response, the Japanese Government sent JICA missions for preliminary studies in February and March 1975 and subsequently met the request by undertaking the Topographic Mapping Project in East Kenya (37 sheets of 1/50,000 scale topographic maps covering approximately 27,000 km²) which was completed in March 1981 after six years of work and the resulting products were officially delivered in August of the same year.

In the course of the project, Kenyan counterparts from the Survey of Kenya joined the Japanese in the field work and came to Japan at the invitation of JICA to join in the off-site work done in Japan. Not only the final products but all other products resulting in the intervening processes such as aerial photos and 1/50,000 topographic map prints as well were delivered to the Kenyan Government on the occasion of their offical presentation. "The East Africa Specifications" prepared by the British Directorate of Overseas Surveys was applied to these 1/50,000 topographic maps but since there were not provisions set for its application, "The Map Symbols and System of Representation and its Application" was compiled in consultation with the Survey

of Kenya to provide for such rules. It is believed that such an effort has significantly contributed to the transfer of base map making technology.

Prior to the completion of the topographic mapping, a request was submitted by the Kenyan Government to make thematic maps for the same area as covered by the topographic mapping. After meetings held between JICA missions and Kenyan side over the period of January to April 1981, it was agreed that the Japanese Government would undertake a three-year project (for the 7th – 9th Years of the Topographic Mapping Project) starting in fiscal year 1981, subsequent to the topographic mapping, to meet that Kenyan request covering areas with high development potential (the Tana River Delta Area and the Ranching Project Area totalling some 14,700 km^2 in area).

This project was conducted for the purpose of developing thematic maps based on the 1/50,000 topographic maps to provide such base information on the land as vegetation, present land use, landforms, surface geology, soils, etc. and thus to contribute, along with the topographic maps, to effective implementation of the development plans in East Kenya.

II. OUTLINE OF STUDY AREA

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II - 1 LOCATION

The study area is approximately 14,700 km² in area located between 2° and 3° south latitudes and 39° and 41° east longitudes including the coastal East Kenya facing the Indian Ocean. Administratively, the area involves four Districts, namely, Lamu, Kilifi, and Tana River of Coast Province and Garissa of Northeastern Province; Lamu in the east, Kilifi in the south, Tana River in the central, north and west, and Garissa in a very small portion of the north (Fig. II-1).

According to the major development objectives and contents of this project, the study area was divided at 40° east longitude into two sections, the Tana River Delta Area on the east and the Ranching Project Area on the west.

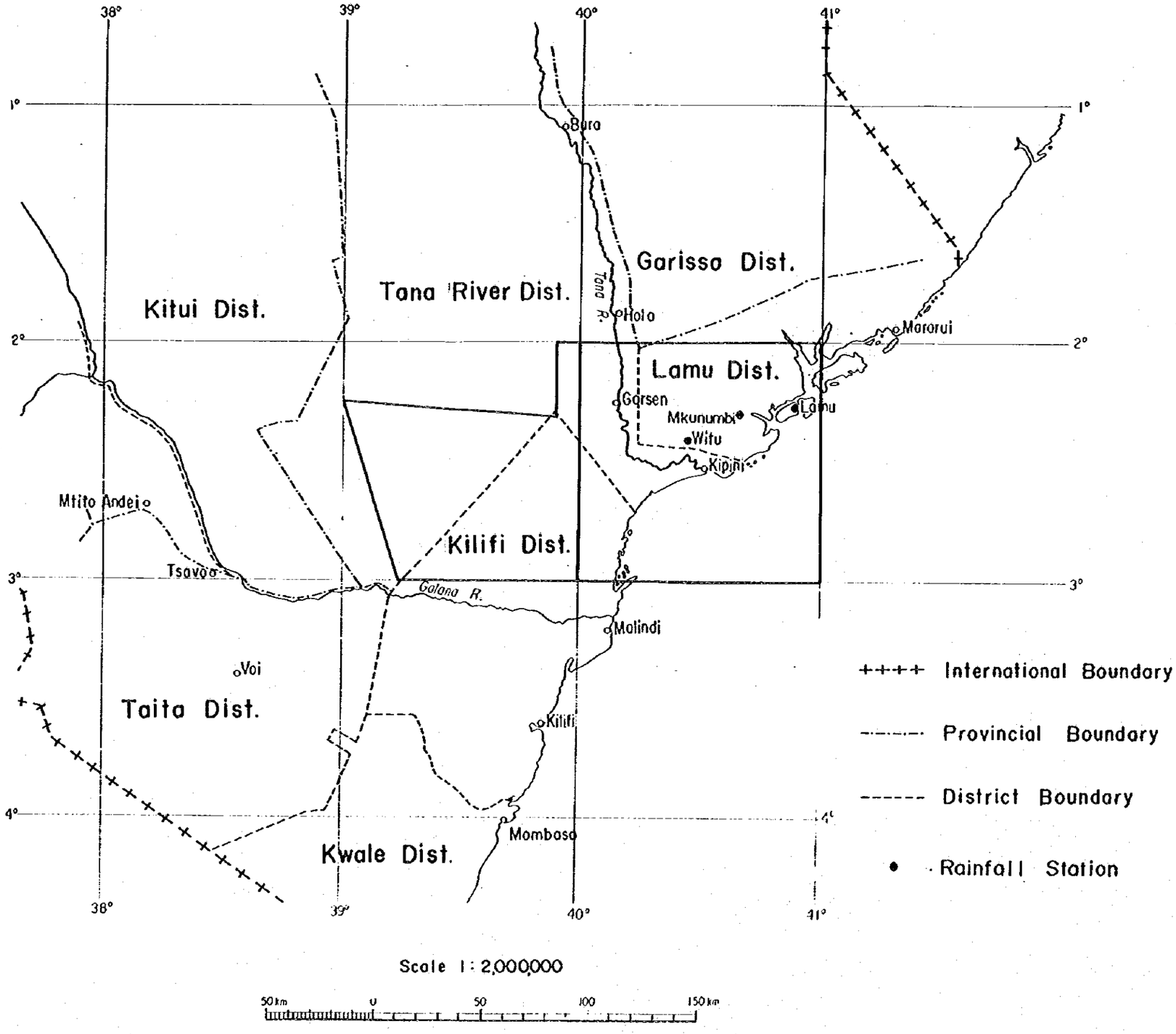

Fig. II-1 Study area and administrative boundaries

II - 2 CLIMATE

Climatic conditions, like soils, have a significant influence on suitabilities of crops and agricultural production. Specifically, rainfall, evaporation and temperature, and their balanced relations are critical to agricultural management. Meteorological observation data spanning more than 15 years were available at three locations inside the study area -- the Lamu Meteorological Office, Mkunumbi, and Witu plantation (Fig. II-1). The areas covered, however, are highly concentrated towards the sea coasts and there are quite a few portions lacking in data. Therefore, the climatic conditions of the study area were analysed by supplementing the above data with those from surrounding areas.

II - 2 - 1 ANNUAL MEAN RAINFALL AND ANNUAL POTENTIAL EVAPORATION

The annual mean rainfalls for the study area and its surrounding areas are as shown in Fig. II-2. From this figure, the study area can be divided into two; one coastal with annual mean rainfalls ranging from 600 mm – 1200 mm and the other inland with rainfalls of 200 mm – 600 mm.

In more detail, the isohyet lines run parallel to the coastal lines with volumes declining as they move inland. The highest rainfalls in the study area amounting to 1000 mm to 1200 mm occur in an area running from Witu to Mpeketoni.

Annual potential evaporations were analysed and made into charts by T. Woodhead (1968), According to them, the annual potential evaporations in the study area and the surrounding areas are as shown in Fig. II-3, reaching up to 1800 mm – 2400 mm and decreasing as they move inland away from the coast. The annual mean rainfalls and the annual potential evaporations show a very similar tendency to decrease as they move inland from the coast.

II - 2 - 2 MONTHLY MEAN RAINFALL AND MONTHLY POTENTIAL EVAPORATION

Monthly mean rainfall data for Lamu, Mkunumbi, and Witu, are as shown in Fig. II-4. It is seen from this figure that there are two peaks of rainfall occurring, one in May and another, to a lesser extent, in September--Novemebr. From rainfall patterns, H.M.H. Braun (1978) defined the seasons as the long rain season (April–June), the short rain season (October-December), the dry season (January–March), and the transitional season (July–September). These definitions very

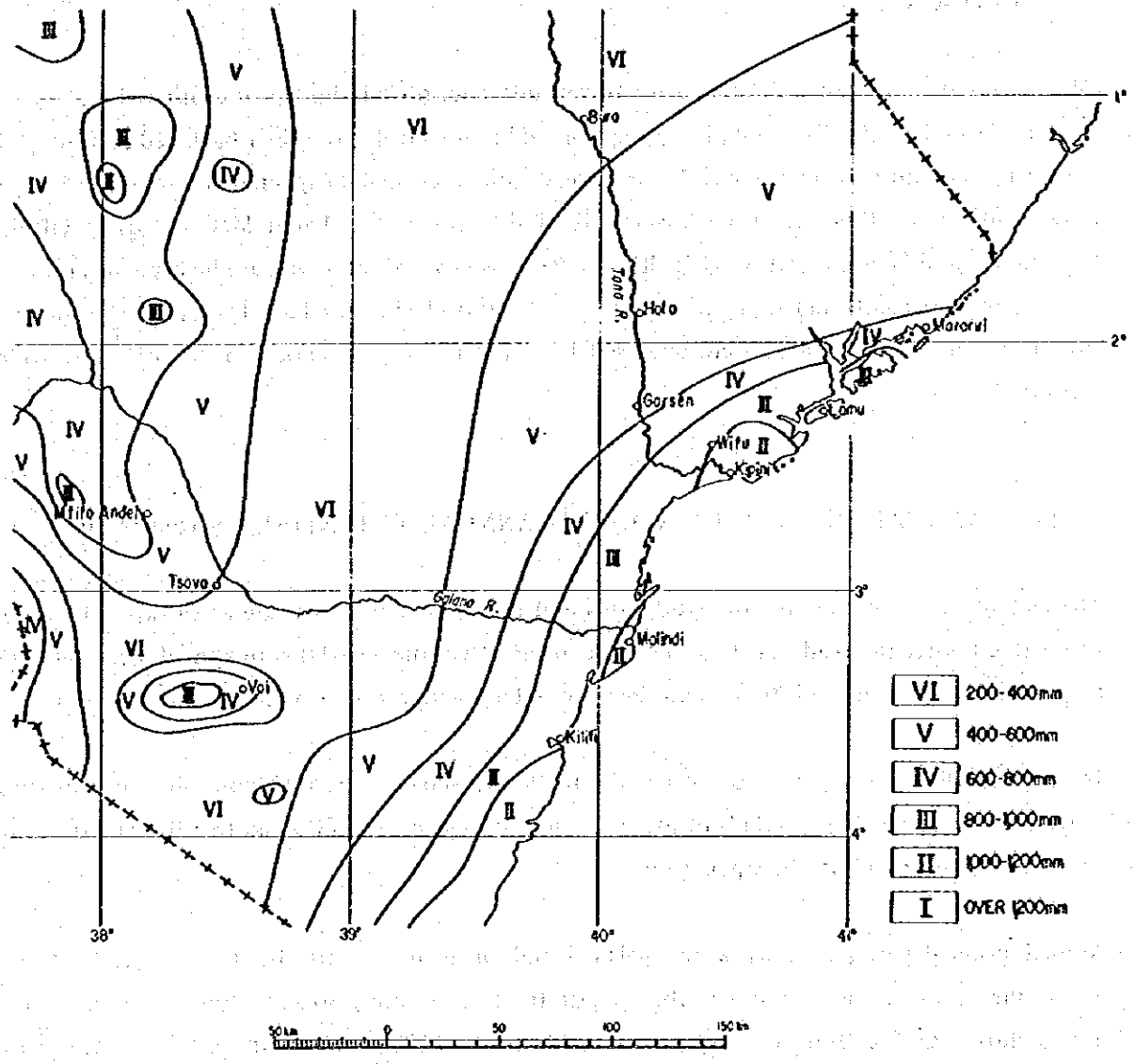

Fig. II-2 Annual mean rainfall (mm)

(Michieka D.O. 1978)

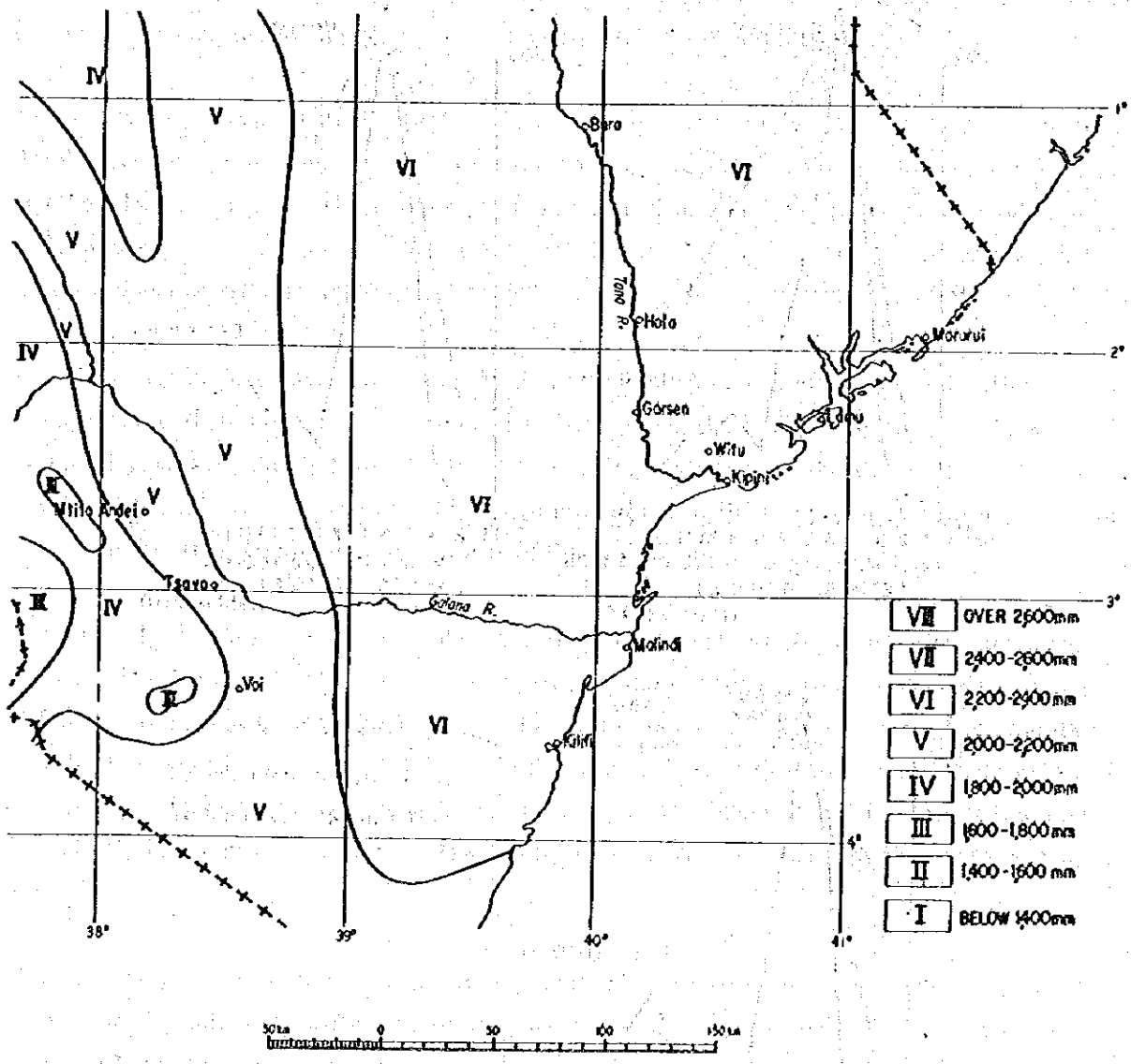

Fig. II-3 Annual potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

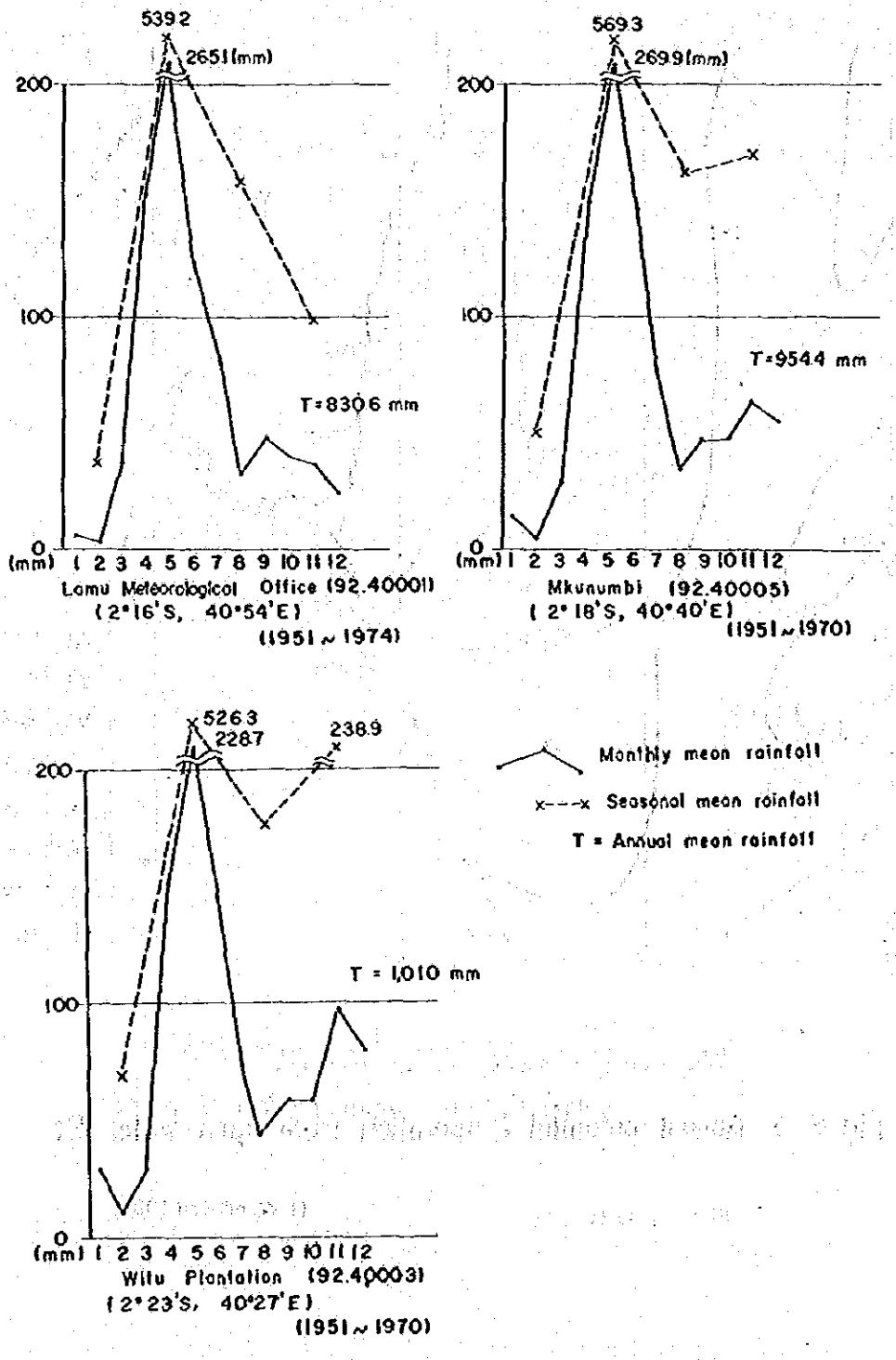

Fig. II-4 Monthly mean rainfall at Lamu, Mkunumbi and Witu

(Kenya Meteorological Department 1951 ~ 1974)

well reflect the features as seen in Fig. II-4. Monthly mean rainfalls for the study area and the surrounding areas are shown in Fig. II-5 – 16 (East African Community (EAC) 1971).

Accordingly, with respect to the Tana River Delta Area, the January–March period is defined as the dry season, April–June the long rain season, July–September the transitional season, and October–December as the short rain season. The annual mean rainfall for this area is 600 mm – 1200 mm with the rainfall reaching about half that level during the long rain season and the lowest of less than 10 mm in February.

The Ranching Project Area has less amounts of rainfall of 200 mm – 600 mm with seasonal changes not as distinctive as in the Tana River Delta Area. The January–March period is defined as the dry season, April–June the rain season, July–September the dry season, October–December the rain season. The monthly mean rainfall is less than 100 mm even during the rain season and less than 10 mm in most months of the dry season.

The monthly potential evaporation data for the study area and the surrounding areas are as shown in Fig. II-17 – 28. The monthly potential evaporations for the study area range 150 mm – 225 mm and nearly correspond to the monthly mean rainfalls in their movement from month to month. And there is not much difference in that respect between the Tana River Delta Area and the Ranching Project Area. But if any, evaporations slightly higher in the Tana River Delta Area and slightly lower in the months of May – July than in other months with 150 mm – 175 mm/month.

When monthly mean rainfalls and monthly potential evaporations are compared, except for the months of May and June when rainfall exceeds evaporation in coastal areas running from Lamu Island to Witu, evaporation is generally higher than rainfall in all other areas throughout a year. Differences between evaporation and rainfall are larger in the January–March dry season and the July–September transitional season in both the Tana River Delta Area and the Ranching Project Area. It means that the Tana River Delta Area is subject to drought hazards except during the rain seasons, whereas the Ranching Project Area is plagued by drought all year round.

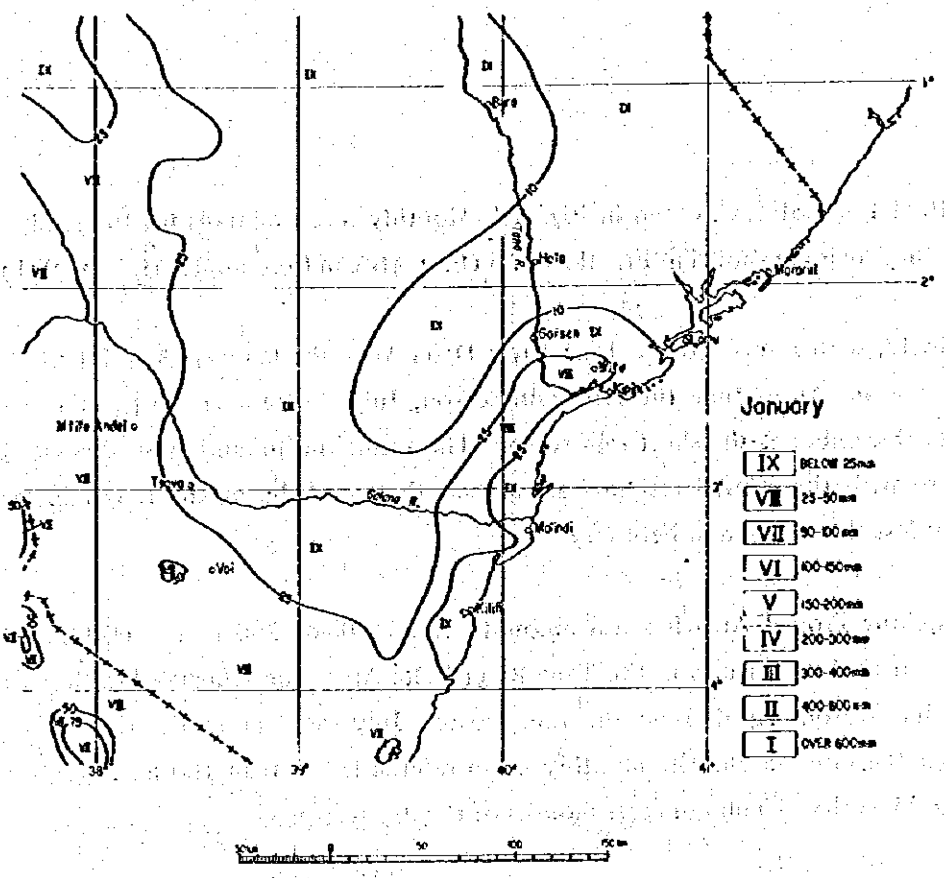

Fig.II-5 Monthly mean rainfall (mm)

(EAC 1971)

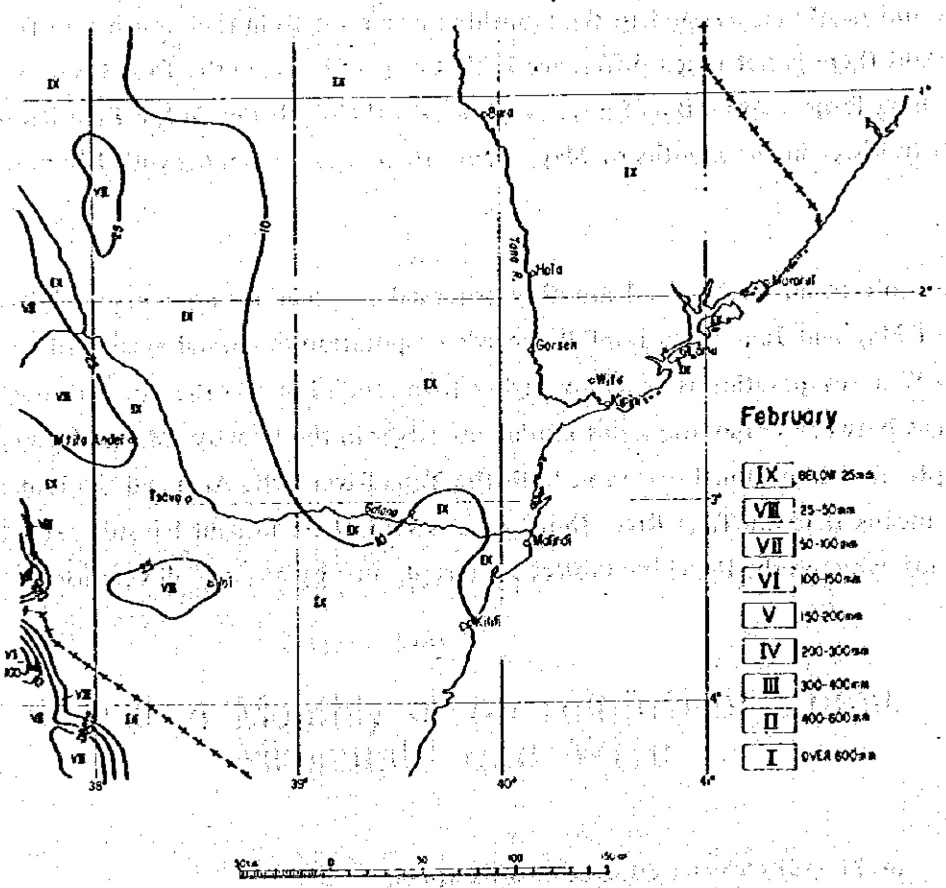

Fig.II-6 Monthly mean rainfall (mm)

 (EAC 1971)

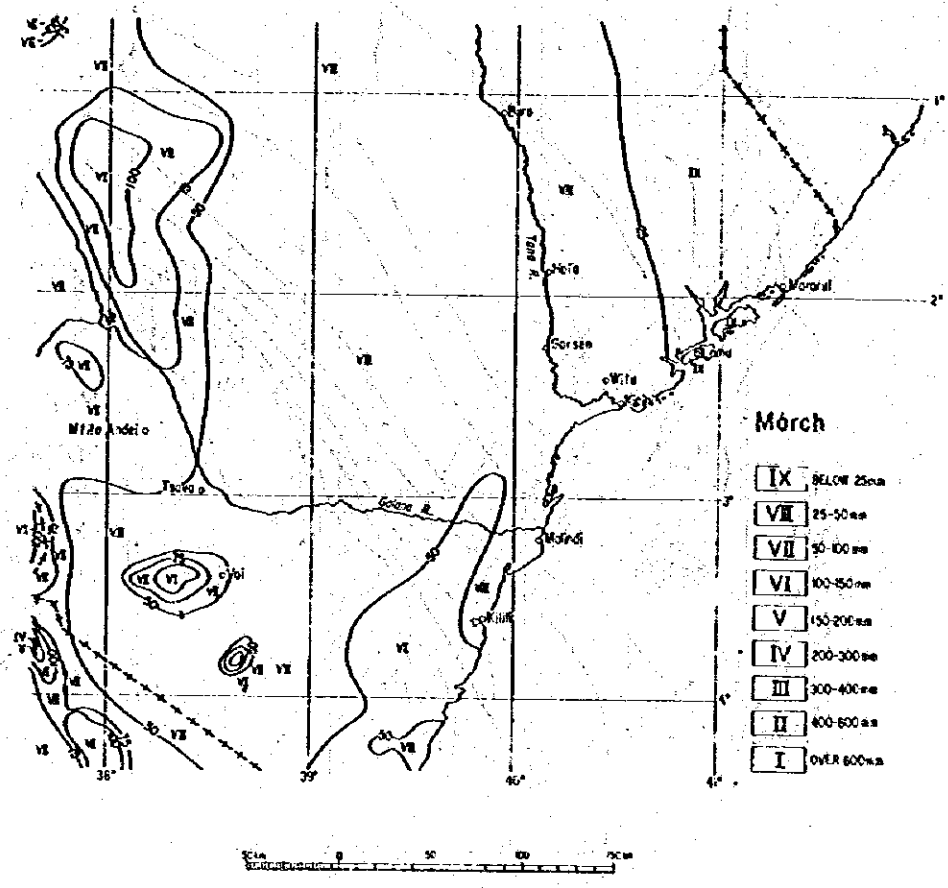

Fig.II-7 Monthly mean rainfall (mm)

(EAC 1971)

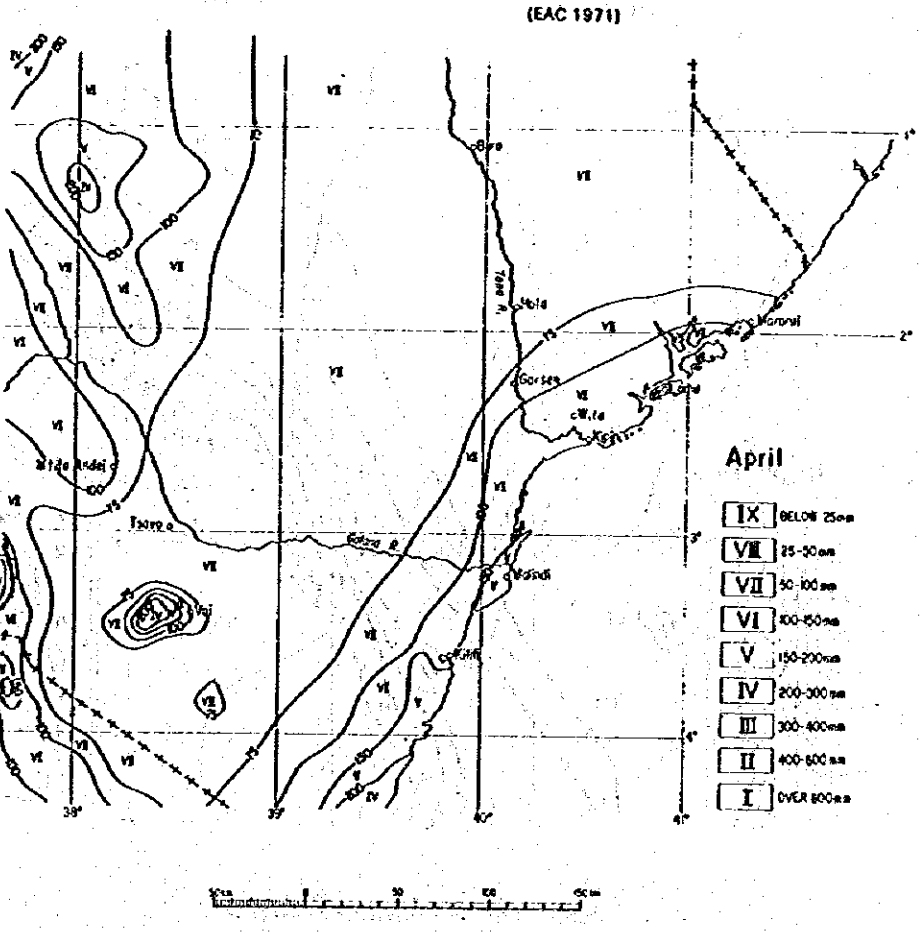

Fig.II-8 Monthly mean rainfall (mm)

(EAC 1971)

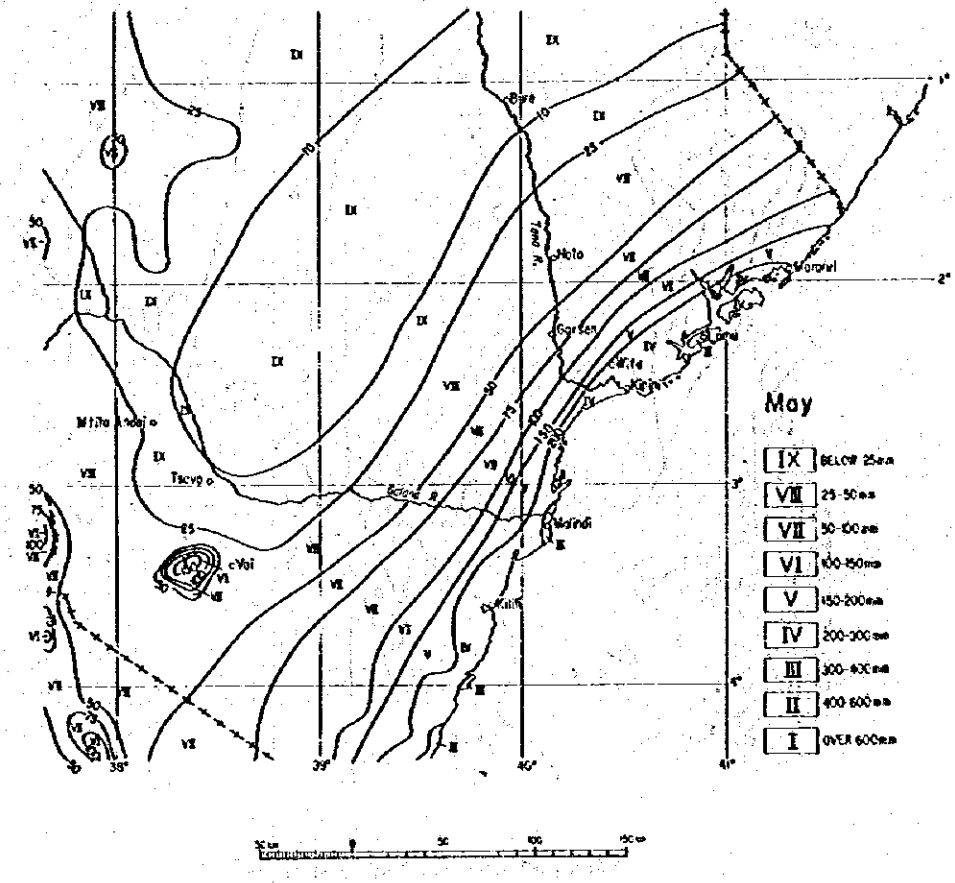

Fig. II-9 Monthly mean rainfall (mm)

(EAC 1971)

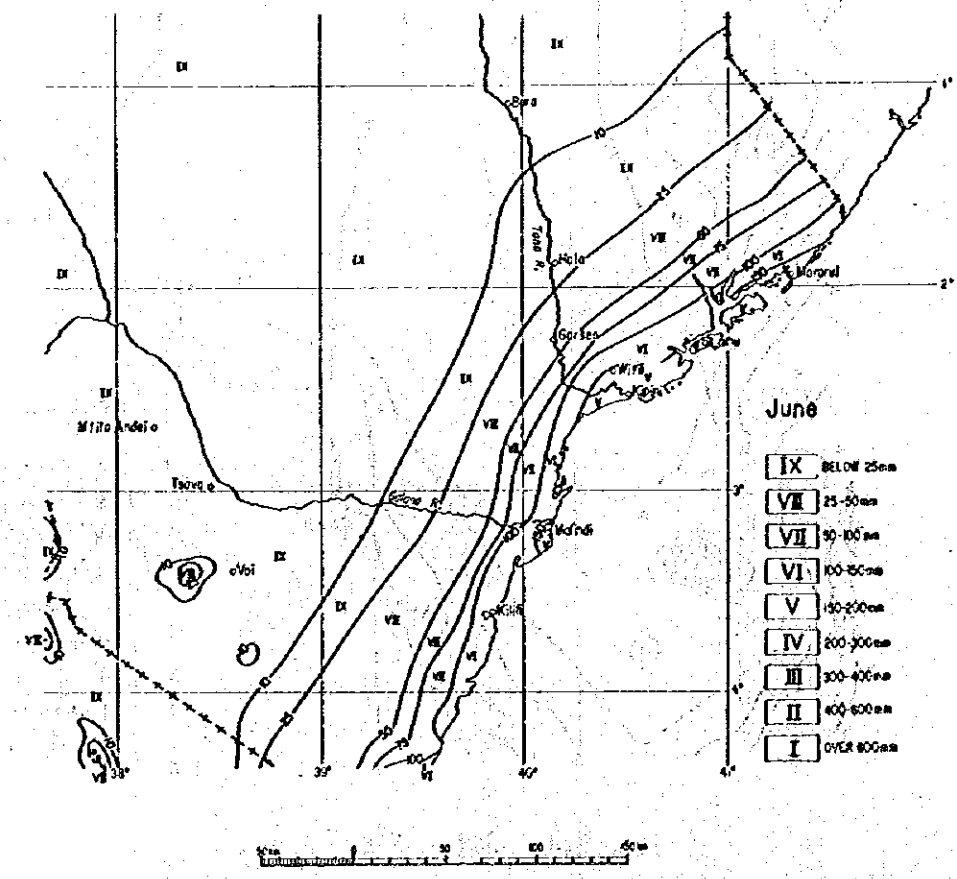

Fig. II-10 Monthly mean rainfall (mm)

(EAC 1971)

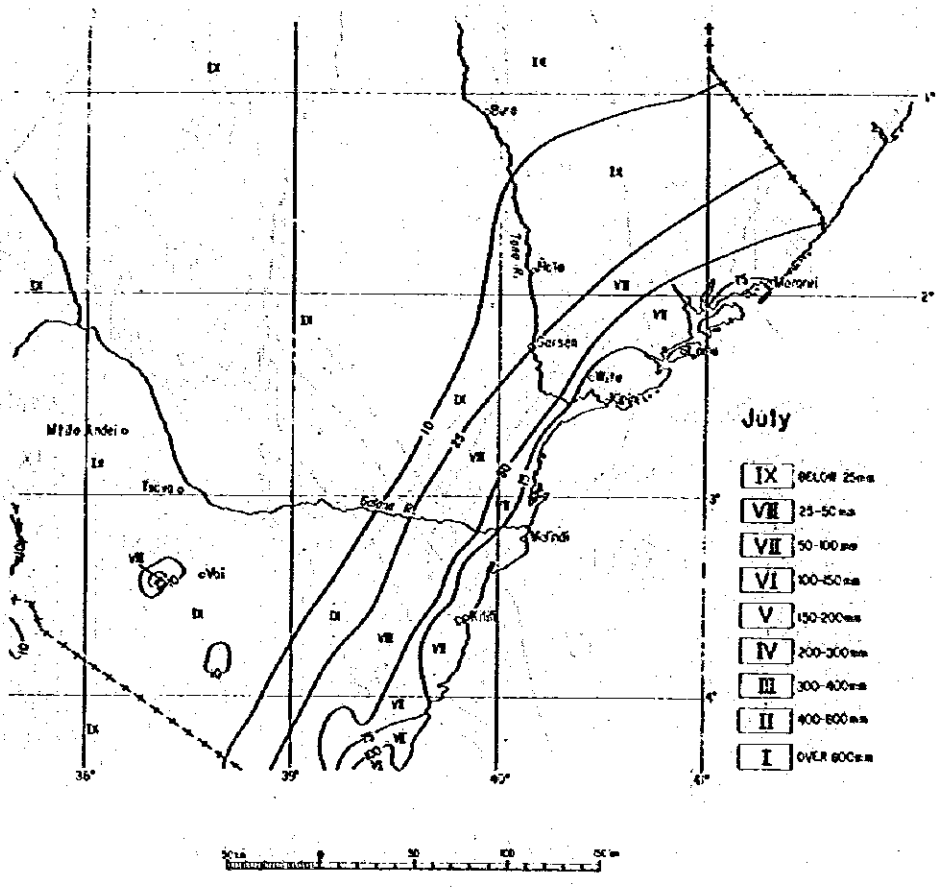

Fig.II-11 Monthly mean rainfall (mm)

(EAC 1971)

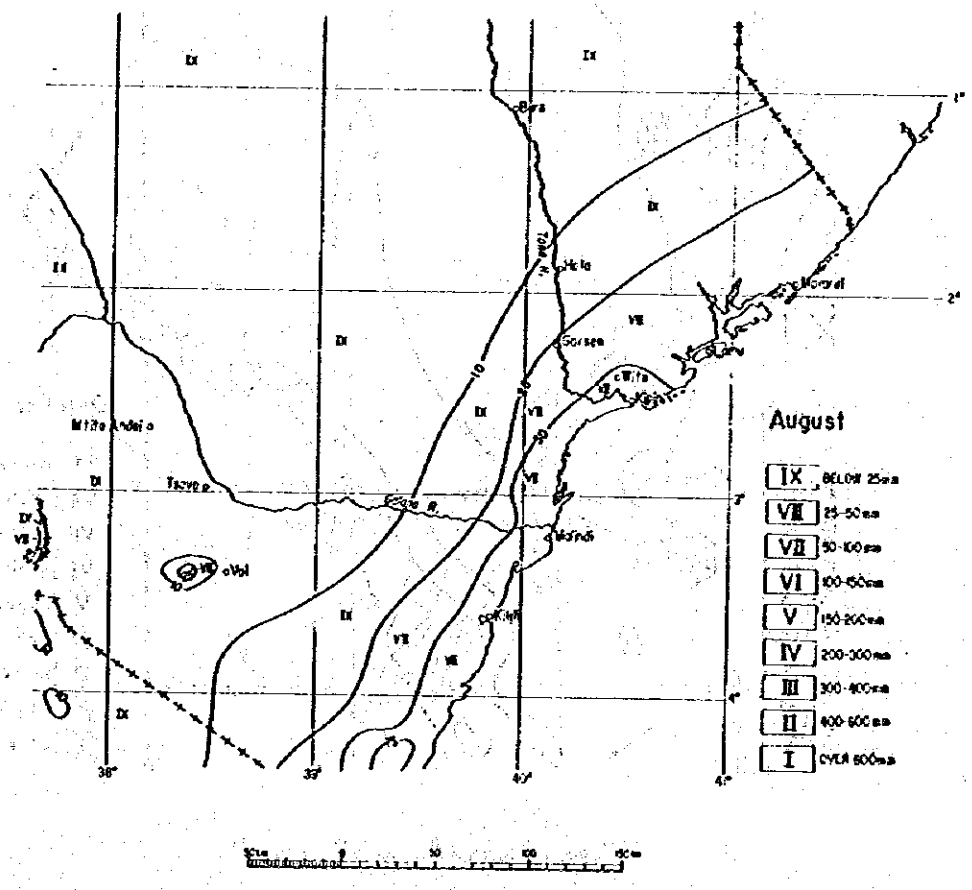

Fig.II-12 Monthly mean rainfall (mm)

(EAC 1971)

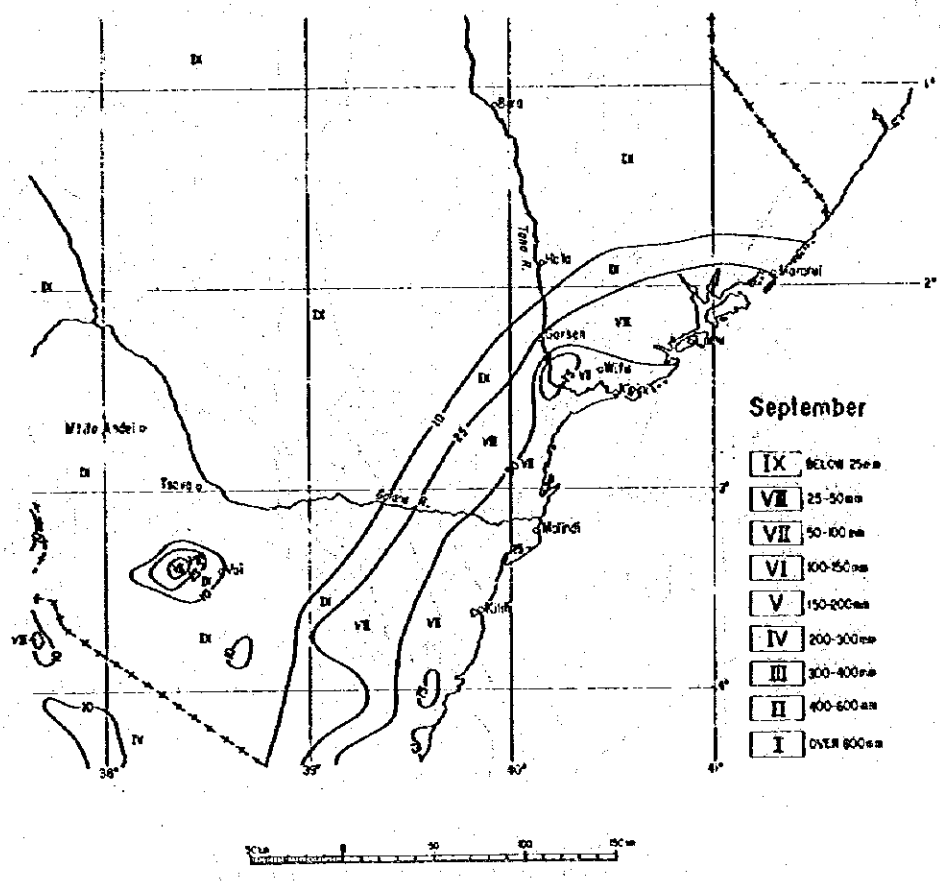

Fig. II-13 Monthly mean rainfall (mm)

(EAC 1971)

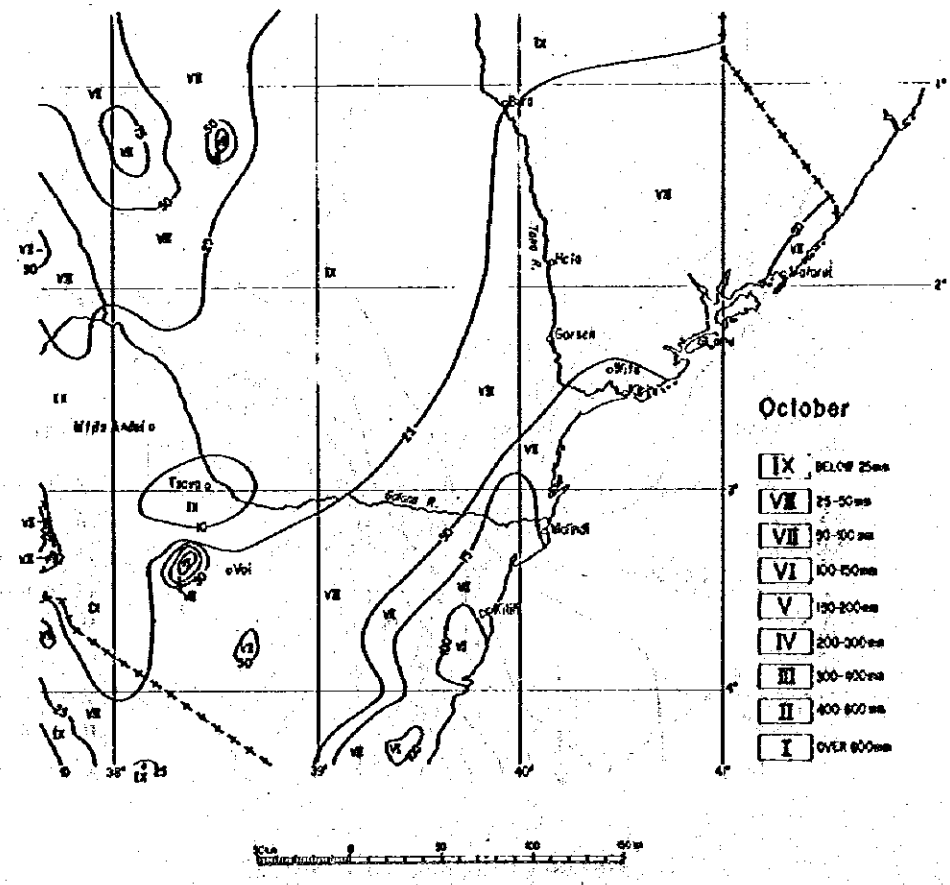

Fig. II-14 Monthly mean rainfall (mm)

(EAC 1971)

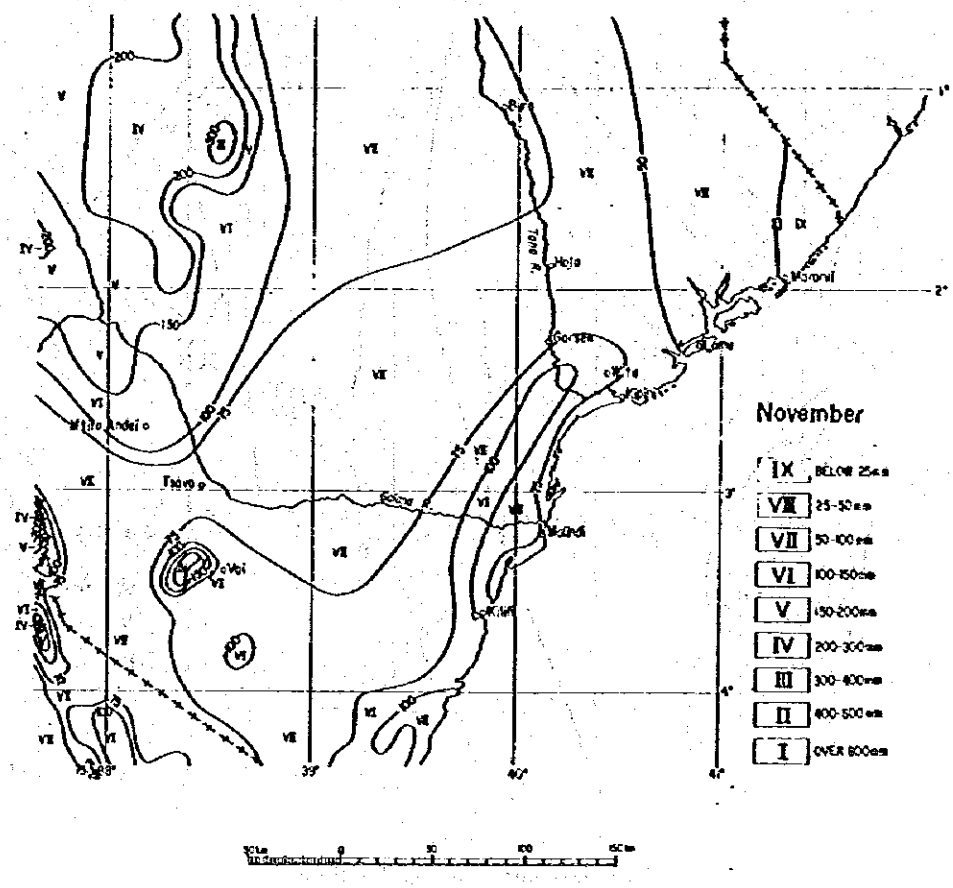

Fig.II-15 Monthly mean rainfall (mm)

(EAC 1971)

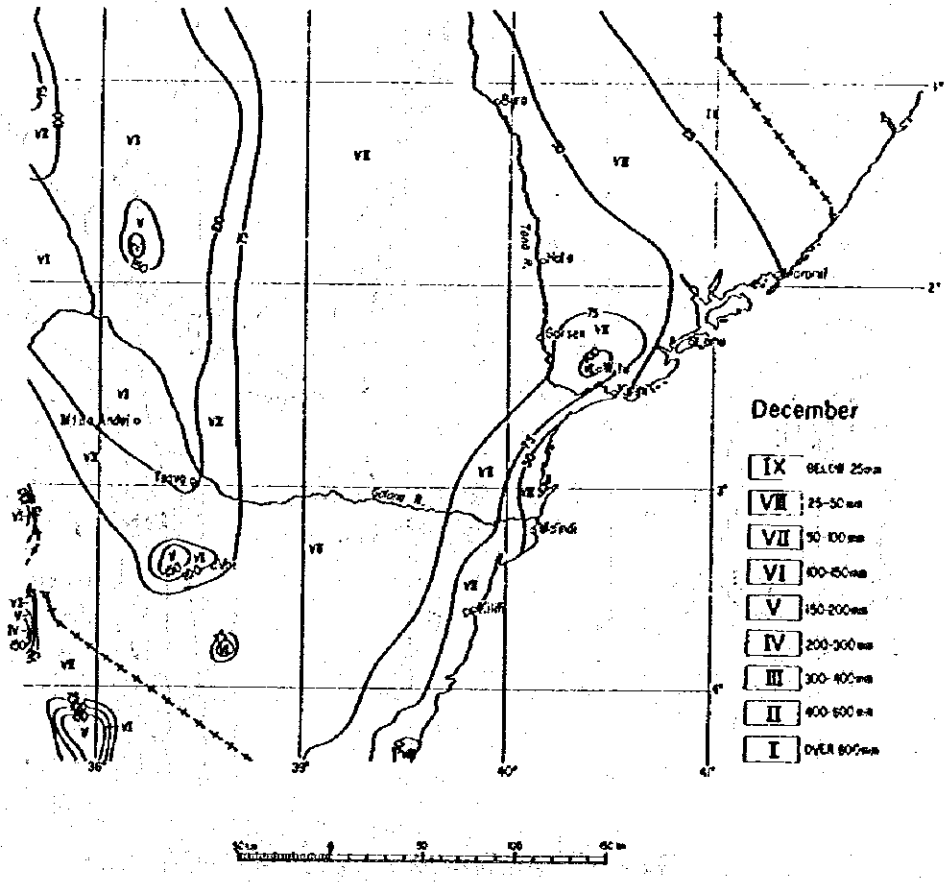

Fig.II-16 Monthly mean rainfall (mm)

(EAC 1971)

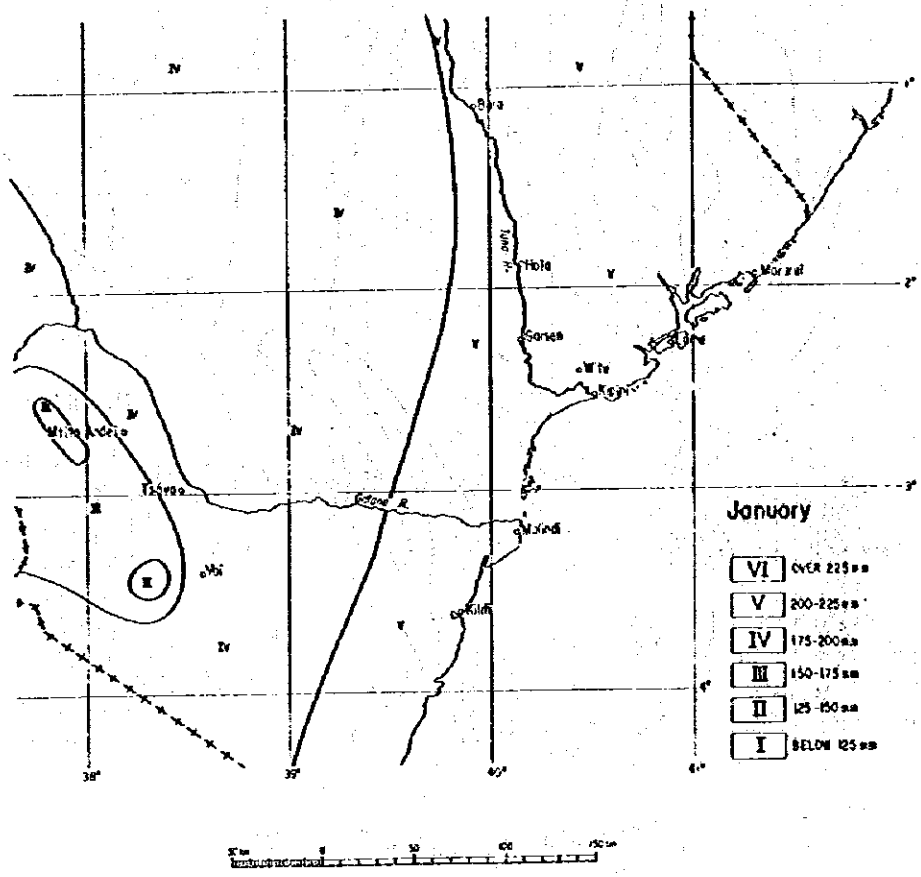

Fig. II-17 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

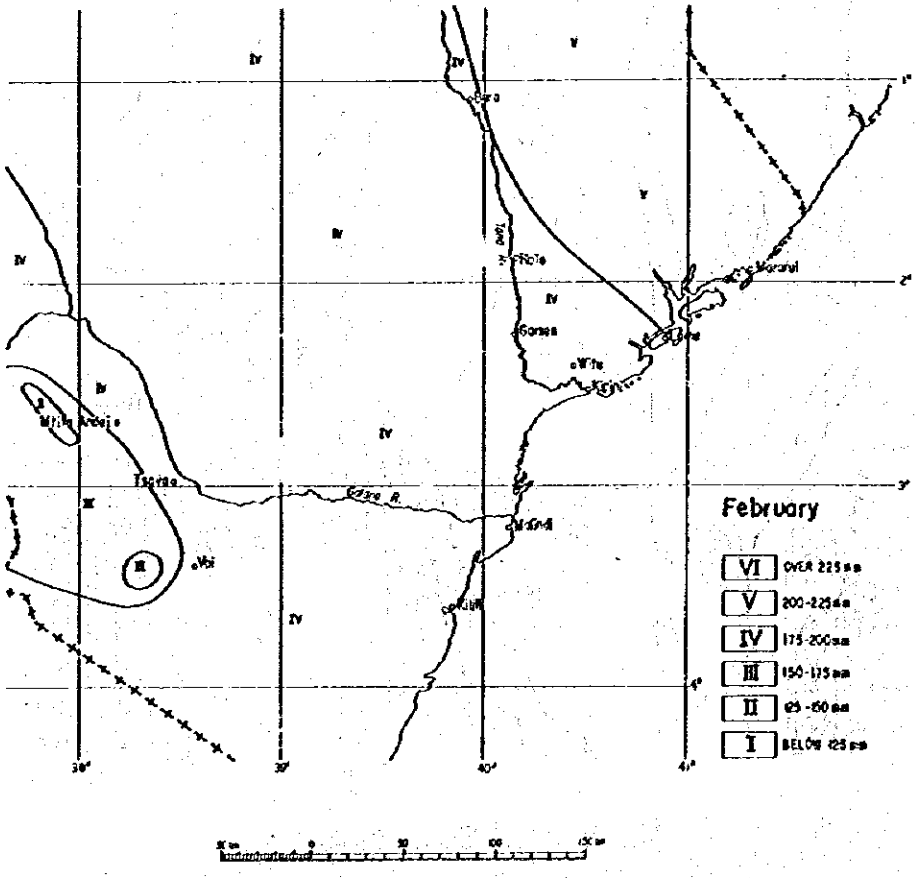

Fig II-18 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

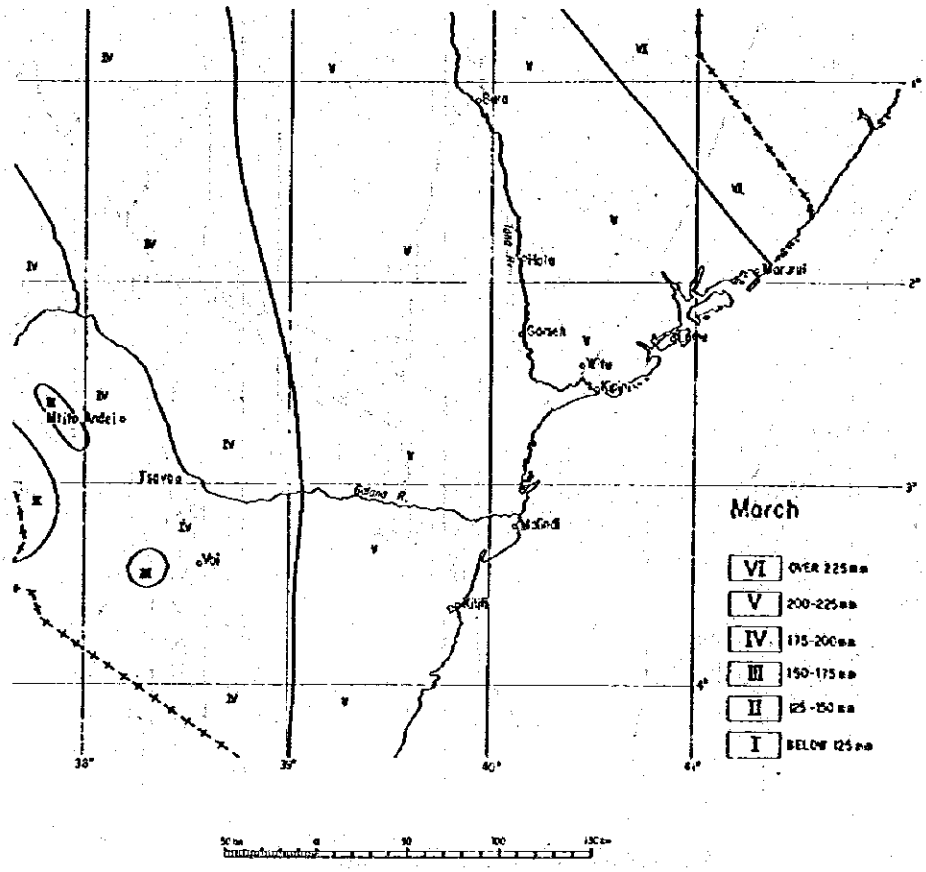

Fig.II-19 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

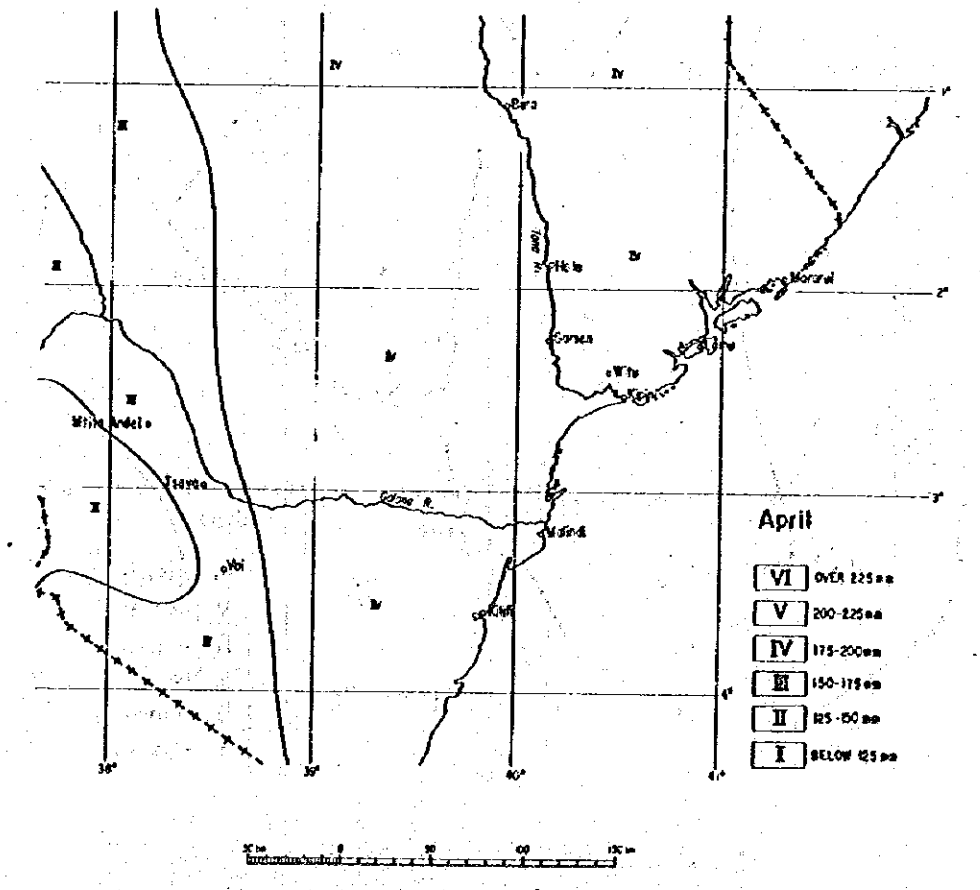

Fig.II-20 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

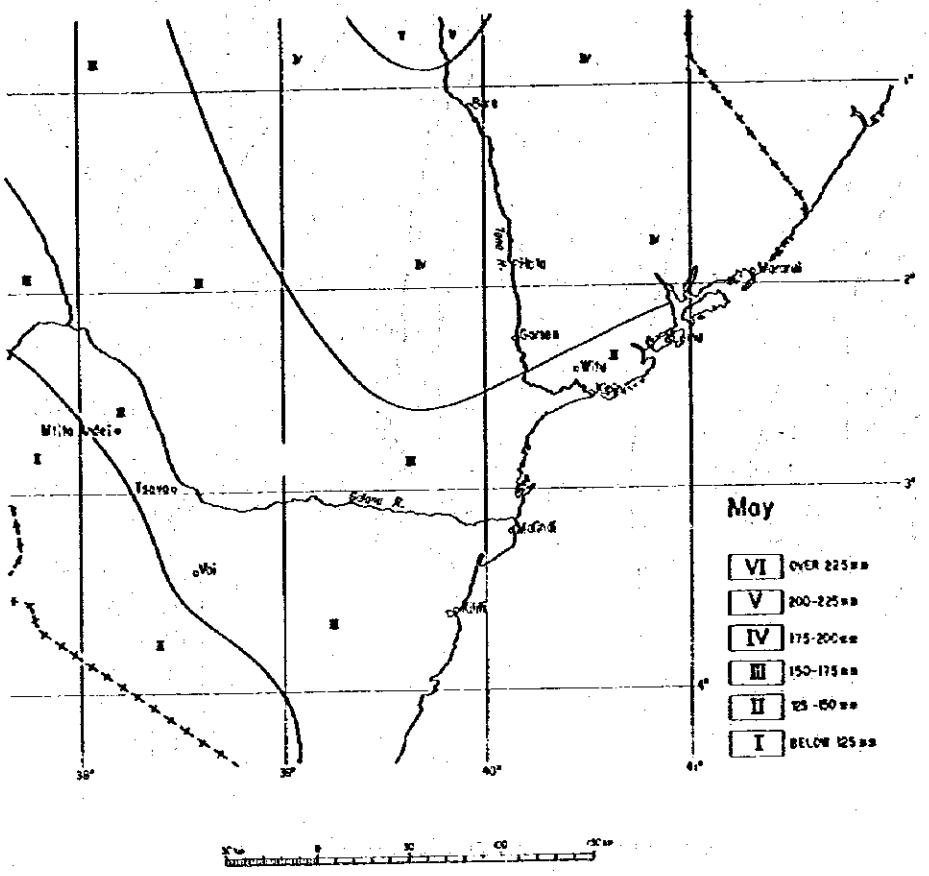

Fig.II-21 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

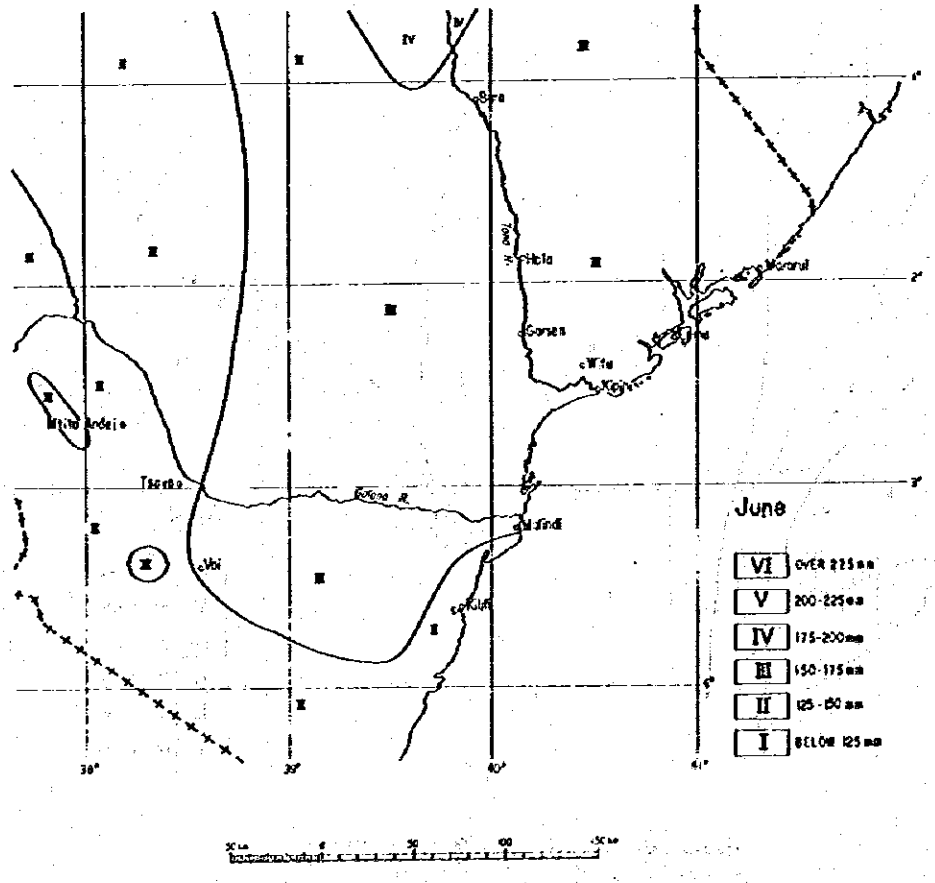

Fig.II-22 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

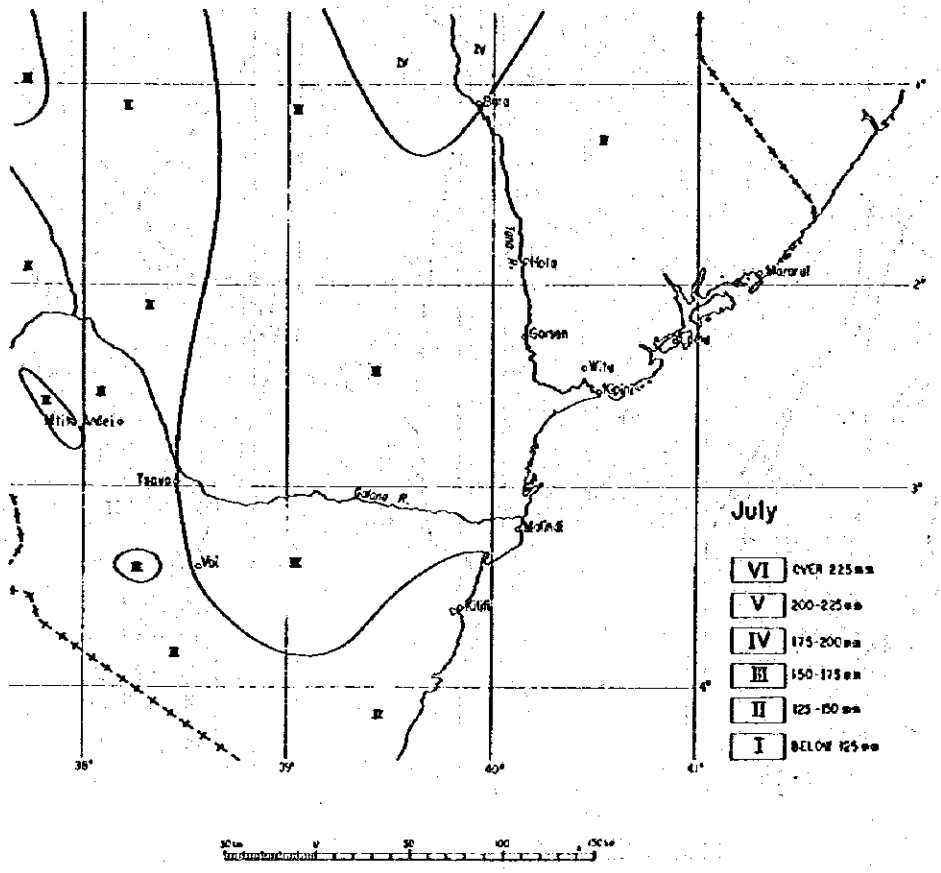

Fig.II-23 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

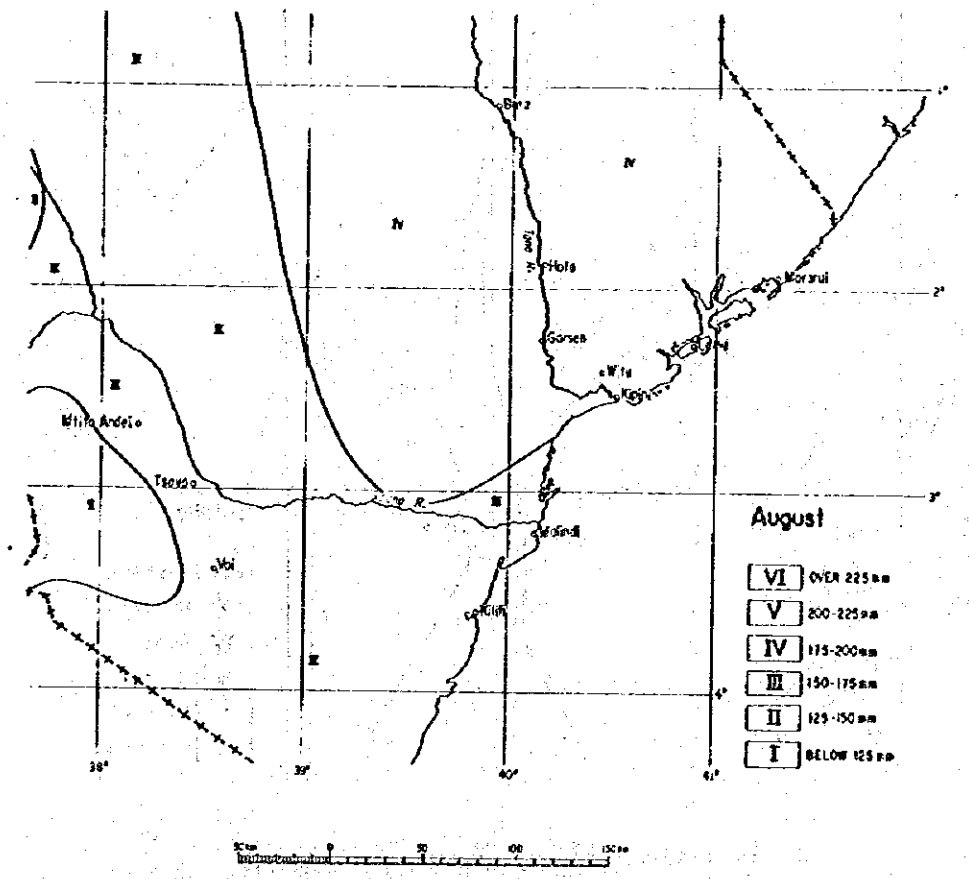

Fig.II-24 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

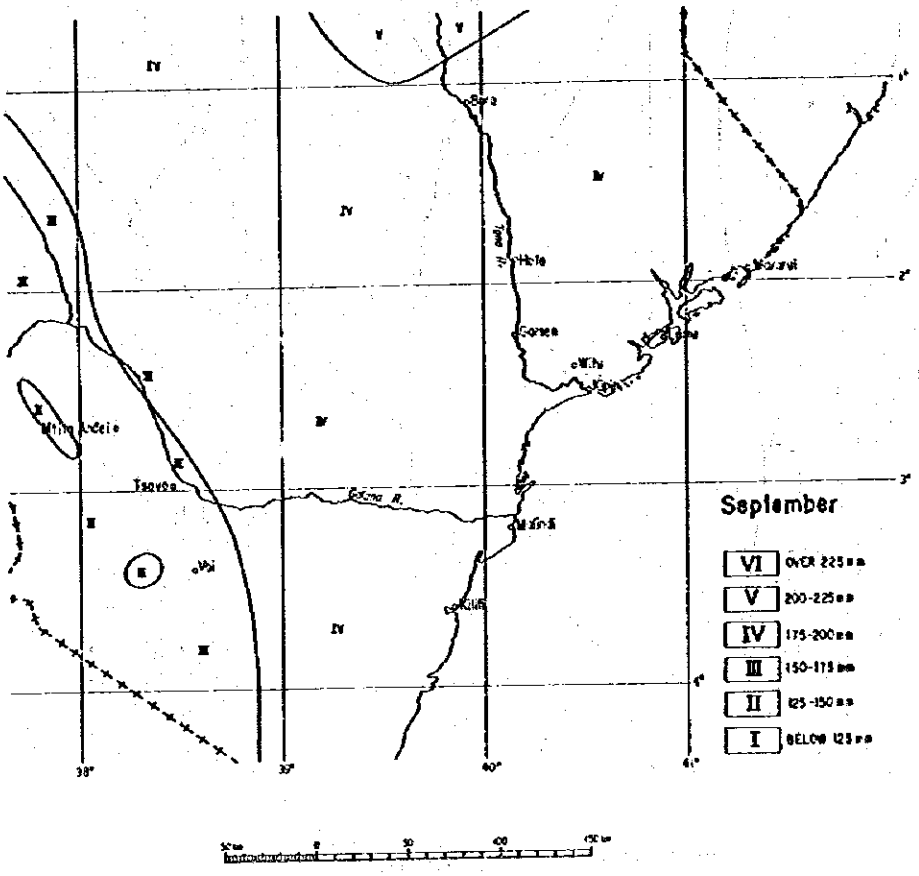

Fig.II-25 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

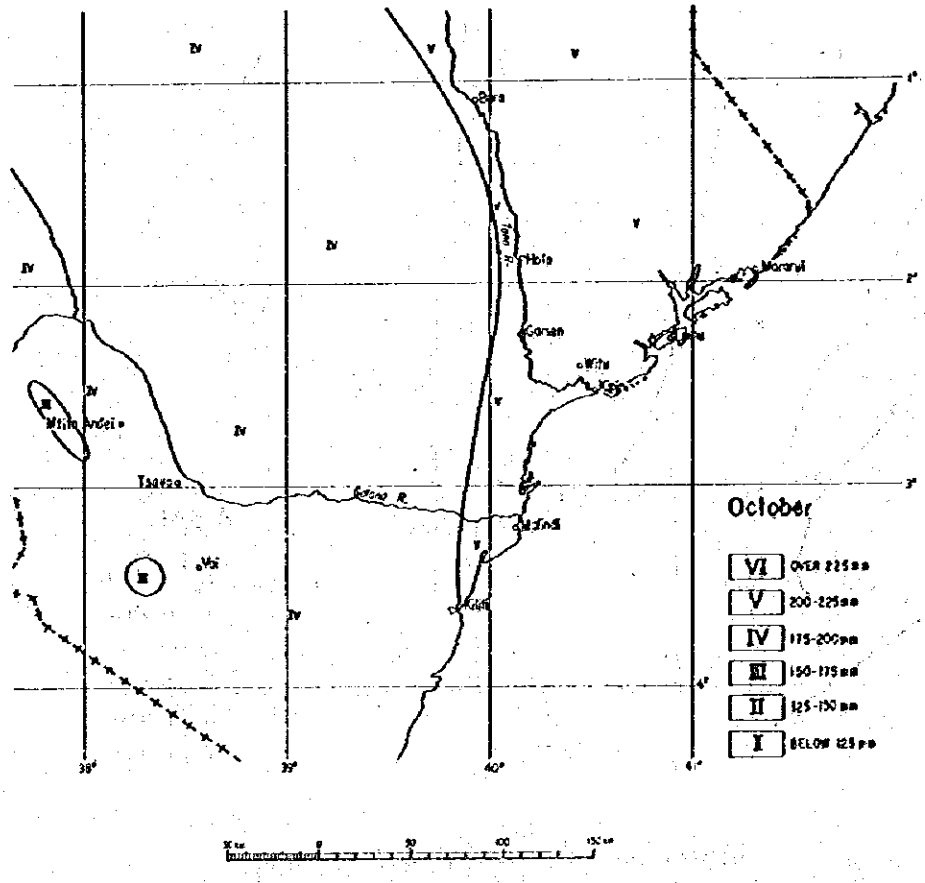

Fig.II-26 Monthly potential evaporation from open water (Penman Eo)

(T.Woodhead 1968)

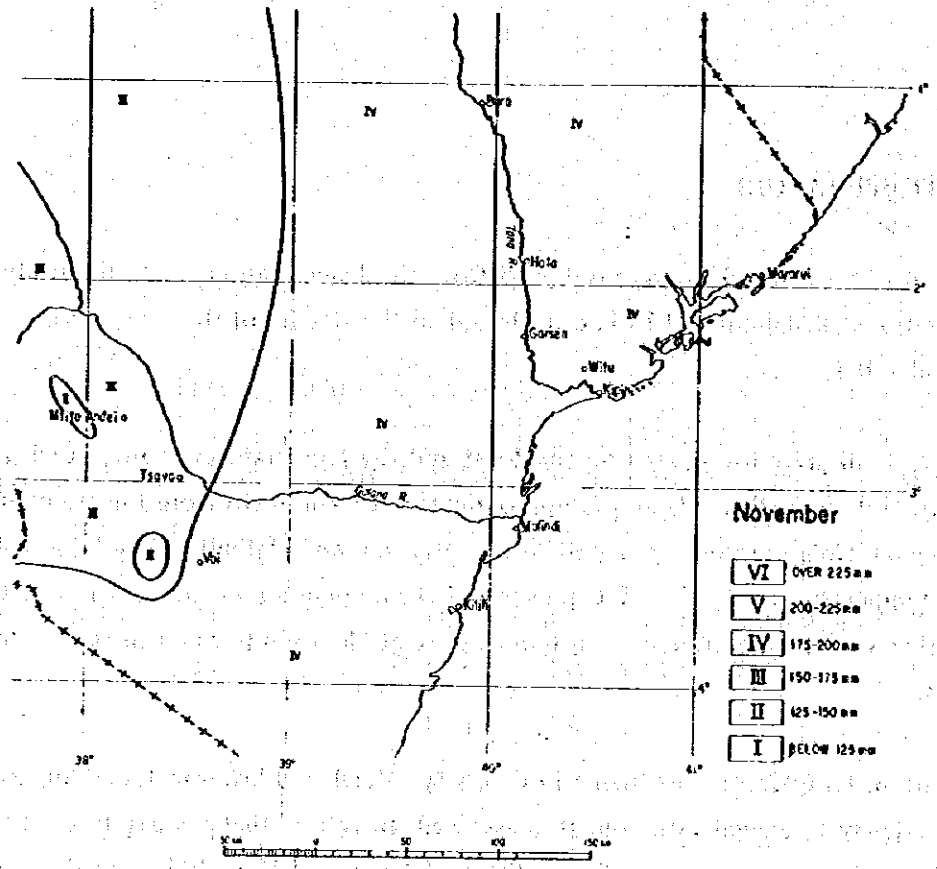

Fig. II-27 Monthly potential evaporation from open water (Penman Eo)

(T. Woodhead 1968)

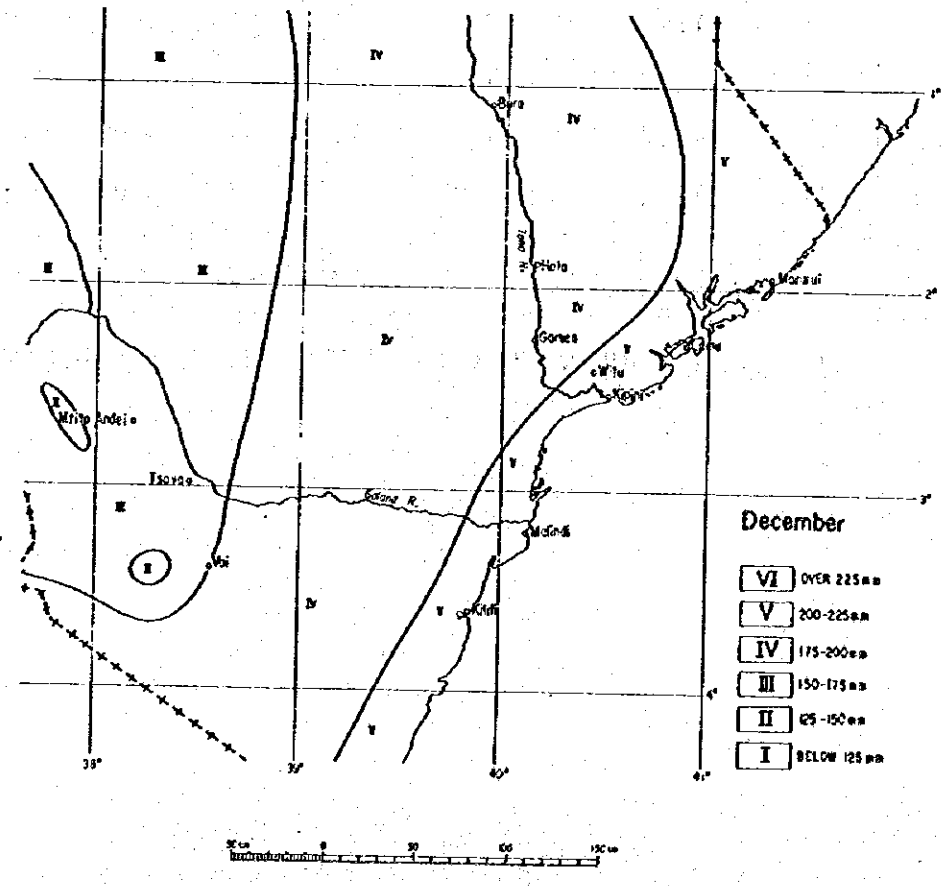

Fig. II-28 Monthly potential evaporation from open water (Penman Eo)

(T. Woodhead 1968)

II - 2 - 3 TEMPERATURE

Meterological observation data were obtained from the Lamu station inside the study area and from the stations at Malindi and Hola outside but in the vicinity of the study area, and they are shown in Table II-1.

Lamu and Malindi are both located on the coast and the temperatures at these two stations are very similar. Hola is further inland and approximately 15 km north from the study area. When temperatures at Hola are compared with those of Lamu and Malindi, it can be noted that the maximum temperatures are 3° – 4°C higher and the minimum temperatures 1° – 2°C lower at Hola. In other words, the differences in temperature at Hola run to as much as 4° – 6° over the coastal area.

At each station, temperatures are higher in February–March and lower in June–August, showing a similar tendency in annual variation. It is assumed, therefore, that temperatures at the coastal zones of the study area are very similar to those of Lamu and Malindi and by the same reason, the inland areas north of Garsen and the Ranching Project area are comparable to Hola.

Table II-1 Average Monthly Temperatures at Lamu, Malindi, Hola

STATION / TEMPERATURE / MONTH	Lamu (1960–1970)			Malindi (1962–1970)			Hole (1966–1970)		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
January	30.6°C	24.3°C	27.5°C	30.5°C	22.8°C	26.7°C	34.6°C	22.3°C	28.5°C
February	31.2	24.7	28.0	31.1	23.1	27.1	35.6	22.9	29.3
March	32.1	25.6	28.9	32.1	24.0	28.1	35.2	23.8	29.7
April	30.7	25.2	28.0	31.0	23.9	27.5	33.5	23.6	28.6
May	28.8	24.3	26.6	28.8	23.2	26.0	32.3	22.4	27.4
June	28.0	23.4	25.7	27.9	22.2	25.1	30.3	20.5	25.4
July	27.3	22.9	25.1	27.4	21.8	24.6	30.7	19.9	25.3
August	27.5	23.0	25.3	27.4	21.5	24.5	31.1	20.0	25.6
September	28.0	23.3	25.7	28.4	21.6	25.0	32.2	20.2	26.2
October	29.1	24.1	26.6	29.5	22.2	25.9	33.8	22.2	28.0
November	30.4	24.4	27.4	30.5	22.6	26.6	33.6	22.9	28.3
December	30.8	24.5	27.7	30.8	23.1	27.0	34.0	22.4	28.2
Year	29.5	24.1	26.8	29.6	22.7	26.2	33.1	21.9	27.5

(CLIMATOLOGICAL STATISTICS FOR EAST AFRICA PART-1 1975)

II - 2 - 4 AGRO-CLIMATIC ZONE

The Kenya Soil Survey (KSS) provides for what is termed "the agro-climatic zone", a combination of moisture availability zone and temperature zone, and regards it important in consideration of agricultural potential. The agro-climatic zone and its features are given in Fig. II-29 and Table II-2 respectively.

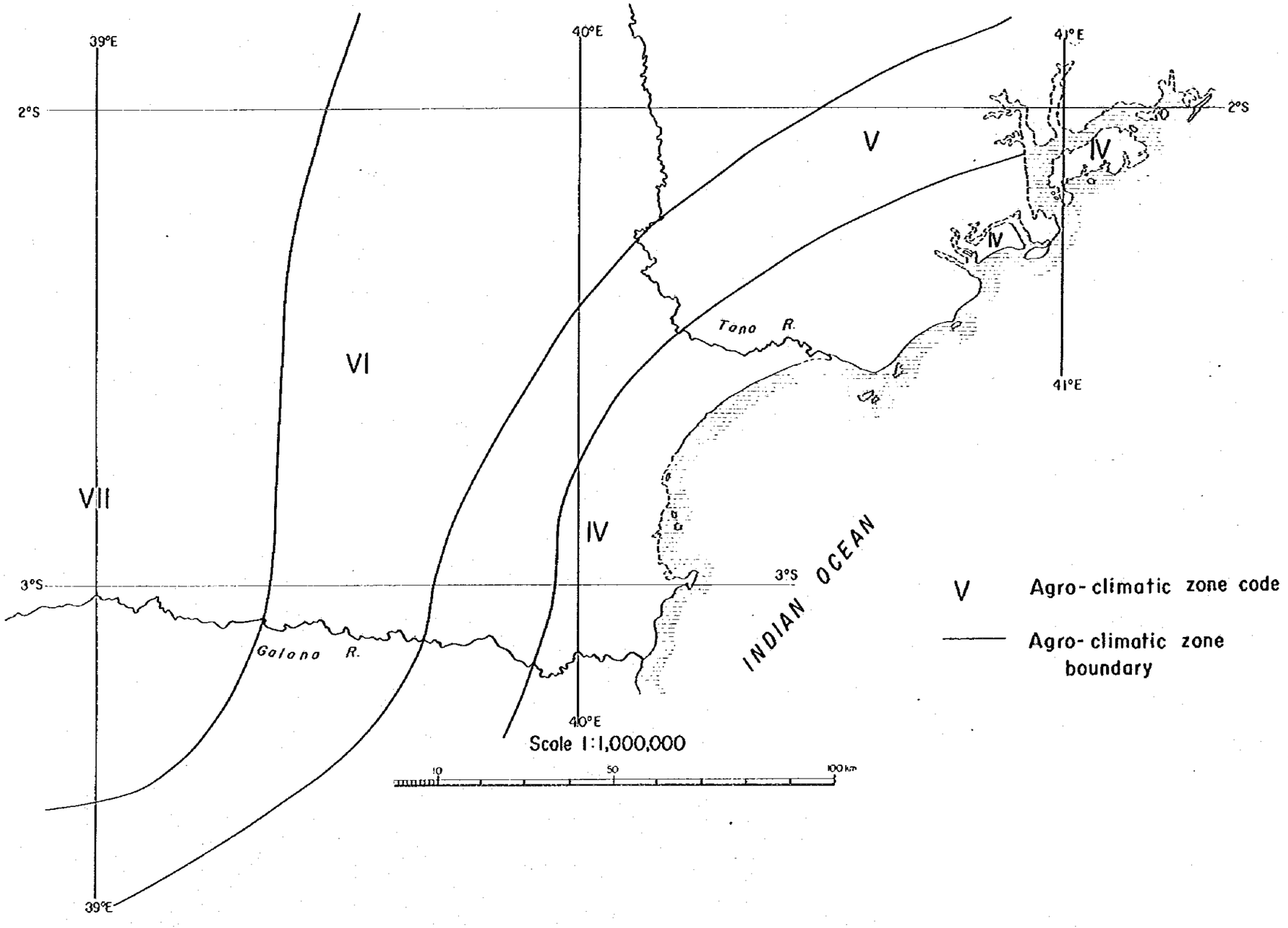

Fig. II-29 Agro-climatic zone map

(Agro-climatic zone map of Kenya 1980)

Table II-2 MOISTURE AVAILABILITY ZONES with an indication of rainfall, evaporation, vegetation, potential for plant growth and risk of crop failure

zone	r/Eo (%)	classification	r average annual rainfall (mm)	Eo average annual potential evaporation (mm)	vegetation	potential for plant growth	risk of failure of an adapted maize crop
			excluding areas above 10,000 ft altitude			assuming that soil conditions are not limiting	
I	>80	humid	1100–2700	1200–2000	moist forest	very high	extremely low (0–1%)
II	65–80	sub-humid	1000–1600	1300–2100	moist and dry forest	high	very low (1–5%)
III	50–65	semi-humid	800–1400	1450–2200	dry forest and moist woodland	High to medium	fairly low (5–10%)
IV	40–50	semi-humid to semi-arid	600-1100	1550–2200	dry woodland and bushland	medium	low (10–25%)
V	25–40	semi-arid	450–900	1650–2300	bushland	medium to low	high (25–75%)
VI	15–25	arid	300–550	1900–2400	bushland and scrubland	low	very high (75–95%)
VII	<15	very arid	150–350	2100–2500	desert scrub	very low	extremely high (95–100%)

II - 3 GEOMORPHOLOGY AND GEOLOGY

The study area is divided into three by geomorphologic and geologic features, namely, the Fundisa Hill Area to the south of the center, the Tana River Delta Area to the east, and the Ranching Project Area to the west. (The Tana River Delta Area and the Ranching Project Area as described below slightly vary in areas from those defined in Fig. III-1.)

The Tana River Delta Area consists of alluvial plains of the Tana River running in the center and terraces on the left (east side) and the right (west - southwest side) banks of the river. The alluvial plains of the Tana River are comprised by low and wet flood plains and dry natural levees extending along the river route. Dunes (relative heights of 10 m – 70 m) occur on the coastal area. Old dunes are distributed over the terraces on both sides of the alluvial plains of the Tana River in several belts nearly parallel to the present coastline. Towards the coast are raised coral reefs.

The terraces on the left bank are less than 60 m in elevation within the study area sloping towards the sea and form valley bottom lands due to water flows during the rain seasons. Dunes are observed in the coastal area. The terraces on the right bank include fans adjoining the Fundisa Hill to the south and low flat coastal plains in the coastal area.

Fundisa Hill is mildly undulating hill of Tertiary sediments ranging in elevation from 100 m to 150 m dissected by dendritic drainages.

The Ranching Project Area is comprised by extensive mainly Mesozoic plains of 150 m to 200 m in elevation. Its western half is flat peneplain, whereas the southern and eastern portions are bottom lowlands formed by dendritic valleys retaining original undulating shallow surfaces extensively. On those original surfaces exist residual hills (relative heights of 20 m – 90 m) due to erosions of Dakadima, Hoshingo, Dakawachu, etc. scatteredly along the northwest – southeast direction, surrounded by mild slopes composed of debris. Dakabuko (elevation: 354 m) in the south has a nearly flat top bounded by scarp with relative heights of 80 m – 150 m to the west.

The Tana River is the only permanent river in the study area. It flows southward meandering through the eastern half of the study area and turning eastward downstream to go into the Indian Ocean. Such other rivers as Gandi and Buna, that represent the hydrology of the eastern half of the Ranching Project Area, are seasonal rivers. The Galana River to the south of the study area running eastward is a permanent river.

II - 4 VEGETATION

The study area is divided by dominant vegetation species into three, namely, the Tana River Delta Area, the Fundisa Hill Area and the Ranching Project Area.

The Tana River Delta Area, having in the coastal area on the Indian Ocean, mangroves, Bushland, Shrubland and Grassland dominantly characterized by species unique to this area, is further divided into three by features of the inland side vegetation. Namely, the left bank (east side) of the Tana River is covered widely by Forest and Wooded bushland which is considered as secondary forest having some climax forests with trees reaching 30 m in height, whereas most of the right bank (west – southwest side) is covered by Bushland. The flood plains of the Tana River in the central part of the area are mainly Grassland. Among Forest and Grassland above, there are quite a few types that are found distributed only in the Tana Delta River Area.

The Fundisa Hill Area is mostly covered by Forest. The Ranching Project Area is mainly Bushland though the central part has extensive distributions of Bushed grassland or Grassland due to such artificial causes as field burning.

II - 5 SOIL

In term of soil distributions which come under strong influence of geology, landform and drainage, the study area is divided into the Tana River Delta Area, the Fundisa Hill Area and the Ranching Project Area.

In the east of the Tana River Delta Area, Cambisols and Arenosols are mainly distributed. Cambisols are found under the forest near Pandanguo, and Arenosols are widely distributed in the terrace around Mkunumbi. In the alluvial land of the Tana River two types of soil are distributed. Vertisols are developed in the place where the flooding occurs frequently, and Fluvisols are developed on the little higher place than Vertisols are. The western part of the Tana River Delta Area sees a wide distribution of Solonetz.

At the Fundisa Hill Area Cambisols which is strongly calcareous and moderately sodic are mainly distributed.

In the Ranching Project Area the distribution of soils is simpler than that of the Tana River Delta Area. Luvisols develop on the Triassic sediments and Solonetz develop on the Pleistocene river sediments.

II - 6 LAND USE

(1) Population and Settlement

Populated parts of the study area are distributed on the natural levees along the Tana River, the terraces to the east of the Tana River mouth, the islands, and the southern part of Fundisa Hill. These are areas favoured by climate and acquisition of water. The population total 88,000.

The largest town in the study area is Lamu, a tourist centre on the east coast of the Lamu Island with a population of 8,394. Other major settlements include Mokowe (population: 1,554) on the continental coast with a terminal for ferry connection with Lamu, Garsen (population: 1,007), a traffic centre on the west bank of the Tana River, and Witu (population: 2,288) located between Garsen and Mokowe. Populations were quoted from Kenya Population Census, 1979.

(2) Transportation

a. Road

B (National Trunk Road) Route 8 running from Mombasa to Garrissa goes through the Tana River Delta Area in the north-south direction from the coast of the Indian Ocean along the western edge of the Tana River. At Garsen, it branches out to the east as C (Primary Road) Route 112 reaching Mokowe by way of Witu. Those are the trunk roads in the study area. Though unpaved, they have regular bus services. C 112 is connected by ferry services as it crosses the Tana River.

There are such other roads connecting settlements as D (Secondary) and E (Minor and Track) roads and not a few of these become impassable during the rain seasons. In the Ranching Project Area, there is a relatively well developed road network though the roads are not paved.

b. Airstrip

There is an airstrip on Manda Island to the east of Lamu. It has a ferry connection to Lamu. At major settlements like Garsen, Witu, Mokewe, Mkunumbi and also in the Ranching Project Area, there are airstrips for small private aircraft.

(3) Industries and Land Use

a. Cultivated Land

There are plantations of coconuts, mangos, cashews, on the terraces in the east of the Tana River, Lamu Island, and Fundisa Hill in the south, and those of bananas along the Tana River.

Other cultivated land includes a large scale plantation settlement at Mpeketoni on the eastern terraces and small scale rice paddies scatteredly along the Tana River. There are cultivated lands in the vicinity of every settlement raising maize, cotton.

b. Livestock

In the Ranching Project Area is the Galana Ranch which gets water supply from the Galana River by means of pipelines as well as from under the ground. In the Tana River Delta Area, there are rangelands raising cattle. They rely on rains for most of its water needs. During the dry season, they turn to the flood plains of the Tana River for water and grass.

c. Timber and Charcoal

As a major timber resource, there are mangroves in the coastal area. In the settlements on the terrace charcoal is produced.

d. Tourism

Lamu attracts a sizeable number of tourists as a unique tourist place with its Arabic type town. On the coast of the Indian Ocean, east of the Tana River mouth, including the islands of Lamu and Manda, there are ruins of historic settlements.

e. Salt Field

There are sun-dry salt fields located on the sandflats in areas from the southern end of the Tana River Delta over to the southern coastal area.

III. RESULTS OF STUDY

III. RESULTS OF STUDY

The study was performed in the following procedure. (Refer to the annex for Implementation and methodology of the Study.)

Reconnaissance Survey

A reconnaissance Survey of the entire study area was conducted to set criteria for study and policy for subsequent phases of the study.

Preliminary Photo Interpretation

For each theme of the study, photo interpretation was performed based on the findings of the reconnaissance survey, existing documents and other information, and interpretation maps were compiled on 1/50,000 scale topographic maps.

Field Survey

In addition to the field observations, auger boring, vegetation sampling survey and other necessary surveys were conducted and based on the findings the interpretation maps were corrected.

Thematic Map Compilation

Based on the findings of the field surveys, the interpretation maps were further substantiated by final photo interpretation and compilation manuscripts of the thematic maps were produced.

Drafting and Printing

Based on the manuscripts, each thematic map was finalized and printed in accordance with the specifications. The index of the thematic maps produced is given in Fig. III-1.

The aerial photographs (scale: 1: 60,000) used above were those taken during 1977--1979 and the topographic maps (scale: 1: 50,000) used as bases were those published in 1981.

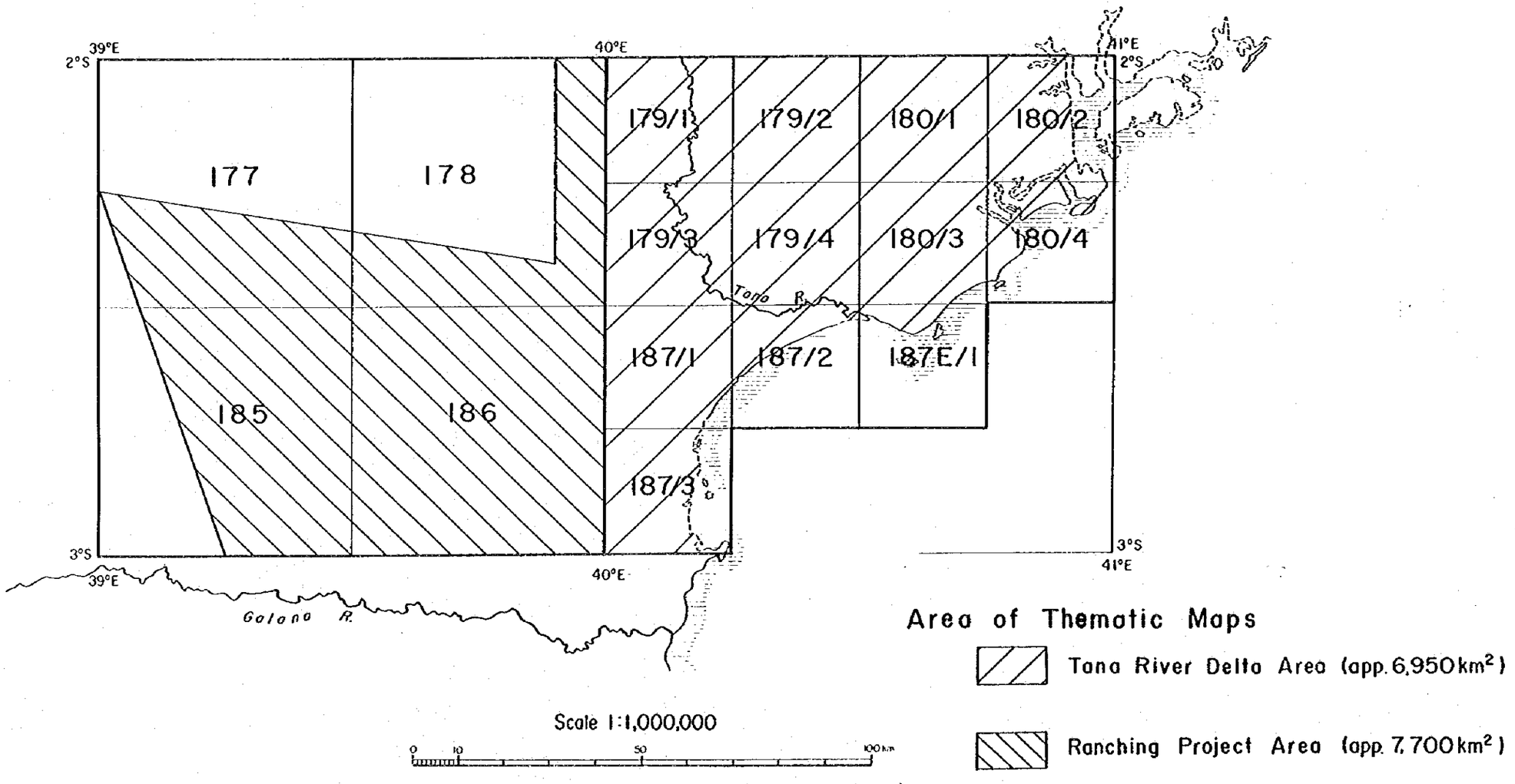

Fig. Ⅲ-1 Thematic map index

III - 1 GELOLOGY

Geology of the study area had been partially studied by L.A.J. Williams (1962) and R.G. Dodson (1966). While referring to their study results, geologic data were acquired by conducting auger boring as well as outcrop observation on the basis of the interpretation maps. Electric prospecting was conducted in the Mkumumbi area in the eastern part of the Tana River Delta Area and parts of the Ranching Project Area.

The legend items of geology for the study area and the schematic map of geology are gigen in Table III-1 and Fig. III-2 respectively. The study results for Tana River Delta Area and Ranching Project Area were made into 1/50,000 and 1/100,000 scale geology maps (blue prints) respectively. With respect to the Tana River Delta Area, they served as basis for surface geology and soil mapping (scale: 1/50,000).

III - 1 - 1 TRIASSIC (Tr_1)

With light yellow medium grained sandstones as a major component, this is comprised also by dark gray – reddish brown shales and gray – reddish brown conglomerates. It corresponds to R.G. Dodson's (1966) Duruma Sandstone. It is distributed in the western half of the Ranching Project Area and, except for the residual hills of Dakabuko and Dakadima, mostly covered by Pliocene (Pl_1) and Pleistocene (Pt_5) which are referred to later.

Structurally, it presents a homocline with strikes and dips of N25°E, 15°SE at Dakabuko, N20°W, 10°NE at Dakadima, and N10°W, 25°NE at Lale Hill.

III - 1 - 2 JURASSIC (Ju_1)

Distributed in the eastern half of the Ranching Project Area, this corresponds to L.A.J. Williams' (1962) upper Jurassic deposits. It has few outcrops. Core observations by auger boring shows that it is composed mainly of calcareous sandstones and conglomerates. It contacts the lower Triassic at its basal conglomerates in uncomformity and partially in faults. Structurally, it is assumed to have an eastern homocline.

Table III-1 Legend Items of Geology

Geological Age		Symbol	Explanation
Quaternary	Recent	Re_0	Alluvial deposits; silts, sands and clays
		Re_1	Beach sands and muds of the coastal creeks
		Re_2	Dune sands
		Re_3	Fan deposits; clays, sands and gravels
			~~ Unconformity ~~~~~
	Pleistocene	Pt_1	Old dune sands
		Pt_2	Raised coral reef
		Pt_3	Lagoonal calcareous sandstones
		Pt_4	Lagoonal sands and clays
		Pt_5	Pleistocene river sediments; sandy clays, sands and gravels
			~~ Unconformity ~~~~~
Tertiary	Pliocene	Pl_1	Pliocene marine sediments, sandy clays and bright red sands
		Pl_2	Pliocene river sediments; gray silty sands and gravels
			~~ Unconformity ~~~~~
	Miocene	Mi_1	Miocene sediments; limestones, calcareous sandstones and clayey sandstones
			~~ Unconformity ~~~~~
Jurassic		Ju_1	Jurassic sediments; calcareous sandstones and conglomerates
			~~ Unconformity ~~~~~
Triassic		Tr_1	Triassic sediments; sandstones, conglomerates and shales

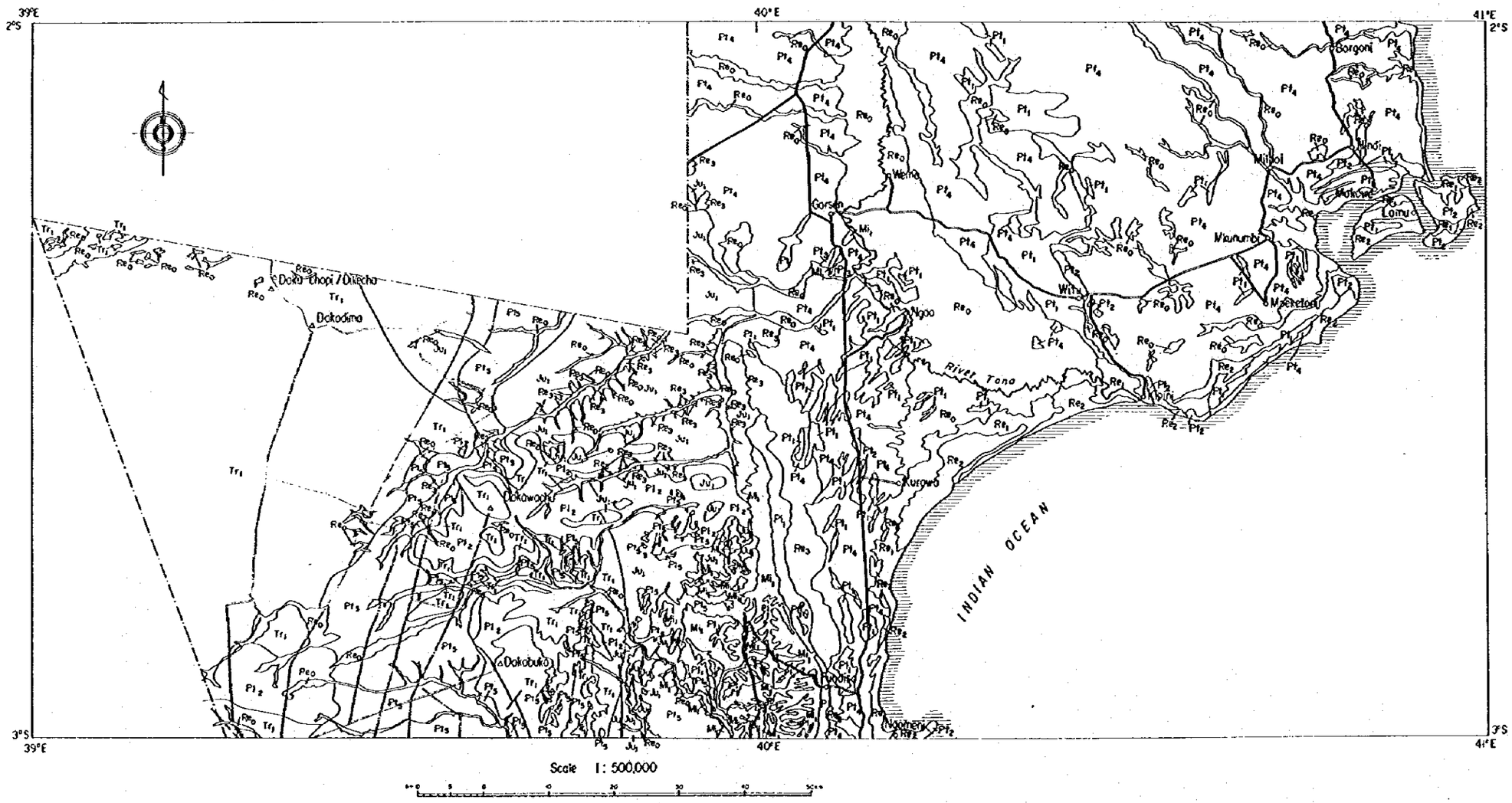

Fig. Ⅲ-2 Schematic map of Geology

III - 1 - 3 TERTIARY

(1) Miocene (Mi_1)

Composed mainly of limestones containing large amounts of fossilized sea shells and foraminiferas accompanied by calcareous sandstones, this is distributed in Fundisa Hill and Minjira Hill to the south of Garsen. The limestones are yellowish white and accompanied by red soils. It contains fossils of mollusca, gastropods, foraminiferas as well as corals and spikes of sea urchins.

(2) Pliocene (alluvial sediments - Pl_2)

Consisting of gray silt gravels, this is distributed in the Lale Hill area and east of Dakawachu in the Ranching Project Area. From its facies, it is asumed alluvial.

(3) Pliocene (marine sediments - Pl_1)

Consisting of dark brown - dark olive gray sandy clays, this is distributed east and west of Fundisa Hill. From its facies, it is assumed marine.

III - 1 - 4 QUATERNARY

(1) Pleistocene (alluvial sediments - Pt_3)

This consists of dark gray sandy clays and reddish brown sands as major components accompanied by pebble bed. It occurs in areas at the foot of Lale Hill, fanning out to east. From its facies, it is assumed fluvial.

(2) Pleistocene (lagoonal sands, clays - Pt_4)

Consisting of dark gray – dark brown lagoonal sands and clays, this is distributed north of Fundisa Hill only.

(3) Pleistocene (lagoonal calcareous sandstones – Pt_3)

This consists of light brown – gray white calcareous medium to coarse grained sandstones. Laminae and sand pipes are well developed. It is distributed north of Fundisa Kibaoni and southeast of Mpeketoni.

(4) Pleistocene (coral limestones – Pt_2)

Consisting of light yellowish brown – reddish brown conglomerated or layered coral limestones, it is distributed west of Kurawa, small terraces from Witu to Kipini, east of Mpeketoni, south of Hindi, and Manda Island. The limestones contain fossils of sea shells, spikes of sea urchins in addition to corals.

(5) Pleistocene (old dune sands – Pt_1)

Consisting of dark brown – dark olive gray fine to coarse grained sands, they occur mainly in small terraces and micro reliefs. Old dunes are distributed in the north-south direction near Fundisa Hill, northeast-southwest at Ngao, east-west at Witu, and northeast-southwest in the northwest of Milhoi.

(6) Recent (fan deposits – Re_3)

Consisting mainly of dark gray sandy clays, accompanied with round gravels, it is distributed east and west of Fudisa Hill.

(7) Recent (dune sands – Re_2)

Consisting of light yellow – light olive fine to coarse sands, they occur in parallel to the present coastline.

(8) Recent (beach sands and muds of coastal creeks – Re_1)

Beach sands consist of white – light yellowish white fine to coarse sands and form the present coasts. Muds of coastal creeks consist of black – dark brown clays and indicate relatively calm environment for sedimentation. Humic layers are developed where mangroves grow.

(9) Recent (alluvial deposits; silts, sands, clays – Re_0)

Consisting of light yellowish gray – dark brown – dark gray sands, silts and clays, this is widely distributed along the Tana River. It also occurs on a smaller scale in valley bottoms and lowland of Gandi, Adadi and Buna Rivers.

III - 1 - 5 GEOLOGICAL HISTORY AND STRUCTURE

Geological structure of the study area is not clear due to the limited presence of outcrops. The basement of the study area appears to be composed of the Triassic deposits and the Jurassic deposits adjoining in uncomformity and has a homocline sloping generally northeast or east.

Cretaceous and early Tertiary deposits are not confirmed as existing in the coastal area of Kenya. It is assumed therefore that the basement was raised around those periods, and eroded, to form a homocline structure.

During the mid-Tertiary, Miocene sediments were developed around Fundisa Hill. And in the late Tertiary, alluvial sediments and marine sediments were developed in the Ranching Project Area and Fundisa Hill respectively. At Fundisa Hill, two or three flats of what appears like depositional surfaces of Pliocene marine sediments were observed to indicate intermittent upheavals had taken place.

During the Quaternary, active erosion took place west of Dakabuko in the Ranching Project Area to cause fluvial sediments of the Pleistocene around Dakabuko – Fundisa, lagoonal sands, clays, calcareous sandstone deposits in the Tana River Delta Area, and coral reefs formed. Furthermore, during the Alluvial period, sand dunes and fluvial deposits of the Tana River were formed.

Little is known about details of faults and folds in the study area. L.A.J. Williams (1962) noted a Kazakini fault running north from south of the study area. But it was not based on actual observation of any geologic or geomorphologic features to support the presence of faults. In the course of our survey, there was nothing discovered to prove the existence of any fault and therefore it was asumed that there actually exists no Kazakini fault in the study area.

L.A.J. Williams (1962) also pointed out the possibility of Duruma sandstones forming a syncline between Dakabuko and Dakawachu. But there are few data available to prove it and so this is no

more than a possibility. With respect to his assumption of anticline in the Fundisa area, there are few data and it is considered that there is little evidence to support his suggestion.

III - 1 - 6 ECONOMIC GEOLOGY

(1) Groundwater

Water supply is a very serious problem in the coastal region of Kenya. The Tana and Athi Rivers serve as important sources of water supply. But in areas with no access to these rivers, water holes and groundwater are relied upon. In order to survey the presence of shallow groundwater (less than 50 m in depth), electic pospecting was performed at typical locations.

Measurements were taken by the Wenner Method with electrode intervals of 0.5 – 50 m. Analysis was made by means of visual observation and the standard curve method combined. The underground structure was examined by performing layer comparisons based on the resistivity method and resistivity of layer.

In the Tana River Delta Area, prospecting was performed at 19 locations south of Mkunumbi. As a result, it has been found that there is no constant shallow groundwater at Mkunumbi. Whereas in the Ranching Project Area, prospecting was performed at 4 locations in the central part. But there has been found no permanent distribution of shallow groundwater in this area.

From these results and aerial photo interpretation, it is concluded that there is little promise of shallow groundwater in the Tana River Delta Area and the Ranching Project Area as well except for areas near the main stream of Tana River, Hadu, and several locations in the Ranching Project Area.

(2) Aggregates

Coral limstones are crushed at locations west of Hindi, Witu, and Kurawa and made available for wide use as aggregates for road construction. Lagoonal calcareous sandstones are quarried south of Fundisa Kibanoni, Garsen and used as materials for civil engineering works.

(3) Ilmenite

As L.A.J. Williams (1962) noted, the beach sands on the Indian Ocean coast contains ilmenite. But due to its poor quality, it is not commercialized.