III - 2 LANDFORM

Regarding landform classification, the preliminary photo interpretation was first performed. The interpretation was confirmed and corrected using the results of observation of macro, meso, and micro reliefs in the field survey and the results of survey on the constituent materials of landform. Landform classification was complemented by the final photo interpretation.

Slope classification was made by performing morphometry from the 1/50,000 scale topographic map (Tana River Delta Area only). Drainage classification was made by reading the 1/50,000 scale topographic maps and interpreting aerial photos, and the drainage classification thus made was confirmed by the field survey.

Based on the above data, the Landform, Slope and Drainage Map (Landform and Drainage Map for Ranching Project Area) were compiled.

The legend of landform shown in Table III-2 was made based on the "Definitions of Land Forms in Relation to Soil Mapping and Map Legend Construction" of Kenya Soil Survey and by adding some legend items for lowlands. Figure III-3 shows the schematic map of landform. Slope classification was made by the classification of Kenya Soil Survey. Drainage was classifed into permanent river and seasonal river.

As for printing colour design of Landform, Slope and Drainage Map and Landform and Drainage Map, flood plains, valley bottom lowlands and other plains are in green to bluish green, natural levees and dunes, in yellow group colours, terraces, in orange group with a gradual change in colour from cold to warm along with an ascending change in level from a wet lowland to a dry highland, and hills, plateaus and uplands, in brown to purple. Slope classification (Tana River Delta Area only) was represented by Arabic figures, and drainage, by dark blue lines (solid lines and broken lines).

The 1/50,000 scale topographic map was used as a basic map. This is the same with Vegetation and Present Land Use Map, and Surface Geology and Soil Map.

Table III-2 Legend of Landform

Macro – Meso Relief			Symbol	Landform Type
Hills			H	Hill
			Hr	Residual hill
			Hs	Minor scarp
Footslopes			F	Footslope
			C	Talus (Scree) slope
Plateaus			L	Plateau
Uplands			U	Upland
			Ud	Dissected peneplain
Plains	Erosional plains		Pn	Peneplain
	Sedimentary Plains	Piedmont plains	Y	Piedmont plain
		Terraces	Pt_1	Higher terrace
			Pt_2	Middle terrace
			Pt_3	Lower terrace
		River alluvial plains	Pf	Fan
			Pl	Natural levee
			A	Flood plain
			V	Valley bottom lowland
			Or	Old river bed
		Coastal plains	Pc	Coastal plain
			PcL	Raised coral reef
			Il	Interlevee lowland
			Z	Coastal ridge
			D	Dune
			Dz	Old dune and old coastal ridge
		Tidal flats	Tm	Marsh, Mangrove flat
			Ts	Sand flat
Bottom lands			B	Bottom land
Miscellaneous			S	Swamp
			Ol	Oxbow lake
			O	Pan and pond
			W	Bad land
				River
				Cliff

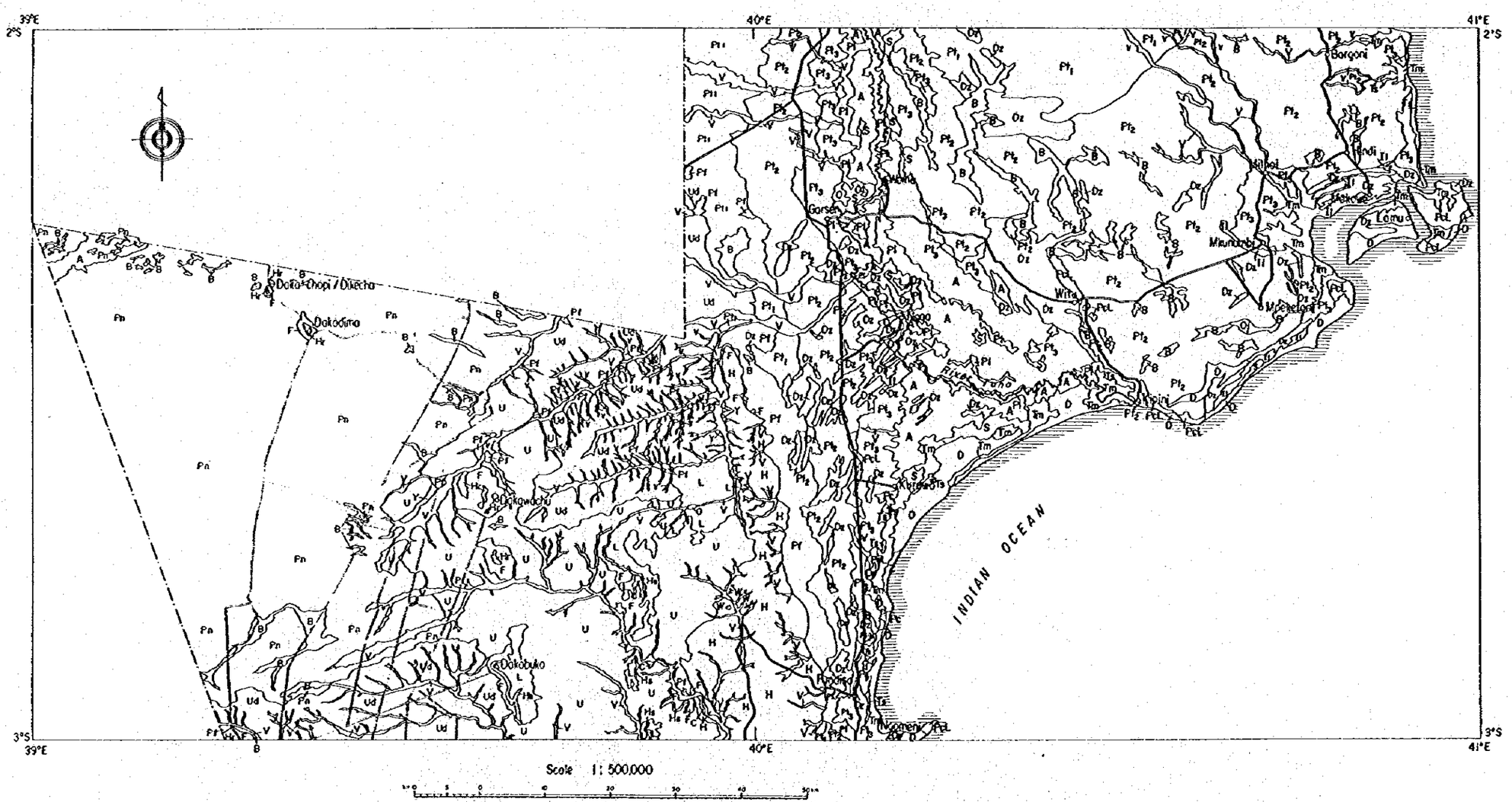


Fig. III-3 Schematic map of Landform

III - 2 - 1 HILLS

Hills are landforms dissected until the original landforms disappear, characterized by substantial relief and slope, but not so much like a mountain, and elevated above the adjacent landscape. Slope is generally 8 – 30% (30 – 40% maximum). Relief is at most 300 m and is generally about 100 m high. Landforms dissected by dendritic drainage and of continuous reliefs extending over a vast area are defined as Hill (H). Against the erosion isolated landforms are Residual hill (Hr). Relatively steep, linear cliffs separating surfaces lying at different levels are Minor scarp (Hs).

(1) Hill (H)

Hill refers to Fundisa Hill, which is 50 – 80 m in relief, rolls, and is dissected by small dendritic drainage. Geologically, Fundisa Hill is composed primarily of Tertiary limestones and calcareous sandstones.

(2) Residual hill (Hr)

Residual hill refers to Dakadima, Dakawachu and Hoshingo Hill in Ranching Project Area. Relative heights are 20 – 90 m. Geologically, these hills are composed of Triassic rocks.

(3) Minor scarp (Hs)

Minor scarp (Hs) is a steep linear cliff. It occurs to the west of Dakabuko and in the Gandi River Valley region to the east of Dakabuko. Geologically, minor scarps lying to the west of Dakabuko are of Triassic sandstones, and those in the Gandi River region, of Jurassic calcareous sandstones.

III - 2 - 2 FOOTSLOPES

Footslopes are formed at the foot of mountains and around residual hills. Gradients of slopes are 2 – 8% (up to 16% near mountains). Their relative heights are usually 10 m or below. Footslopes are classified into relatively large-scaled gentle slopes (gentle slopes at the foot of mountains) and small-scaled sharp slopes (taluses) formed at the foot of steep cliffs and slopes by fragments of rocks dropped from above.

(1) Footslope (F)

Footslope is distributed around Dakabuko, Dakawachu and Dakadima and along the Gandi River in a large scale. It is composed primarily of medium grained sand.

(2) Talus slope (C)

Talus slope is smaller in scale and distributed along small rivers and streams in Fundisa Hill. It is composed primarily of coarse grained sand.

III - 2 - 3 PLATEAUS (L)

Plateau is a flat- or almost flat-surfaced landform, elevated above the adjacent landscape and limited by an abrupt descent on at least one side. Some plateaus are dissected by deep valleys; however, their flat surfaces are in about the same elevation. Their origins are tectonic or of residual hills. The surface gradient is 0 – 8% (8 – 16% in some cases), and relief is 50 m or less. Plateaus are distributed in Dakabuko in Ranching Project Area and to the north east of the Gandi River. Geologically, the plateaus are composed of Triassic sandstones or of Jurassic sandstones and Pliocene silty sands and gravels (Pl_2).

III - 2 - 4 UPLANDS

Uplands have undulations, but surfaces of a flat or gently sloped original landform are in about the same elevation. Dissection is caused by the past erosion; the present erosion is quite weak. The surface is in gentle undulation. Gradient of slopes is 0 – 16%, and relief is usually 50 m or less. Those uplands deeply dissected are called dissected peneplain (Ud), differentiated from Upland (U).

(1) Upland (U)

Upland is widely distributed around Dakawachu and extends east to the Gandi River. The land surface undulates at a pitch of 1 – 2 km at a relative height of 10 odd metres. Geologically, uplands are composed of Triassic sandstones and Jurassic calcareous sandstones.

(2) Dissected peneplain (Ud)

Dissected peneplain is found widely in areas about Lale Hill and to Dakabuko and also extends north-east to the Mukale area. As compared with Uplands (U), the valley density is higher. The land surface assumes undulations rising at a pitch of 4 – 5 km. Geologically, dissected peneplain is composed primarily of Jurassic calcareous sandstones.

III - 2 - 5 PLAINS

Plains are level or quite gently undulating landforms, and the land surface is almost free of irregularities. Plains are subdivided into erosional plains and sedimentary plains according to the process of formation.

(1) Erosional plains

(a) Peneplain (Pn)

Paneplain is a land surface changed to a plained by erosion over a long period of time and consists of shallow valleys and broad tracts between rivers. Surface gradient is 0 – 5%, and relief is 10 m or less. Peneplain is widely distributed in the western half of Ranching project Area. Geologically, peneplains are composed of Triassic sandstones.

(2) Sedimentary plains

(a) Piedmont plain (Y)

Piedmont plain is a gentle, sedimentary slope extending along the foot of mountains and is formed by confluent fans. Surface gradient is 0 – 5%, and relief is within 20 m. Foot plain is distributed along the downstream of the Buna River and the Adadi River in Ranching Project Area.

(b) Terraces

Terraces are plains of level or nearly level surface bounded by a steep slope or cliff from a lower land. Terraces were formerly river plains or coastal plains. Surface gradient is nearly horizontal, and relief is within 10 m. Terraces were classified into higher terrace (Pt_1), middle terrace (Pt_2), and lower terrace (Pt_3) according to the period of formation, relative height, and other factors. Terraces are formed by sands

and clays. Higher terrace is widely distributed along the eastern edge of Fundisa Hill and to the north of the Hill. Middle terrace accounts for a large part of terraces extending to the east of Tana River Delta and is distributed continuously on the east of Pt_1 in the area extending to the west and south of the delta. Lower terrace is distributed in the eastern area extending from Mkunumbi to Mokowe and along the coast extending to the south of the southwest end of Tana River Delta.

(c) River plains

i) Fan (Pf)

Fan is a fan-shaped sedimentary landform of gravels sloping gently from the lower mouth of a stream toward a plain. Fan is continuously distributed on the east of Fundisa Hill and also along small rivers in Ranching Project Area.

ii) Natural levee (Pl)

Natural levee is formed mainly by sandy materials transported from upstream and deposited along the river channel. Natural levee is continuously distributed along the new and old channels of the Tana River, and their heights above flood plains are 5 m or less.

iii) Flood plain (A)

Flood plain is a flat lowland formed by regular floods. Flood plain is composed of deposits of various grain sizes, usually coarse grained sandy deposits. Flood plain extends over the broad tract behind natural levee lying along the Tana River and get submerged naturally in the rain season.

iv) Valley bottom lowland (V)

Valley bottom lowland is a flood plain formed in a narrow, long valley. Valley bottom lowland is distributed in the eastern Milhoi region and along the right bank of the Tana River to the north of Garsen in Tana River Delta Area. As for Ranching Project Area, it is distributed along valleys of the Gandi River, the Adadi River and the Buna River. It is made of fine grained sands and clays.

v) Old river bed (Or)

Old river bed is a past river channel isolated by a change in river course. Old river bed is distributed along the both sides of the Tana River. It is very likely to get submerged in the rain season. It is composed of fine grained sands and clays.

(d) Coastal plains

i) Coastal plain (Pc)

Coastal plain is a relatively level plain formed by a bottom of the sea which raised in a quite recent epoch and its height is several metres or less above sea level. Coastal plain is broadly distributed along the Indian Ocean extending to the south of Tana River Delta. They are composed of medium grained sands.

ii) Raised coral reef (PcL)

Raised coral reef is a recent coral reef appearing above the present sea surface. Raised coral reef is broadly distributed in Kipini, Witu, Mpeketoni and Manda Island and composed of skeletal remains of coral, mollusca, and spikes of sea urchins.

iii) Interlevee lowlands (Il)

Interlevee lowland is a low-level, swampy land of poor drainage between or behind dunes or coastal ridges and is composed of fine grained materials. Interlevee lowland is distributed long and narrow, east of Kipini along the coast.

iv) Coastal ridge (Z)

Coastal ridge is a long, narrow ridge formed by marine deposition. Coastal ridge is composed of sandy deposits and distributed along the coast.

v) Dune (D)

Dune is a mound of sand formed by wind. Dune is usually distributed in parallel with the coast. Gradient of slopes is 0 – 10%, and some dunes are as high as 80 m in relative height. Dune is almost continuously distributed from the front of Tana River Delta to Manda Island.

vi) Old dune and old coastal ridge (Dz)

Old dune and old coastal ridge are dunes and coastal ridges formed at an old time and stabilized at present. They are distributed on the inland side. Several rows of them run in parallel on terraces located on both sides of Tana River Delta and from slightly inside the present coast line toward the inland. Their running directions are north to south in the southern region, northeast to southwest on the west of the delta, east to west on the east of the delta, and northwest to southeast in the northern region.

(c) Tidal flats

i) Marsh, Mangrove flat (Tm)

Marsh and Mangrove flat are an intertidal flat land of quite poor drainage. Mangrove flat is a swamp distinguished by the abundance of mangrove trees. It is composed of muds or fine grained sands and distributed south of the southwest end of Tana River Delta, about the month of the Tana River, about Mpeketoni, Milhoi, and Mokowe in the eastern region, Manda Island, and so on.

ii) Sand flat (Ts)

Sand flat is a low-level, flat land extending from a mangrove flat toward the inland, composed primarily of sandy deposits.

III - 2 - 6 BOTTOM LAND (B)

Bottom land is a flat, basin-like lowland formed by blocking a valley. Bottom land of a large scale is distributed about the Kenyatta Lake in the eastern terrace region, Witu, and so on. Bottom land is also found in peneplains in the western part of Ranching Project Area. It is likely to get submerged in the rain season.

III - 2 - 7 MISCELLANEOUS

(1) Swamp (S)

Swamp is a waterlogged land of poor drainage and flooded in the rain season. Swamp is distributed behind natural levees along the Tana River, in the area surrounded by dunes, and in a partial area of bottom lands.

(2) Oxbow lake (Ol)

Oxbow lake is the body of water in an abandoned channel of a formerly meandering stream after a neck cutoff. Oxbow lake is distributed on both sides of the Tana River. It is composed of fine grained sands and clays.

(3) Pan and pond (O)

The body of water other than oxbow lakes.

(4) Bad land (W)

Bad land is a land of poor vegetation with numerous gullies developed in its slope. Bad land is distributed in a part of Fundisa Hill.

(5) River

(6) Cliff

III - 3 VEGETATION AND PRESENT LAND USE

Vegetation was classified by physiognomy through the preliminary photo interpretation, and the results of the classification were checked by field survey. Land use items such as farm and village were also determined from aerial photos. Sampling survey of vegetation (139 samples) was conducted for an area of about one hectare (100 m x 100 m). Check lists of representative species of trees, herbage and grasses in the Kenya Soil Survey's format were prepared to determine dominant species and subdominant species. Based on this determination, vegetation was classified into subdivisions.

The final photo interpretation was conducted based on the results of the above survey and analysis to prepare the Vegetation and Present Land Use Map.

As shown in Table III-3, vegetation was classified by physiognomy and divided further according to tree phases and species. Farm, plantation, town, village, and so on were determined as land use classification items. The schematic map of vegetation/present land use is shown in Fig. III-4. Criteria for vegetation classification by physiognomy are given in Table III-4. Types of land use (timber production, charcoal production, livestock grazing, etc.) for the respective vegetation items are shown in the last column of the table.

As for print colour design, colours for vegetation were changed gradually from green group colours of forests to yellow of grasses according to crown density and tree height, and land use (farm, village, etc.) was represented in principle in warm colours from orange to red.

Table Ⅲ－3 LEGEND OF VEGETATION / PRESENT LAND USE

Division	Symbol	Sub-division	Dominant species	Land Use	
Forest	F–1	Forest (1)	Manilkara sansibarensis, Terminalia brownii, Chlorophora excelsa / Brachiaria brizantha	Timber production	
	F–2	Forest (2)	Brachystegia spiciformis, Suregada zanzibarensis, Cissus rotundifolia, Adenium obesum, Euphorbia grandicornis, Afzelia cuanzensis / Mariscus macropus, Mariscus sp. Panicum maximum	Timber production	
	F–3	Forest (3)	Diospyros cornii, Thespesia danis, Grewia sp., Dobera glabra / Panicum maximum, Leptothrium senegalense	Wildlife grazing Charcoal production	
	F–4	Forest (4)	Hyphaene coriacea, Harrisonia abyssinica / Panicum maximum, Panicum infestum, Hyperhenia rufa	Wildlife grazing	
	F–5	Forest (5)	Phoenix reclinata, Barringtonia racemosa	Wildlife grazing	
	F–6	Forest (6)	Avicennia marina, Rhizophora mucronata, Bruguiera gymnorrhiza /	Timber production	*1.
Woodland	WBt–1	Wooded bushland thicket (1)	Elaeodendron aquifolium, Rhoicissus revoilii, Millettia lasiantha, Croton dichogamus, Nectaropetalum Kaessneri / Mariscus macropus, Enteropogon sp.	Wildlife grazing	
	WBt–2	Wooded bushland thicket (2)	Dobera glabra, Grewia sp., Commiphora schimperi / Panicum infestum, Leptothrium senegalense, Cenchrus ciliaria, Panicum maximum	Wildlife grazing	*1
	WBt–3	Wooded bushland thicket (3)	Borassus aethiopum, Combretum sp. / Echinochloa sp., Cynodon dactylon	Wildlife grazing	
	WB–1	Wooded bushland (1)	Delonix elata, Platycelyphium voense, Boscia coriacea, Indigofera spinosa, Grewia forbesii, Cassia singueana / Aristida kenlensis, Schoenefeldia transiens	Wildlife grazing	*2
	WB–2	Wooded bushland (2)	Diospyros cornii, Thespesia danis, Terminalia spinosa, Croton dichogamus / Sporobolus marginatus, Schoenefeldia trasiens	Wildlife grazing Livestock grazing	
	WB–3	Wooded bushland (3)	Hyphaene coriacea, Terminalia spinosa, Thespesia danis / Digitaria milanjiana, Panicum infestum	Wildlife grazing Livestock grazing	*1,2
Bushland	Bt	Bushland thicket	Dombeya sp., Grewia similis / Panicum maximum, Enteropogon macrostachyus	Wildlife grazing	
	B–1	Bushland (1)	Dobera glabra, Thespesia danis, Grewia tenax, Combretum hereroense, Ecbolium striatum, Diospyros cornii, Indigofera schimperi / Schoenefeldia transiens Digitaria milanjiana	Livestock grazing Wildlife grazing	*2
	B–2	Bushland (2)	Boscia coriacea, Combretum hereroense, Commiphora campestris, Commiphora erythraea, Commiphora riparia, Dobera glabra, Cordia sinensis, Hermania uhligii, Salvadora persica, Euphorbia robecchii / Schoenefeldia transiens, Sporobolus helvolus, Panicum sp.	Livestock grazing Wildlife grazing	*2
	BG–1	Bushed grassland (1)	Dobera glabra, Thespesia danis, Grewia tenax, Combretum hereroense, Ecbolium striatum / Cynodon dactylon, Cenchrus ciliaris, Schoenefeldia transiens	Ranching area	
	BG–2	Bushed grassland (2)	Cordia sinensis, Boscia coriacea, Dobera glabra, Grewia villosa / Eragrostis superba, Enteropogon macrostachyus, Schoenefeldia transiens	Ranching area	
	BG–3	Bushed grassland (3)	Acacia zanzibarica / Sporobolus helvolus	Livestock grazing, Wildlife grazing	
Shrubland	S	Dwarf Shrubland	Maytenus undatus, Balanites orbicularis / Panicum infestum, Cyperus articulatus	Wildlife grazing	
Grassland	G–1	Grassland (1)	/ Schoenefeldia transiens, Cenchrus ciliaris	Ranching area	
	G–2	Grassland (2)	/ Echinochloa haploclada, Echinochloa staginina, Sporobolus helvolus, Panicum maximum, Cynodon dactylon	Livestock grazing Wildlife grazing	
	G–3	Grassland (3)	/ Cyperus rotundas, Echinochloa colonum	Wildlife grazing, seasonal rice fields	
	G–4	Grassland (4)	Suaeda monoica / Sporobolus spicatus	Wildlife grazing	
Cultivated land	Cr・Co	Cropland (Cr: Rice / Co: Others)			
	C_2	Cropland (mixed cropland and grazing area)			
	Pm・Pco・Pb	Plantation (Pm: Cashew nut and Mango / Pco: Coconut / Pb: Banana and Mango)			
	P_2	Plantation (other)			
Farmland	Fa	Farm (cattle enclosure)			
Others	T	Town			
	V	Village			
	Ab・Am・Ag	Airstrip (Ab: Bound surface / Am: Murram surface / Ag: Grass surface)			
	Ra・Rd	Motorable road (Ra: All weather road / Rd: Dry weather road)			
	Sf	Salt field			
	P	Pan and pond			
	Bl	Barren land			
	D	Dam			

Notes

*1 : Heights of trees are sometimes lower than 10 m.

*2 : Patches of grasses are sometimes scattered.

/ : In the column of dominant species, the former are trees, shrubs and herbs, the latter are grasses and sedges.

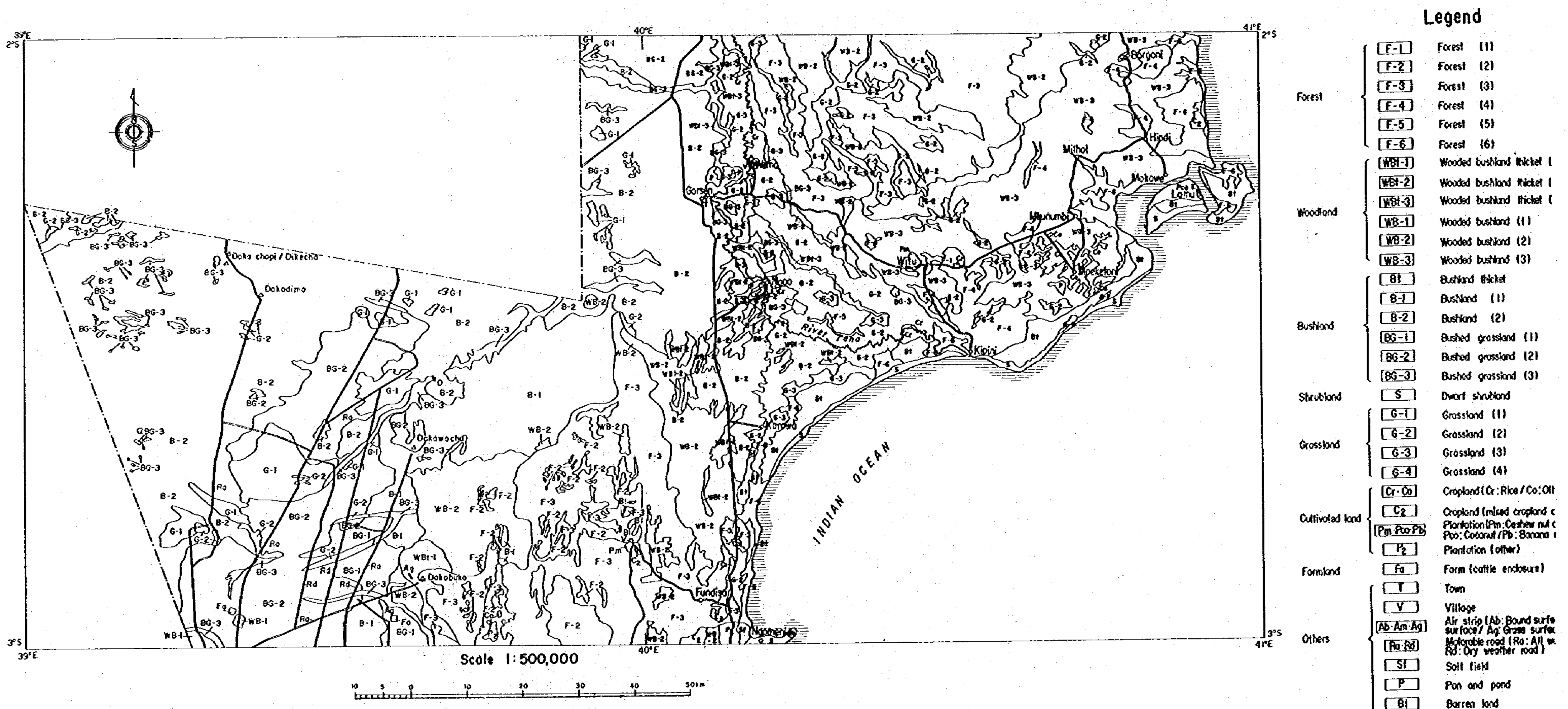


Fig. III-4 Schematic map of Vegetation/present land use

Table III-4 Classification by physiognomy

Division	Vegetation	Tree (more than 10 m)	Shrub		Grass
			Tall (6 – 10 m)	Small (less than 6 m)	
Forest		more than 20			
Woodland	Wooded bushland thicket	5 – 20	more than 20	more than 20	
	Wooded bushland	5 – 20	more than 20		
Bushland	Bushland thicket	less than 5	more than 20	more than 20	
	Bushland	less than 5	more than 20		
	Bushed grassland	less than 5	5 – 20		more than 20
Shrubland	Dwarf shrubland	less than 5		more than 20	
Grassland		less than 5	less than 5		more than 20

Figures indicate crown cover (%)

III - 3 - 1 FOREST

Landscape of vegetation of 10 m or higher in tree height and 20% or more in crown density.

Forest is classified into six groups according to dominant species. Forests (2) and (3) are distributed in Ranching Project Area, whereas Forest (1), (3), (4), (5) and (6) are mainly found in Tana River Delta Area.

(1) Forest (1) (F-1)

Climax forest distributed to the east of Witu. Forest (1) is dominated by Manikara sansibarensis, Terminalia brownii and Chlophora excelsa. Some trees are as high as 30 m. Forest (1) is now protected and controlled by the Government.

(2) Forest (2) (F-2)

Forest characterized by Brachystegia spiciformis, distributed sporadically in Fundisa Hill. Dominant species are Brachystegia spiciformis, Suregada zanzibarensis, Cissus rontundifolia, Adenium obesum, Euphorbia grandicornis and Afzelia cuanzensis.

(3) Forest (3) (F-3)

Forest characterized by Diospyros cornii, distributed widely in Fundisa Hill and the northern part of terraces located on the east of Tana River Delta Area. Dominant species are Thespesia danis, Grewia sp. and Dobera glabra.

(4) Forest (4) (F-4)

Forest characterized by Hyphaena coriacea, distributed in the eastern terraces of Tana River Delta Area at around Hindi and to the north of Kipini. Dominant species is Harrisonia abyssinica.

(5) Forest (5) (F-5)

Forest characterized by Phoenix reclinata, distributed along the Tana River. Dominant species is Barringtonia racemosa.

(6) Forest (6) (F-6)

Mangrove forest, distributed in the mouth of the Tana River, in the coastal area to the south of Tana River Delta, Lamu Island, and so on. Dominant species are Avicennia marina, Phizophora mucronata, and Bruguiera gymnorrhiza.

III - 3 - 2 WOODLAND

Landscape of vegetation of 5–20% in crown density of trees (10 metres or higher in height). Woodland is classified into wooded bushland thicket and wooded bushland according to height and crown density of shrubs of less than 10 metres in height. Both groups are divided further into three subgroups each according to dominant species.

(1) Wooded bushland thicket

Woodland of tall shrubs of 6–10 m in height and small shrubs of less than 6 m with crown density of more than 20% respectively.

(a) Wooded bushland thicket (2) (WBt-1)
Distributed on the west of Dakabuko in Ranching Project Area. Dominant species are Elaeodendron aquifolium, Rhoicissus revoilii, Milletia lasiantha, Croton dichogamus and Nectaropetalum kaessneri.

(b) Wooded bushland thicket (2) (WBt-2)
Distributed only around Kurawa and Ngao in Tana River Delta Area. Dominant species are Dobera glabra, Grewia sp. and Commiphora schimperi.

(c) Wooded bushland thicket (3) (WBt-3)
Distributed only on the left bank of the Tana River to the east of Garsen. Dominant species are Borassus aethiopom and Combretum sp..

(2) Wooded bushland

Woodland of tall shrubs and small shrubs with a combined crown density of more than 20%. Divided into three subgroups according to dominant species.

(a) Wooded pushland (1) (WB-1)

Distributed in Lale Hill in the southwestern part of Ranching Project Area. Dominant species are Delonix elata, Platycelyphium voense, Boscia coriacea, Indigofera spinosa, Grewia forbesii and Cassia singueana.

(b) Wooded bushland (2) (WB-2)

Dominant species are Diospyros cornii, Thespesia danis, Terminalia spinosa and Croton dichogamus. Distributed surrounding Forest (3) on both sides of Fundisa Hill and eastern terraces of Tana River Delta Area, characterized by Diospyros cornii. It is the second-growth of Forest (3).

(c) Wooded bushland (3) (WB-3)

Distributed widely in the southern half of eaetern terraces of Tana River Delta Area, adjacent to Wooded bushland (2). Not found in Ranching Project Area. Dominant species are Hyphaena coriacea, Terminalia spinosa, Thespesia danis. Most likely the second-growth of Forest (4).

III - 3 - 3 BUSHLAND

Landscape of vegetation formed mainly by tall shrubs and small shrubs of less than 10 m in height including those taller than 10 m but with a crown density of less than 5%. Classified into three groups according to crown densities of tall shrubs of 6–10 m in height and small shrubs of less than 6 m. Bushland thicket is a bushland of both tall shrubs and small shrubs with a crown density of more than 20% respectively. Bushland is of both tall and small shrubs but with a combined crown density of 20%. Bushed grassland is also of both tall and small shrubs of a combined crown density of 5–20% and with grass coverage of more than 20%. Bushland is divided further into two subgroups, and Bushed grassland into three subgroups according to dominant species.

(1) Bushland thicket (Bt)

Distributed only in the inland side near the coast in Tana River Delta Area. Dominant species are Dombeya sp. and Grewia similis.

(2) Bushland

(a) Bushland (1) (B-1)

Distributed surrounding the western part of Fundisa Hill in the east of Ranching Project Area. Dominant species are Dobera glabra. Thespesia danis, Grewia tenax, Combretum hereroense, Ecbolium striatum, Diospyros cornii and Indigofera schimperi.

(b) Bushland (2) (B-2)

Distributed widely from the western half of Ranching Project Area over to Garsen west of Tana River Delta. Dominant species are Boscia coriacea, Combretum hereroense, Commiphora campestris, Commiphora erythraea, Dobera glabra, Cordia sinensis, Hermania uhligii, Salvadora persica and Euphorbia robecchii.

(3) Bushed grassland

(a) Bushed grassland (1) (BG-1)

Distributed in a small scale in the central region of Ranching Project Area. Dominant species are Dobera glabra, Thespesia danis, Grewia tenax, Combretum hereroense, and Ecbolium striatum. Bushed grassland (1) is a grazing land formed by artificially reducing tall shrubs of Bushland (1).

(b) Bushed grassland (2) (BG-2)

Distributed in the cetral region of Ranching Project Area and north of the western part of Tana River Delta. Dominant species are Cordia sinensis, Boscia coriacea, Dobera glabra and Gnewia villosa. Originally Bushland (2) but artificially turned into grazing land, it has dominant species similar to those of Bushland (2).

(c) Bushed grassland (3) (BG-3)

Distributed sporadically in Ranching Project Area and Tana River Delta Area. Dominant species is Acacia zanzibarica.

III - 3 - 4 SHRUBLAND

Trees of more than 10 m in height are less than 5% in crown density as in Bushland. Of shrubs of less than 10 m in height, those of less than 6 m alone are more than 20% in crown density. Small shrubs uniformly range in height from 2 m to 3 m, occurring only in the dunes along the coast. Shrubland has only one sub-division.

(1) Dwarf Shrubland (S)

Dominant species are Maytenus undalus and Balanites orbicularis.

III - 3 - 5 GRASSLAND

Landscape of trees of more than 10 m in height and shrubs of less than 10 m in height with a crown density of less than 5% respectively and with grass coverage of more than 20%. Classified into four groups according to dominant grass species. Grasslands (2), (3), and (4) are distributed in Tana River Delta Area, whereas Grasslands (1) and (2) are found in Ranching Project Area.

(1) Grassland (1) (G-1)

Distributed north and west of Dakawachu in Ranching Project Area. Dominant grass species are Schoenefeldia transiens and Cenchrus ciliaris. Formed by artificial burning of tall shrubs and small shrubs as in Bushed grasslands (1) and (2).

(2) Grassland (2) (G-2)

Distributed extensively in Tana River Delta and sporadically in Ranching Project Area. Dominant grass species are Echinochloa haploclada, Echinochloa staginina, Sporobolus helvolus, Panicum maximum and Cynodon dactylon.

(3) Grassland (3) (G-3)

Distributed in Tana River Delta Area only. Dominant grass species are Cyperus rotundas and Echinochloa colonum.

(4) Grassland (4) (G-4)

Distributed on the inland side of Forest (6) (mangrove forest) at ends of Tana River Delta. Dominant grass species are Suaeda monoica and Sporobolus spicatus.

III - 3 - 6 CULTIVATED LAND

Classified into cropland and plantation. They are divided further into two groups respectively.

(1) Cropland (Cr: Rice, Co: Others)

Crops raised include rice, maize, cotton, sesame, banana. Cropland is distributed around Mpeketoni in the east of Tana River Delta Area, along the Tana River, and in Fundisa Hill. Rice fields are found only in Wema, Ngao and other places along the Tana River.

(2) Cropland (mixed cropland and grazing area) (C_2)

Cropland and grazing area mixed. Distributed around Fundisa.

(3) Planation (Pm: Cashew nut and Mango, Pco: Coconut, Pb: Banana and Mango)

Pm is cultivated with cashew nut and mango; Pco with coconut; and Pb with banana and mango. Pm is distributed in the Fundisa Hill area, Pco in Lamu Island and Kipini, and Pb along the Tana River.

(4) Plantation (Other) (P_2)

A random veriety of crops are raised. Distributed around Fundisa Hill.

III - 3 - 7 FARM (CATTLE ENCLOSURE) (Fa)

An enclosure set up around a house, in which cattle is kept. Distributed in Witu, east of Garsen, and in a part of Ranching Project Area.

III - 3 - 8 OTHERS

Classified into Town, Village, Airstrip, Motorable road, Salt field, Pan and pond, Barren land and Dam.

(1) Town (T)

Lamu, Mpeketoni, Witu, Garsen, Ngao, Fundisa, and so on.

(2) Village (V)

Located sporadically along the Tana River, on the coast side of terraces lying on both sides of delta, in Lamu Island, Manda Island, Fundisa Hill, etc.

(3) Airstrip (Ab: Bound surface, Am: Murram surface, Ag: Grass surface)

Only the airstrip in Manda Island is bound. Other airstrips are of murram (Am) or grass (Ag).

(4) Motorable road (Ra: All weather road, Rd: Dry weather road)

Most motorable roads are all weather roads (Ra). There are some that are partly dry weather roads (Rd) as they go through flood plains and valley bottom lowlands.

(5) Salt field (Sf)

Salt fields are found in the coast of the southern end of Tana River Delta alone.

(6) Pan and pond (P)

(7) Barren land (Bl)

A land devoid of vegetation, referring to bad lands in Fundisa Hill and sandy beaches in coastal area.

(8) Dam (D)

III - 4 SOIL

The preliminary photo interpretation was conducted while referring to available literature and data. Concurrently 320 points for auger boring and 32 points for pit digging were selected in the Tana River Delta Area. During the field survey, auger boring (depth: 1.0 – 2.0 m) and pits (1.0 – 1.5 m) were made to observe and record the typical horizon, texture, colour, structure, consistence, colour mottling, concretions, of soils. Descriptions of soils were made according to the Guidelines for Soil Profile Description (FAO,1977).

A total of 96 samples (three for each pit) were taken for soil analysis. The soil analysis was based principally on the method of G. Hinga (1980) except that the Tyurin Method was employed for organic carbon, the method of measuring residual phosphate after absorption with a spectrophotometer for phosphate absorption coefficients, and the weight method for SiO_2/R_2O_3. Based on field observation and soil analysis data, the final photo interpretation was conducted. And the surface geology and soil maps were edited according to "Soil Map of the World 1:5,000,000, Volume I (FAO-UNESCO, 1974)". Fig. III-5 shows the schematic map of soil.

The soil classification system of the Surface Geology and Soil Map for the Tana River Delta Area complies with that of the soil map prepared by the Kenya Soil Survey. Namely, for each soil unit code the system calls for listing of macro relief, geology (kind of parent material), and soil unit in this order as shown in Table III-5. The soil classification codes as shown on the map each indicate these three items of information represented by alphabetic abbreviations respectively with the last one or two small letters indicating the soil unit. (Their full names are given in the last parantheses in the list of the legend.) The legend of the map contains descriptions of the slope classes, soil texture classes, and horizon thickness classes.

The colour scheme to identify the soil units on the printed map was determined through discussions with the Kenya Soil Survey.

For the Ranching Project Area, only soil observations by auger boring were made along with the landform survey in the field.

Unless otherwise specified soil unit descriptions in the legend denote the characteristics of the subsoil (usually B horizon) above 100 cm depth.

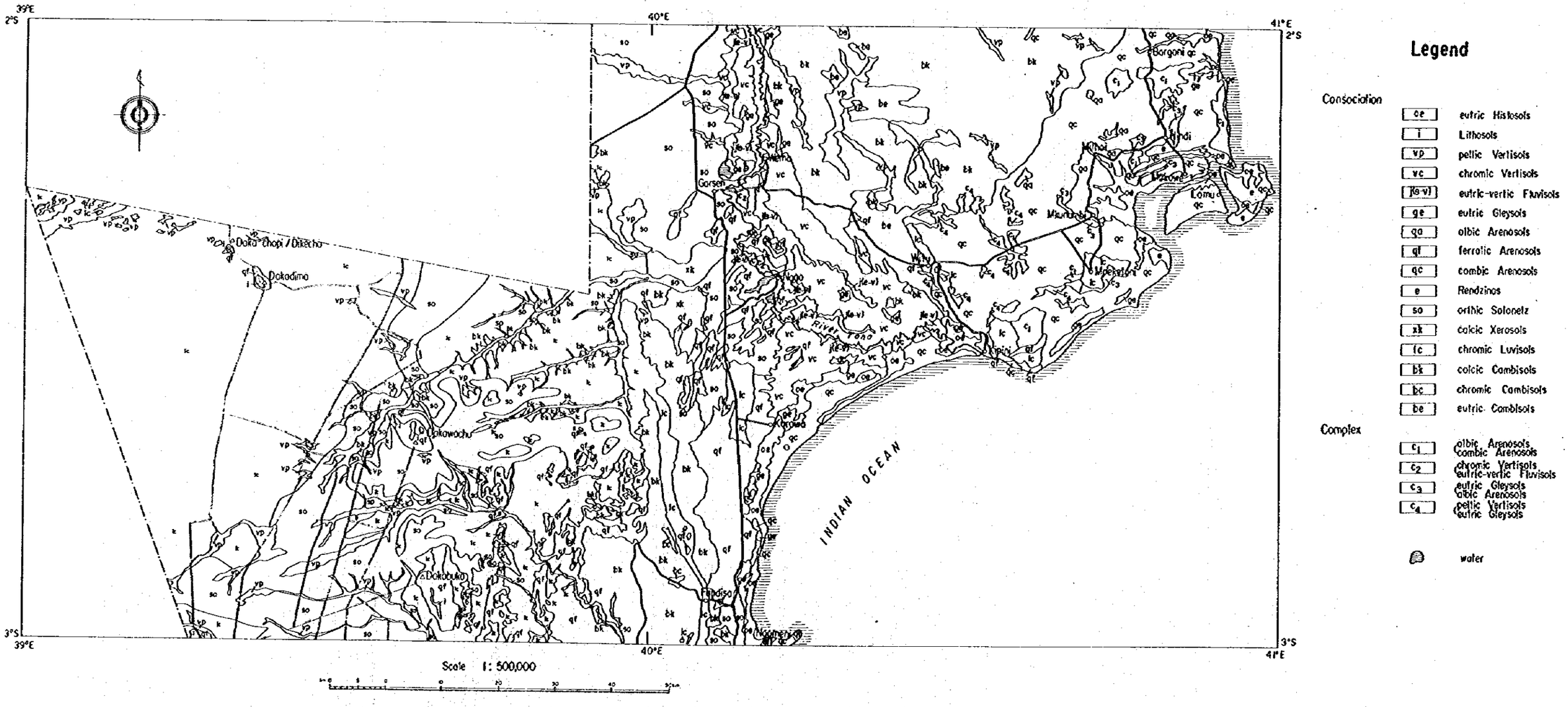


Fig. Ⅲ-5 Schematic map of Soil

Table III-5 Legend of Surface Geology and Soil

H HILLS (low relief intensity, slopes 5–16%)

HLS Soils developed on Miocene sediments; limestones and clayey sandstones

- **HLSqf** somewhat excessively drained, very deep, weak red, loose sand (ferralic Arenosols)
- **HLSbk** moderately well drained, very deep, light olive brown, friable, strongly calcareous, moderately sodic, slightly gravelly siltly clay loam (calcic Cambisols, sodic phase)

HO Soils developed on Pliocene sediments; sandy clays and bright red sands

- **HOlc** well drained, very deep, reddish brown, friable, slightly calcareous silt (chromic Luvisols)
- **HObk** moderately well drained, deep to very deep, dark yellowish gray, friable, strongly calcareous, moderately sodic, slightly gravelly silty clay loam (calcic Cambisols, sodic phase)
- **HObc** well drained, moderately deep to very deep, red, friable, slightly calcareous silt (chromic Cambisols)

Pt PLAINS OF RIVER TERRACES (slopes 0–2%)

PtJ Soils developed on lagoonal sands and clays

- **PtJqf** somewhat excessively drained, very deep, yellowish red, loose, sand to sandy loam (ferralic Arenosols and ferric Luvisols)
- **PtJqa** somewhat excessively drained to well drained, very deep, yellowish brown, mottled, loose to firm, sand to sandy loam; in places over pesoferric material (albic Arenosols)
- **PtJqc** somewhat excessively drained, very deep, brownish yellow to brown, loose, sand to sandy loam; in places mottled (cambic Arenosols)
- **PtJso** moderately well drained, very deep, grayish brown, firm to very firm, strongly calcareous, slightly saline, strongly sodic, clay loam to clay (orthic Solonetz)
- **PtJxk** moderately well drained, very deep, dark brown, very firm, strongly calcareous sandy loam; in places moderately sodic (calcic Xerosols partly sodic phase)
- **PtJlc** moderately well drained, very deep, red to brown, slightly calcareous, firm loam (chromic Luvisols)
- **PtJbk** moderately well drained to imperfectly drained, very deep, brown, very firm, strongly calcareous, moderately sodic, sandy loam to silty clay loam (calcic Cambisols, sodic phase)
- **PtJC$_1$** complex of:
  - well drained, very deep, light olive brown, mottled, loose to firm, sand to loamy sand (albic Arenosols)
  - somewhat excessively drained, very deep, light olive brown, loose sand (cambic Arenosols)

PtJ' Soils developed on calcareous lagoonal sands and clays

- **PtJ'lc** well drained, deep to very deep, dusky red, firm, very few stones, loam to sandy clay loam; in places slightly calcareous (chromic Luvisols)

Pr RIVER ALLUVIAL PLAINS (slopes 0–2%)

PrA Soils developed on Recent alluvial deposits; sands, silts and clays

- **PrAvp** imperfectly drained, very deep, very dark brown, firm, moderately calcareous, slightly saline, cracking clay (pellic Vertisols)
- **PrAvc** moderately well drained to imperfectly drained, very deep, dark brown, mottled, very firm, cracking clay; in places slightly calcareous and moderately sodic (chromic Vertisols)
- **PrAj(e-v)** well drained, very deep, stratified cracking soils of varying colour, consistence and texture; in places slightly calcareous and moderately sodic (eutric and vertic* Fluvisols)
- **PrAqa** moderately well drained, very deep, light gray, mottled, loose, sand to loamy sand (albic Arenosols)
- **PrAso** moderately well drained, very deep, black, firm, moderately calcareous, strongly sodic clay loam (orthic Solonetz)
- **PrAC$_1$** complex of:
  - moderately well drained, very deep, brown, mottled, very firm, cracking silty clay (chromic Vertisols)
  - well drained to moderately well drained, very deep, stratified cracking soils of varying colour, consistence and texture; in places moderately calcareous and sodic (eutric and vertic* Fluvisols)

PrA$_3$ Soils developed on fan deposits; clays, sands and gravels

- **PrA$_3$bk** moderately well drained, very deep, dark grayish brown, friable, strongly calcareous, moderately sodic, slightly gravelly silty clay loam to silty clay (calcic Cambisols, sodic phase)

Pc COASTAL PLAINS (slopes 0–16%)

PcA Soils developed on Recent alluvial deposits; sands, silts and clays

- **PcAge** moderately well drained, very deep, pinkish gray, mottled, loose sand (eutric Gleysols)

PcA$_1$ Soils developed on beach sands and muds of the coastal creeks

- **PcA$_1$qc** excessively drained, very deep, light brownish gray, loose, strongly calcareous, slightly saline sand (cambic Arenosols)

PcA$_2$ Soils developed on dune sands

- **PcA$_2$qf** somewhat excessively drained to well drained, very deep, red, loose to friable, sand to sandy loam; in places slightly calcareous (ferralic Arenosols)
- **PcA$_2$qc** somewhat excessively drained to well drained, very deep, yellowish brown, loose, sand to sandy loam; in places mottled and slightly calcareous (cambic Arenosols)
- **PcA$_2$bc** well drained to moderately well drained, very deep, dark brown, mottled, friable, sandy loam to clay loam (eutric Cambisols)
- **PcA$_2$bk** well drained, very deep, very pale brown, very firm, strongly calcareous, sandy loam to sandy clay loam (calcic Cambisols)
- **PcA$_2$C$_1$** complex of:
  - imperfectly drained, very deep, light gray, mottled, friable silty clay loam (eutric Gleysols)
  - well drained, very deep, pale brown, mottled, loose sand (albic Arenosols)

PcL Soils developed on coral limestones

- **PcLqf** well drained, very deep, red, loose sand (ferralic Arenosols)
- **PcLe** well drained, shallow, dusky red, strongly calcareous, silty clay loam (Rendzinas)
- **PcLlc** well drained, deep to very deep, red, firm, slightly calcareous, loam; in places very few stones (chromic Luvisols)

PcS Soils developed on calcareous lagoonal sandstones

- **PcSqf** somewhat excessively drained, very deep, red, loose sand (ferralic Arenosols)
- **PcSe** well drained, shallow, dusky red, strongly calcareous silty clay loam (Rendzinas)

PcJ Soils developed on lagoonal sands and clays

- **PcJge** moderately well drained to poorly drained, very deep, yellow to pale yellow, mottled, friable, slightly calcareous, loam to clay (eutric Gleysols)
- **PcJso** imperfectly drained, very deep, light brownish gray, firm, strongly calcareous, strongly sodic, clay (orthic Solonetz)
- **PcJC$_1$** complex of:
  - moderately well drained, very deep, light gray, mottled, friable sandy clay to clay loam (eutric Gleysols)
  - moderately well drained, very deep, dark brown, mottled, loose sand (albic Arenosols)

T TIDAL FLATS (slopes 0–2%)

TA$_1$ Soils developed on beach sands and muds of the coastal creeks

- **TA$_1$oe** poorly drained, very deep, very dark grayish brown, strongly saline, humic material overlain by 0–40 cm of loose sand; in places slightly calcareous (eutric Histosols)
- **TA$_1$ge** poorly drained, very deep, yellowish brown, mottled, loose, moderately saline, sand to sandy loam (eutric Gleysols)

B BOTTOMLANDS (slopes 0–2%)

BA Soils developed on Recent alluvial deposits; sands, silts and clays

- **BAvp** imperfectly drained, very deep, very dark gray, mottled, firm, cracking clay; in places strongly calcareous and moderately sodic (pellic Vertisols)
- **BAso** poorly drained, very deep, light gray, firm, strongly calcareous, strongly sodic, clay loam (orthic Solonetz)
- **BAge** poorly drained, very deep, gray, mottled, friable, sandy clay to clay (eutric Gleysols)
- **BAC$_1$** complex of:
  - imperfectly drained, very deep, very dark grayish brown, mottled, friable, clay loam to clay (eutric Gleysols)
  - moderately well drained, very deep, dark grayish brown, mottled, loose sand (albic Arenosols)
- **BAC$_2$** complex of:
  - imperfectly drained, very deep, very dark gray, mottled, firm, cracking clay (pellic Vertisols)
  - moderately well drained, very deep, light yellowish brown, mottled, loose, loam to clay (eutric Gleysols)

S SWAMPS (slopes 0–2%)

SA Soils developed on Recent alluvial deposits; sands, silts and clays

- **SAge** imperfectly drained, very deep, pinkish gray, mottled, friable, silt loam to clay (eutric Gleysols)

The name marked with * is quoted from "The Application of the FAO/UNESCO Terminology of the Soil Map of the World Legend for Soil Classification in Kenya".

III - 4 - 1 SOILS DEVELOPED ON HILLS (H)

(1) Soils developed on Miocene sediments: limestones and clayey sandstones (LS)

(a) HLSqf (ferralic Arenosols)

Area: 6.38 Km²

Vegetation and present land use: Bushland.

Soil: Somewhat excessively drained, very deep, weak red, loose sand; gradual transition from A horizon to B, with B horizon being uniform.

Remark: Chemical soil fertility is low and this unit is distributed at Minjila Hill in south of Garsen.

(b) HLSbk (calcic Cambisols, sodic phase)

Area: 176.25 Km²

Vegetation and present land use: Forest, Grazing.

Soil: Moderately well drained, very deep, light olive brown, friable strongly calcareous moderately sodic, slightly gravelly silty clay loam; distinct transition from A horizon to B.

Remark: This unit is widely distributed in Fundisa Hill.

(2) Soils developed on Pliocene sediments; sandy clays and bright red sands (O)

(a) HOlc (chromic Luvisols)

Area: 116.17 Km²

Vegetation and present land use: Forest, Woodland, Cultivated land.

Soil: Well drained, very deep, reddish brown, friable, slightly calcureous silt; unifrom B horizon with good physical properties.

Remark: This unit is distributed in the edge of Fundisa Hill.

(b) HObk (calcic Cambisols, sodic phase)

Area: 59.47 Km²

Vegetation and present land use: Forest, Woodland, Cultivated land.

Soils: Moderately well drained, deep to very deep, dark yellowish gray, friable, strongly calcareous, moderately sodic, slightly gravelly silty clay loam; distinct transition from A horizon to B.

Remark: This unit is distributed in the ridge of Fundisa Hill.

(c) HObc (chromic Cambisols)

Area: 5.70 Km²

Vegetation and present land use: Forest, Cultivated land.

Soil: Well drained moderately deep to very deep, red, friable, slightly calcareous silt; gradual transition from A horizon to B, with B horizon being uniform.

Remark: Few gravelly limestones are contained in B horizon, and this unit is distributed in Fundisa Hill.

III - 4 - 2 SOILS DEVELOPED ON TERRACES (Pt)

(1) Soils developed on lagoonal sands and clays (J)

(a) PtJqf (ferralic Arenosols)

Area: 287.25 Km²

Vegetation and present land use: Woodland, Bushland, Forest.

Soil: Somewhat excessively drained, very deep, yellowish red, loose, sand to sandy loam.

Remark: Chemical soil fertility is low, and this unit is distributed widely in terraces around Kurawa. Within this mapping unit there are inclusions of ferric Luvisols.

(b) PtJqa (albic Arenosols)

Area: 110.86 Km²

Vegetation and present land use: Woodland, Grassland.

Soil: Somewhat excessively drained to well drained, very deep, yellowish brown, mottled, loose to firm, sand to sandy loam; in places over pesoferric material.

Remark: Chemical soil fertility is low, and this unit has albic horizon (E) below A horizon, being distributed in slightly wet area of terraces.

(c) PtJqc (cambic Arenosols)

Area: 1,067.08 Km²

Vegetation and present land use: Woodland, Forest, Grassland.

Soil: Somewhat excessively drained, very deep, brownish yellow to brown, loose, sandy loam; in place mottled.

Remark: Chemical soil fertility is low, and this unit has almost uniform soil profile, being distributed widely in terraces around Mkunumbi.

(d) PtJso (orthic Solonetz)

Area: 701.65 Km²

Vegetation and present land use: Bushland, Bushed grassland, Woodland.

Soil: Moderately well drained, very deep, grayish brown, firm to very firm, strongly calcareous, slightly saline, strongly sodic, clay loam to clay.

Remark: This unit is distributed widely in terraces north of Garsen.

(e) PtJxk (calcic Xerosols, partly sodic phase)

Area: 137.43 Km²

Vegetation and present land use: Bushland

Soil: Moderately well drained, very deep, dark brown, very firm, strongly calcareous sandy loam; in places moderately sodic.

Remark: This unit has an arid regime, being distributed in terraces south of Garsen.

(f) PtJlc (cambic Luvisols)

Area: 48.61 Km²

Vegetation and present land use: Forest, Wooded bushland thicket.

Soil: Moderately well drained, very deep, red to brown, slightly carcareous, firm loam.

Remark: This unit is distributed in terraces around Kurawa.

(g) PtJbk (calcic Cambisols, sodic phase)

Area: 1,382.09 Km²

Vegetation and present land use: Forest, Woodland, Grassland, Bushed grassland.

Soil: Moderately well drained to imperfectly drained, very deep, brown, very firm, strongly calcareous, moderately sodic, sandy loam to silty clay loam.

Remark: A large quantity of concreted calcium is contained with strong alkalinity in B horizon, while much humic substance in A horizon. This unit is widely distributed in terraces on the left side of the Tana River.

(h) $PtJC_1$ (complex of albic Arenosols and cambic Arenosols)

Area: 162.36 Km²

Vegetation and present land use: Woodland forest, Grassland.

Soil: Complex of PtJqa and PtJqc

Remark: This unit is distributed in terraces around Mokowe.

(2) Soils developed on calcareous lagoonal sands and clays (J')

(a) PtJ'lc (chromic Luvisols)

Area: 91.99 Km²

Vegetation and present land use: Woodland, Forest, Cultivated land.

Soils: Well drained, deep to very deep, dusky red, firm, very few gravels, loam to sandy clay loam; in places slightly calcareous.

Remark: Gravelly limestones are containing in B horizon. This unit is distributed around Mpeketoni.

III - 4 - 3 SOILS DEVELOPED ON RIVER ALLUVIAL PLAINS (Pr)

(1) Soils developed on Recent alluvial deposits: sands, silts and clays (A)

(a) PrAvp (pellic Vertisols)

Area: 6.76 Km²

Vegetation and present land use: Bushland, Bushed grassland.

Soil: Imperfectly drained, very deep, very dark brown, firm, moderately calcareous, slightly saline, cracking clay.

Remarks: This unit is distributed along minor rivers.

(b) PrAvc (chromic Vertisols)

Area: 566.49 Km²

Vegetation and present land use: Grassland, Bushed grassland.

Soil: Moderately well drained to imperfectly drained, very deep, dark brown, mottled, very firm, cracking clay: in places slightly calcareous and moderately sodic.

Remark: This unis is widely distributed in flood plains.

(c) PrAj(e-v) (eutric-vertic* Fluvisols)

* The name of vertic Fluvisols is quoted from "The Application of the FAO/UNESCO Terminology of the Soil Map of World Legend for Soil Classification in Kenya".

Area: 196.07 Km²

Vegetation and present land use: Bushed grassland, Grassland, Wooded bushland thicket.

Soil: Well drained, very deep, stratified cracking soils of varying colour, consistence and texture; in places slightly calcareous and moderately sodic.

Remark: This unit is distributed in the natural levee along the Tana River.

(d) PrAqa (albic Arenosols)

Area: 5.98 Km²

Vegetation and present land use: Woodland, Grassland.

Soil: Moderately well drained, very deep, light gray, mottled, loose, sand to loamy sand.

Remark: This unit is distributed along minor rivers.

(e) PrAso (orthic Solonetz)

Area: 26.47 Km²

Vegetation and present land use: Bushland, Glassland, Bushed grassland.

Soil: Moderately well drained, very deep, black, firm, moderately calcareous, strongly sodic clay loam.

Remark: This unit is distributed in lowland around Tarassa.

(f) $PrAC_1$ (complex of chromic Vertisols and eutric-vertic Fluvisols)

Area: 26.24 Km²

Vegetation and present land use: Grassland, Bushed grassland.

Soil: Complex of PrAvc and PrAj(e-v)

Remark: This unit is distributed in flood plain and natural levee of the Tana River.

(2) Soils developed on fan deposits; clays, sands and gravels (A_3)

(a) PrA_3 bk (calcic Cambisols, sodic phase)

Area: 170.45 Km²

Vegetation and present land use: Woodland, Forest, Bushland.

Soil: Moderately well drained, very deep, dark grayish brown, friable, strongly calcures moderately sodic, slightly gravelly silty clay loam to silty clay.

Remark: This unit is distributed to the east of Fundisa Hill.

III - 4 - 4 SOILS DEVELOPED ON COASTAL PLAINS (Pc)

(1) Soils developed on Recent alluvial deposits; sands, silts and clays

(a) PcAge (eutric Gleysols)

Area: 11.29 Km²

Vegetation and present land use: Grassland.

Soil: Moderately well drained, very deep, pinkish gray, mottled, loose sand.

Remark: This unit is distributed in lowland near the coast.

(2) Soils developed on beach sands and muds of the coastal creeks (A_1)

(a) PcA_1 qc (cambic Arenosols)

Area: 22.21 Km²

Vegetation and present land use: Forest.

Soil: Excessively drained, very deep, light brownish gray, loose, strongly calcareous, slightly saline sand.

Remark: This unit is distributed in the coastal ridge, and within this mapping unit there are inclusions of Regosols.

(3) Soils developed on dune sands (A_2)

(a) PcA_2 qf (ferralic Arenosols)

Area: 255.19 Km²

Vegetation and present land use: Wooded bushland thicket, Woodland, Bushland, Cultivated land.

Soil: Somewhat excessively drained to well drained, very deep, red, loose to friable, sand to sandy loam; diffuse transition from A horizon to B, in places slightly calcareous.

Remark: This unit is distributed on the inland dunes.

(b) PcA_2 qc (cambic Arenosols)

Area: 352.93 Km²

Vegetation and present land use: Bushland, Woodland, Shrubland.

Soil: Somewhat excessively drained to well drained, very deep, yellowish brown loose, sand to sandy loam; in places mottled and slightly calcareous.

Remark: This unit is distributed in most of coastal dunes.

(c) PcA_2 be (eutric Cambisols)

Area: 231.83 Km²

Vegetation and present land use: Woodland, Forest.

Soil: Well drained to moderately well drained, very deep, dark brown, mottled, friable, sandy loam to clay loam.

Remark: This unit is distributed in old dunes around Witu.

(d) PcA_2C_1 (complex of eutric Gleysols and albic Arenosols)

Area: 11.86 Km²

Vegetation and present land use: Woodland, Grassland.

Soil: Complex of eutric Gleysols and albic Arenosols. Well drained to imperfectly drained, very deep, light gray to pale brown mottled, loose to friable, sand to silty clay loam.

Remark: This unit is developed in lowlands near Mokowe.

(4) Soils developed on coral limestones (L)

(a) PcLqf (ferralic Arenosols)

Area: 7.84 Km²

Vegetation and present land use: Bushland, Woodland.

Soil: Well drained, very deep red, loose sand.

Remark: Soils of this unit are derived from thin deposits of dune sands on coral limestones, being distributed on the raised coral reefs near Kipini.

(b) PcLe (Rendzinas)

Area: 56.10 Km²

Vegetation and present land use: Bushland, Forest, Bushland thicket.

Soil: Well drained, shallow, dusky red, strongly calcareous, silty clay loam.

Remark: This unit is distributed mainly in the Manda Island.

(c) PcLlc (chromic Luvisols)

Area: 24.82 Km²

Vegetation and present land use: Woodland, Wooded bushland thicket.

Soil: Well drained, deep to very deep, red, firm, slightly calcareous, loam; in places very few stones.

Remark: This unit is distributed on raised coral reefs near Kurawa and Witu.

(5) Soils developed on calcareous lagoonal sandstones (S)

(a) PcSqf (ferralic Arenosols)

Area: 0.33 Km²

Vegetation and present land use: Woodland.

Soil: Somewhat excessively drained, very deep, red, loose sand.

Remark: This unit is distributed near Mpeketoni.

(b) PcSe (Rendzinas)

Area: 0.16 Km²

Vegetation and present land use: Forest.

Soil: Well drained, shallow, dusky red, strongly calcareous silty clay loam.

Remark: This small unit is distributed around Marereni.

(6) Soils developed on lagoonal sands and clays (J)

(a) PcJge (eutric Gleysols)

Area: 23.89 Km²

Vegetation and present land use: Grassland, Woodland, Bushland.

Soil: Moderately well brained to poorly drained very deep, yellow to pale yellow, mottled, friable, slightly calcareous, loam to clay.

Remark: This unit is mainly distributed in lowlands near the coast.

(b) PcJso (orthic Solonetz)

Area: 10.23 Km²

Vegetation and present land use: Grassland, Bushland.

Soil: Imperfectly drained, very deep, light brownish gray, firm, strongly calcareous and sodic, clay.

Remark: This unit is distributed in lowlands near Terasaa.

(c) $PcJC_1$ (complex of eutric Gley sols and albic Arenosols)

Area: 13.84 Km²

Vegetation and present land use: Woodland, Grassland.

Soil: Complex of eutric Gleysols and albic Arenosols. Moderately well drained, very deep, light gray to dark brown, mottled, loose to friable, sand to clay loam.

Remark: This unit is mainly distributed in lowland near Mkunumbi.

III - 4 - 5 SOILS DEVELOPED ON TIDAL FLATS (T)

(1) Soils developed on beach sands and muds of the coastal creeks (A_1)

(a) TA_1 oe (eutric Histosols)

Area: 239.15 Km²

Vegetation and present land use: Forest, Grassland.

Soil: Poorly drained, very deep, very dark grayish brown, strongly saline, humic material overlain by 0–40 cm of loose sand; in places slightly calcareous.

Remark: This unit is distributed below the mangrove forest.

(b) TA_1 ge (eutric Gleysols)

Area: 97.65 Km²

Vegetation and present land use: Barren land.

Soil: Poorly drained, very deep, yellowish brown, mottled, loose, moderately saline, sand to sandy loam.

Remark: This unit is distributed in the sand flat.

III - 4 - 6 SOILS DEVELOPED ON BOTTOM LANDS (B)

(1) Soils developed on Recent alluvial deposits; sands, silts and clays

(a) BAvp (pellic Vertisols)

Area: 135.87 Km²

Vegetation and present land use: Grassland, Woodland.

Soil: Imperfectly drained, very deep, very dark gray, mottled, firm, cracking clay: in places strongly calcareous and moderately sodic.

Remark: This unit is distributed in bottom lands in terraces.

(b) BAso (orthic Solonetz)

Area: 0.58 Km²

Vegetation and present land use: Woodland.

Soil: Poorly drained, very deep, light gray, firm, strongly calcareous and sodic, clay loam.

Remark: This unit is distributed in bottom lands in terraces near Kurawa.

(c) BAge (eutric Gleysols)

Area: 2.59 Km²

Vegetation and present land use: Grassland, Woodland.

Soil: Poorly drained, very deep, gray, mottled, friable, sandy clay to clay.

Remark: This unit is distributed in bottom lands in terraces near Marereni.

(d) BAC_1 (complex of eutric Gleysols and albic Arenosols)

Area: 10.99 Km²

Vegetation and present land use: Grassland, Bushland.

Soil: Complex of eutric Gleysols and albic Arenosols. Moderately well drained to imperfectly drained, very deep, dark grayish brown, mottled, loose to friable, clay loam to clay.

Remark: This unit is distributed in bottom lands near Mokowe.

(e) BAC_2 (complex of eutric Gleysols and pellic Vertisols)

Area: 77.63 Km²

Vegetation and present land use: Grassland, Woodland.

Soil: Complex of pellic Vertisols and eutric Gleysols. Moderately well drained to imperfectly drained, very deep, light yellowish brown to very dark gray, mottled, loose to friable, loam to clay.

Remark: This unit is distributed in bottom lands at north of Witu.

III - 4 - 7 SOILS DEVELOPED ON SWAMP (S)

(1) Soils developed on Recent alluvial deposits; sands, silts and clays

(a) SAge (eutric Gleysols)

Area: 84.12 Km²

Vegetation and present land use: Grassland.

Soil: Imperfectly drained, very deep, pinkish gray, mottled, friable, silt loam to clay.

Remark: This unit is distributed on swamps along the Tana River. Flooded during the rain season.

III - 4 - 8 OUTLINE OF SOILS IN RANCHING PROJECT AREA

Soils as outlined below were observed in the Ranching Project Area, but descriptions in this area are based only on observations from auger boring.

(1) Lithosols (i)

Soils which are limited in depth by hard rock within 10 cm of the surface, and in this area develop on the Triassic sandstones. Because of shallowness, Lithosols have not much agricultural value. They are distributed in residual hills such as Dakadima and Dakawachu, where vegetation is Bushland or Bushed grassland.

(2) pellic Vertisols (vp)

Soils with heavy clay and cracks. In this area B horizon contains gravelly limestones and concreted Ca, showing strong calcareous. These soils are imperfectly drained and solidified when dried to make ploughing difficult and so the agricultural suitability is low except for grazing. They are distributed in low lands flooded in the rain season where vegetation is Bushland or Bushed grassland.

(3) ferralic Arenosols (qf)

Soils which have coarse texture, deep and red B horizons, and in this area develop on the Pleistocene fluvial deposits. Chemical fertility is low. They are distributed in uplands around Hadu, where vegetation is forest.

(4) orthic Solonetz (so)

Soils with high Na exchange capacity. These soils in this area contain concreted Ca, showing strongly calcareous characteristic, and develop on the Pleistocene and Pliocene fluvial deposits. Because of high alkalinity they have poor soil structures. They are distributed widely in the central part of the Ranching Project Area, where vegetation is Bushed grassland or Grassland.

(5) calcic Xerosols (xk)

Soils having an arid regime and calcic horizons, which in this area develop on lagoonal sand and clay. They are distributed within narrow bounds in Ranching Project Area, where vegetation is Bushland.

(6) chromic Luvisols (lc)

Soils having a horizon of clay accumulation, which in this area develop on the Jurassic and Triassic deposits. These soils contain in places iron stones in B horizon. They are distributed widely on plains west of the Ranching Project Area, where vegetation is Grassland or Bushed grassland.

(7) calcic Cambisols (bk)

Soils having a cambic B horizon with concentrations of soft powdery lime, which in this area develop over the Pliocene deposits. They are distributed on hills east of the Ranching Project Area, where vegetation is forest.

III - 5 SUMMARY OF SURVEY RESULTS

(1) Area by theme and item

Tables III-6 – III-9 show the distribution areas represented in the thematic maps for the Tana River Delta Area.

(a) Geology

In terms of geology, there are distributions of Pt_4 (lagoonal sands and clays), Re_0 (alluvial deposits: silts, sands and clays), Pt_1 (old dune sands), Re_1 (beach sands and muds of coastal creeks) in the order of area sizes (Table III-6). In particular, Pt_4 is distributed widely and evenly on both sides of the Tana River. Pt_4 is followed by Re_0, and together they occupy nearly 70%.

Table III-6 Areas by Legend Items: Geology

Item		Area (km^2)	%
Recent	Re_0	1,128.2	16.2
	Re_1	393.1	5.7
	Re_2	215.5	3.1
	Re_3	171.7	2.5
Pleistocene	Pt_1	637.9	9.2
	Pt_2	81.1	1.2
	Pt_3	3.5	+
	Pt_4	3,943.5	56.8
Pliocene	Pl_1	180.3	2.6
Miocene	Mi_1	181.0	2.6
Water		9.8	0.1
Total (km^2)		6,945.6	100.0

(b) Landform

In terms of landform, terraces (Pt_1, Pt_2, Pt_3) occupy 50% of the Tana River Delta Area, followed by 9% of old dune and old coastal ridge (Dz) and 8% of flood plain (A) (Table III-7). In this area, the flat land reprecent about 90%.

Table III-7 Area by Legend Items: Landform

Item			Area (km^2)	%
Hills	H . Hr		341.0	4.9
Footslopes	F . C		8.5	0.1
Plains	Terraces	Pt_1	429.6	6.2
		Pt_2	2,800.5	40.3
		Pt_3	561.0	8.1
	River Alluvial Plains	Pf	168.3	2.4
		pl	207.2	3.0
		A	545.5	7.9
		V	154.8	2.2
		Or	5.1	0.1
	Coastal Plains	Pc	23.4	0.3
		PcL	80.8	1.2
		Il	60.0	0.9
		Z	22.9	0.3
		D	211.7	3.0
		Dz	636.6	9.2
	Tidal Flats	Tm	239.7	3.4
		Ts	92.0	1.3
Bottom land		B	239.9	3.5
Miscellaneous		S	89.6	1.3
		Ol	1.4	+
		O	24.4	0.4
		W	1.6	+
		Cliff	0.1	+
Total (km^2)			6,945.6	100.0

(c) Vegetation and present land use

Table III-8 shows the distribution areas of the vegetation and present land use. Most widely distributed is Woodland (35%), followed by Forest (24%), Bushland (20%) and Grassland (16%). These four items occupy 95% of the whole. Detailed study shows that those that exceed 10% are WB-3 (17.0%) F-3 (15.6%), G-2 (13.3%) and B-2 (12.2%). Whereas Cropland (Cr, Co, C_2) accounts for only 2.2% and Plantation (Pm, Pco, Pb, P_2) 0.8%.

Table III-8 Areas by Legend Items: Vegetation and Present Land Use

Item		Area (km^2)	%
Forest	F - 1	15.5	0.2
	F - 3	1,086.3	15.6
	F - 4	338.2	4.9
	F - 6	11.3	0.2
	F - 5	191.5	2.8
Woodland	WBt - 2	174.3	2.5
	WBt - 3	34.9	0.5
	WB - 2	1,011.7	14.6
	WB - 3	1,181.5	17.0
Bushland	Bt	279.6	4.0
	B - 2	851.0	12.2
	BG - 2	87.5	13.0
	BG - 3	179.6	2.6
Shrubland	S	39.8	0.6
Grass-land	G - 2	924.6	13.3
	G - 3	123.9	1.8
	G - 4	62.8	0.9
Cropland	Cr · Co	100.3	1.4
	C_2	59.3	0.8
	Pm. Pco. Pb	38.5	0.6
	P_2	14.2	0.2
Farmland	Fa	5.5	0.1
Others	T · V	6.2	0.1
	Ab. Am. Ag	1.0	+
	Sf	10.7	0.1
	P	25.1	0.4
	B_1	90.8	1.3
Total		6,945.6	100.0

(d) Soils

Table III-9 shows the soil distribution areas. Widely distributed are calcic Cambisols (bk, 26%) and cambic Arenosols (qc, 21%). Fluvisols, ferralic Arenosols and chromic Luvisols, which are often used as Cropland, combinedly occupy about 13%. Chromic Vertisols suitable for irrigated agriculture occupies about 8% and Cambisols suitable for rainfed agriculture about 30%.

Table III-9 Areas by Legend Items: Soil

Item			Area (Km^2)	%
eutric	Histosols	oe	239.2	3.4
pellic	Vertisols	vp	142.6	2.1
chromic	Vertisols	vc	566.5	8.2
eutric -vertic	Fluvisols	j(e-v)	196.1	2.8
eutric	Gleysols	ge	219.5	3.2
albic	Arenosols	qa	116.8	1.7
ferralic	Arenosols	qf	457.0	6.6
cambic Arenosols		qc	1,441.2	20.7
Rendzinas		e	56.3	0.8
orthic	Solonetz	so	738.9	10.6
calcic	Xerosols	xk	137.4	2.0
chromic	Luvisols	lc	271.6	3.9
calcic	Cambisols	bk	1,796.5	25.9
chromic	Cambisols	bc	5.7	0.1
eutric	Cambisols	be	231.8	3.3
complx of qa & qc			162.4	2.3
complex of vc & j(e-v)			26.2	0.4
complex of ge & qa			36.7	0.5
complex of vp & ge			77.6	1.1
Water			25.6	0.4
Total			6,945.6	100.0

(2) Relationship between agro-climatic zone and each theme

(a) Relationship between agro-climatic zone and vegetation and present land use

Table III-10 and Fig. III-6 (1), (2) show the above relationship with respect to the Tana River Delta Area. From this table and figure, the following can be pointed out.

i) Forest, Woodland and Grassland decrease in area from Zone IV to zone VI.

ii) Bushland is similar in area Zones from IV to VI.

iii) Shrubland is distributed in Zone IV only.

iv) Cropland (Cr, Co, C_2), Plantation (Pm, Pco, Pb, P_2) and Farmland decrease in area from Zone IV to Zone VI. Town (T), Village (V), Airstrip (Ab, Am, Ag) and Salt field (Sf) show the same tendency.

(b) Relationship between agro-climatic zone and soil

Table III-11 and Fig. III-7 show the relationship between agro-climatic zone and soil. From the table and the figure, the following can be pointed out.

i) eutric Histosols (oe) is mainly distributed in Zone IV, whereas pellic Vertisols (vp) is distributed in Zones V and VI only and not in Zone IV.

ii) chromic Vertisols (vc), eutric Gleysols (ge), ferrelic Arenosols (qf), albic Arenosols (qa), cambic Arenosols (qc), Rendzinas (e) and chromic Luvisols (lc) are mainly distributed in Zone IV, decreasing from Zone V to Zone VI.

iii) eutric – vertic Fluvisols (j(e-v)) increases from Zone IV to Zone VI.

iv) orthic Solonetz (so) is widely distributed in Zone VI, calcic Cambisols(bk) in Zone V, and cambic Arenosols (qc) in Zone IV.

v) Complex is mostly widely distributed in Zone V, followed by Zones V and VI.

Table III-10 Relation between Agro - Climatic Zone and Vegetation (Km^2)

Item / Zone	Forest (F-1,F-3,F-4,F-5,F-6)	Woodland (WBt-2,Wbt-3,WB-2,WB-3)	Bushland (Bt,B-2,BG-2,BG-3)	Schrubland (s)	Grassland (G-2,G-3, G-4)	Cropland (Cr_1Co)	Cropland (C_2)	Plantation (Pm,Pco,Pb)	Plantation (P_2)
IV	758.4 (21.9)	1,337.3 (38.6)	438.8 (12.7)	39.8 (1.1)	593.5 (17.1)	86.4 (17.1)	55.1 (1.6)	35.8 (1.0)	10.7 (0.3)
V	691.8 (29.2)	915.4 (38.7)	369.3 (15.6)	- (0)	350.7 (14.8)	10.2 (14.8)	4.2 (0.2)	2.5 (0.1)	3.5 (0.1)
VI	192.6 (17.3)	149.7 (13.5)	589.6 (53.0)	- (0)	167.1 (15.0)	3.7 (15.0)	- (0)	0.2 (+)	- (0)
Total	1,642.8 (23.6)	2,402.4 (34.6)	1,397.7 (20.1)	39.8 (0.6)	1,111.3 (16.0)	100.3 (16.0)	59.3 (0.9)	38.5 (0.6)	14.2 (0.2)

Item / Zone	Farmland (Fa)	Town (T)	Village (V)	Air strip (Ab,Am,Ag)	Salt field (Sf)	Pan and Pond (P)	Barren land Bl	Total
IV	5.0 (0.1)	1.2 (+)	2.7 (0.1)	1.0 (+)	10.7 (0.3)	8.4 (0.2)	83.7 (2.4)	3,468.6 (100.0)
V	0.5 (+)	- (0)	1.0 (+)	- (0)	- (0)	9.3 (0.4)	7.1 (0.3)	2,365.5 (100.0)
VI	- (0)	0.4 (+)	0.9 (0.1)	- (0)	- (0)	7.4 (0.7)	- (0)	1,111.5 (100.0)
Total	5.5 (+)	1.6 (+)	4.6 (0.1)	1.0 (+)	10.7 (0.2)	25.1 (0.4)	90.8 (1.3)	6,945.6 (100.0)

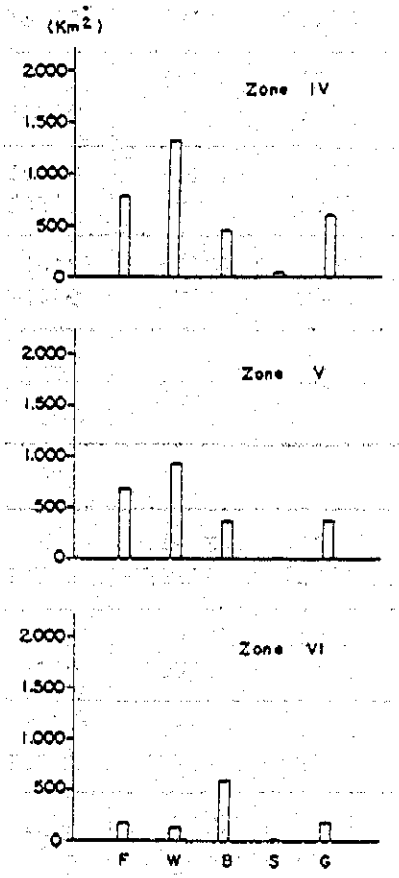


Fig.Ⅲ-6(1)
Areas by Vegetation for each Agro-climatic zone

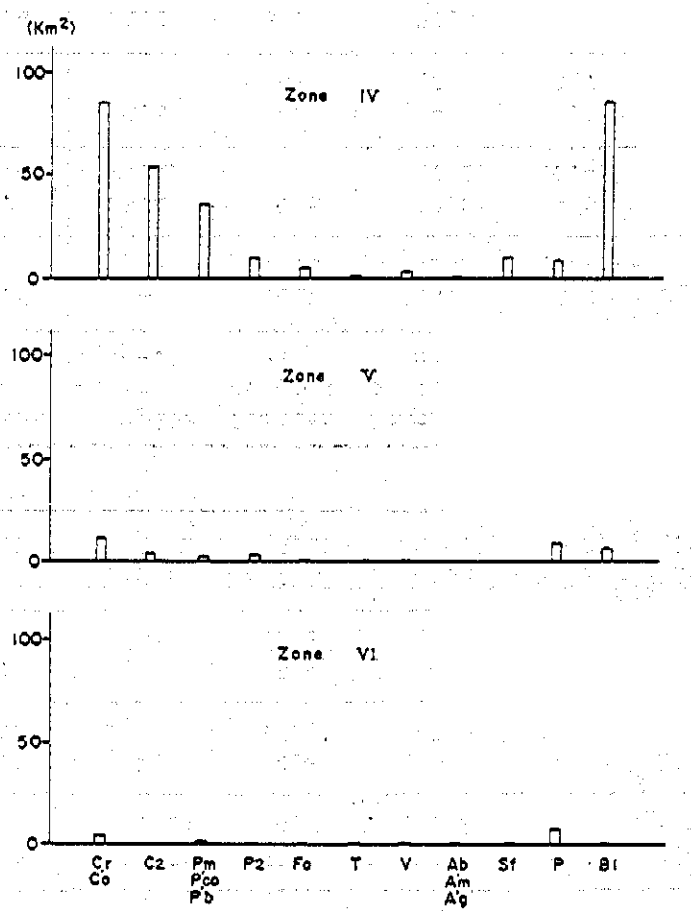


Fig. Ⅲ-6(2)Areas by Land Use for each Agro-climatic zone

Table III-11 Relation between Agro - Climatic Zone and Soil

Item / Zone	oe	vp	vc	j(e-v)	ge	qa	qf	qc	e	so	xk
IV	226.5 (6.5)	1.3 (+)	332.3 (9.6)	54.7 (1.6)	166.3 (4.8)	114.7 (3.3)	282.8 (4.8)	1,275.2 (36.8)	56.3 (1.6)	78.1 (2.3)	- (0)
V	12.7 (0.5)	100.7 (4.3)	131.4 (5.6)	66.9 (2.8)	30.5 (1.3)	2.1 (0.1)	164.8 (7.0)	166.0 (7.0)	- (0)	162.5 (6.9)	117.2 (9.9)
VI	- (0)	40.6 (3.7)	102.8 (9.3)	74.5 (6.7)	22.7 (2.1)	- (0)	9.4 (0.8)	- (0)	- (0)	498.3 (44.8)	20.2 (1.8)
Total	239.2 (3.4)	142.6 (2.1)	566.5 (8.2)	196.1 (2.8)	219.5 (3.2)	116.8 (1.7)	457.0 (6.6)	1,441.2 (20.7)	56.3 (0.8)	738.9 (10.6)	137.4 (2.0)

	lc	bk	bc	be	Complex of qa & qc	Complex of rc & j(e-v)	Complex of ge & qa	Complex of vp & ge	Water	Total
IV	220.2 (6.3)	341.6 (9.8)	5.7 (0.2)	80.2 (2.3)	123.5 (3.6)	- (0)	36.2 (1.0)	64.6 (1.9)	8.4 (0.2)	3,468.6 (100.0)
V	51.4 (2.2)	1,132.3 (47.9)	- (0)	139.3 (5.9)	38.9 (1.6)	25.8 (1.1)	0.5 (+)	13.0 (0.5)	9.5 (0.4)	2,365.5 (100.0)
VI	- (0)	322.6 (29.0)	- (0)	12.3 (1.1)	- (0)	0.4 (+)	- (0)	- (0)	7.7 (0.7)	1,111.5 (100.0)
Total	271.6 (3.9)	1,796.5 (25.9)	5.7 (0.1)	231.8 (3.3)	162.4 (2.3)	26.2 (0.4)	36.7 (0.5)	77.6 (1.1)	25.6 (0.4)	6,945.6 (100.0)

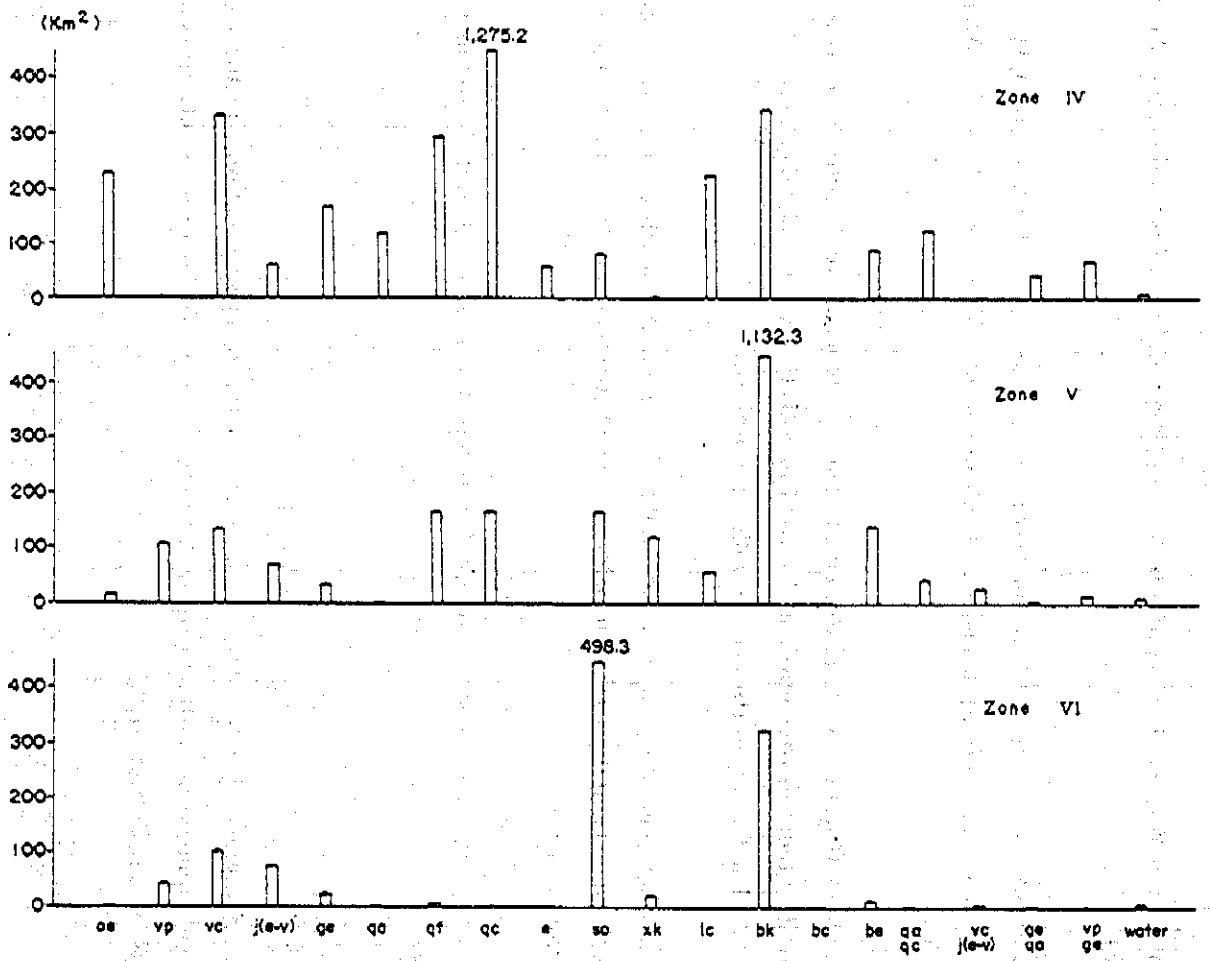


Fig. Ⅲ-7 Areas by Soil for each Agro-climatic zone

(3) Relationship among themes

Fig. III-8 (1) – (3) show the relationship between the vegetation and present land use and the soils. From these figures, the following can be pointed out.

i) Forest and Woodland are concentrated in calcic Cambisols (bk) and cambic Arenosols (qc).

ii) Bushland is concentrated in orthic Solonetz (so) and cambic Arenosols (qc), Shrubland in cambic Arenosols (qc), and Grassland in chromic Vertisols (vc), cambic Arenosols (qc).

iii) Cropland (Cr, Co) is concentrated in cambic Arenosols (qc), chromic Luvisols (lc), ferralic Arenosols (qf), eutric and vertic Fluvisols (j (e-v)). Cropland (C2) is concentrated in calcic Cambisols (bk) and ferralic Arenosols (qf).

iv) Plantation (Pm, Pco, Pb) is concentrated in cambic Arenosols (qc), eutric Cambisols (be), while Plantation (P_2) in orthic Solonetz (so), cambic Arenosols (qc) and calcic Cambisols (bk).

Furthermore, the relationship among landform, vegetation and soil is summarized in Fig. III-9.

(4) Regional outline

By way of summarizing the descriptions given in the foregoing sections, features of the natural environment are outlined below for each regional portion of the study areas including the Ranching Project Area.

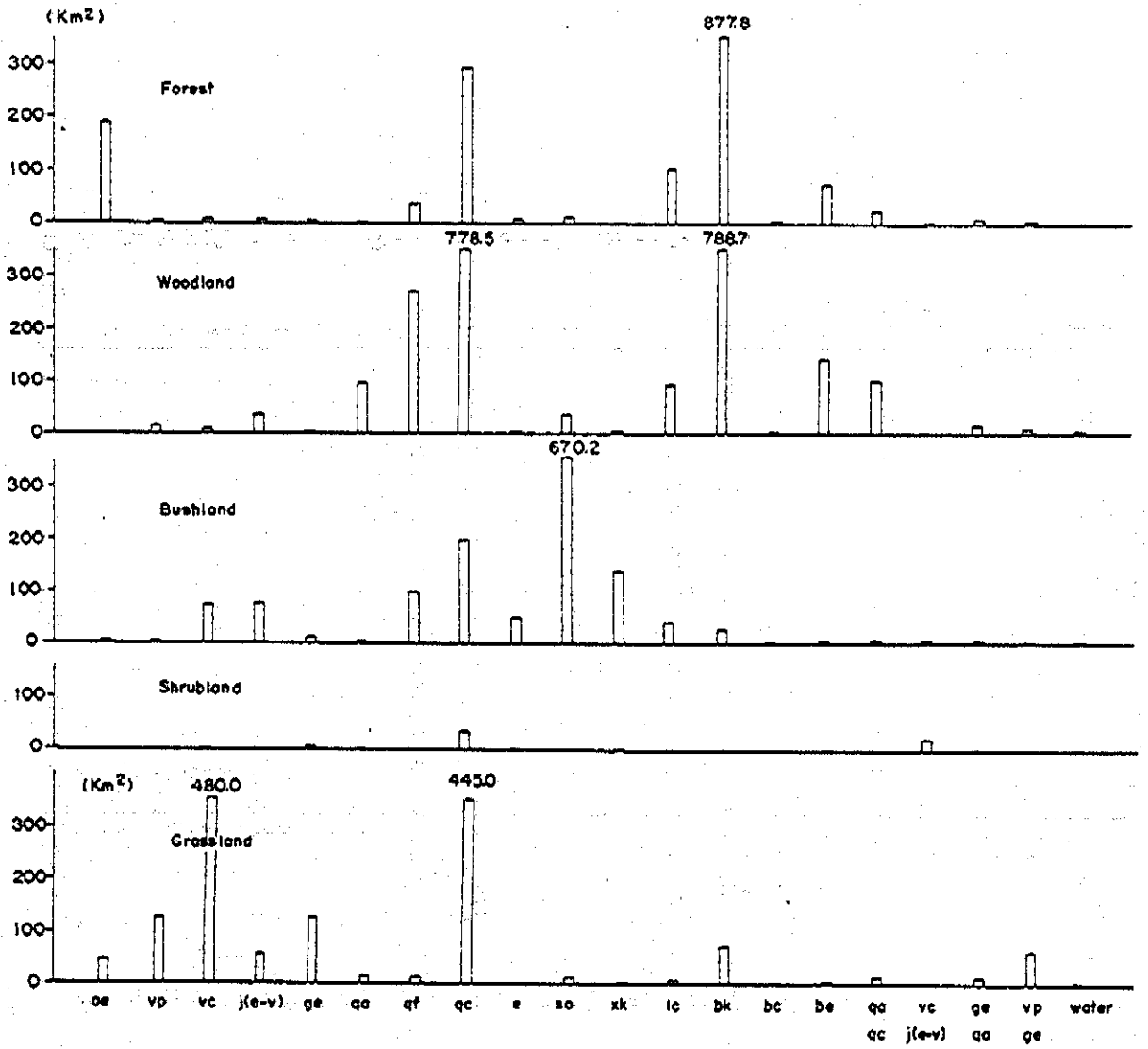


Fig. Ⅲ-8(1) Areas by Soil for each Vegetation

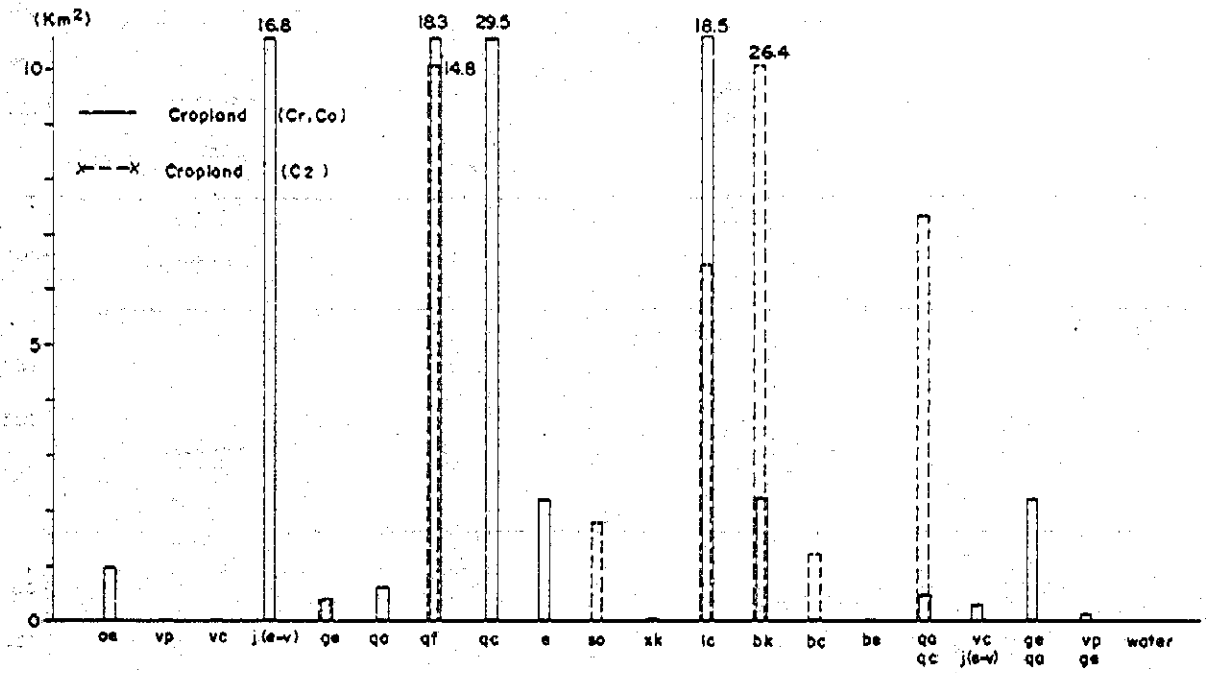


Fig. III-8(2) Areas by Soil for each Vegetation

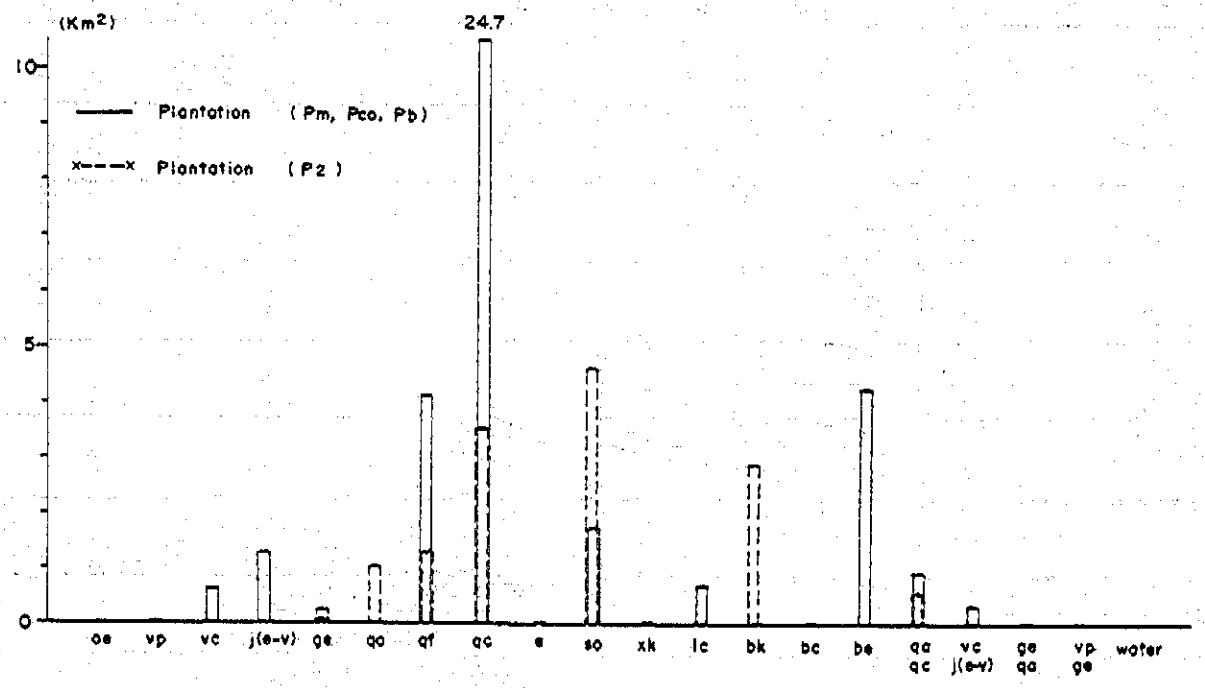


Fig.Ⅲ-8(3) Areas by Soil for each Vegetation

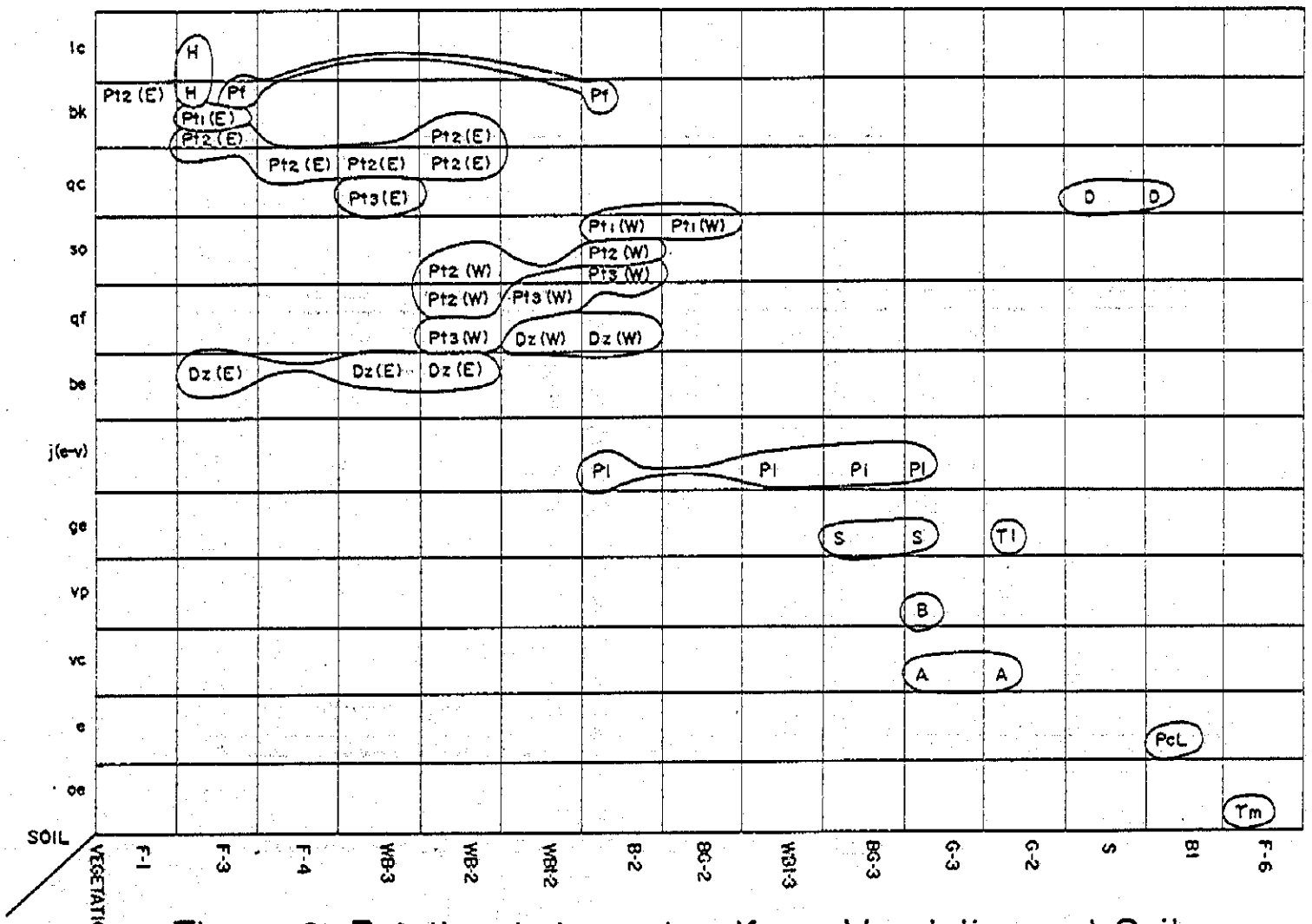


Fig. Ⅲ-9 Relation between Landform, Vegetation and Soil

E: east of Tana River delta

W: west of Tana River delta

(a) Tana River Delta

The Tana River Delta is characterized by the natural levees formed along the old and new streams of the Tana River and the flood plains extending behind the levees.

The flood plain is low and flat, covered with Glassland (G-2) or Bushed grassland. Soils (vc) are heavy clay and relatively fertile. A part of this plain closer to the natural levee is swamp.

The natural levee is elevated normally 2 to 3 m above the flood plain, with vegetation mostly of Grassland (G-3), Bushed grassland or Woodland. Because of access to water supply and reduced vulnerability to flood hazards, many of the villages along the Tana River are located here. Soil texture is coarser than that of the flood plain. Soils are well drained and slightly calcareous.

(b) Terraces in the east of the Tana River Delta

The eartern terraces have a nearly flat landscape. Particularly in the northern area, there are shallow valleys (Bottom lands), showing gentle undulation. Vegetation is Woodland and Forest, the former supposedly being the secondary forest of the latter.

The southern coastal area is the only area where the monthly rainfall exceeds the amount of evaporation (May to June). Near Witu climax Forest (F-1) is observed and relatively large villages are developed such as Witu, Kipini, Mokowe and Lamu. In Mpeketoni, there is a large scale farming settlement.

Soils (bk) including humic material in top soil are moderately fertile in the north-western area covered with Forest. In other soils such as qc, drainage is almost excessive and chemical fertility is low.

There are the old dunes in the western area near the Tana River, and soils (be) near Witu are low in chemical fertility.

To the south of this area, there are the raised coral reefs. In particular, the Manda Island is made up from raised coral reef, with vegetation of Bushland, and well drained, strongly calcareous in soils (e).

Bottom land mostly found in terraces is covered with Grassland or Woodland. Soils (mainly vp) are heavy clay with poor drainage.

(c) Terraces on the west-south side of the Tan River Delta

In this area, the landscape is flat and covered mainly with Bushland. Bushed grassland is observed in the north and Woodland in the south.

Soils (so) are moderately well drained, but mostly strongly calcareous and sodic.

In the fans at the east of Fundisa Hill in the south of this area, the same types of vegetation and soils (bk) are observed.

In this area, there are several rows of old dunes nearly parallel to the existing coast line. This area, where soil texture is sand, is covered with Woodland and Bushland and partially Cultivated land.

(d) Area on the coast of the Indian Ocean

Dunes are developed continuously along the coast from the tip of the Tana Delta to the eastern terraces. Soils (qc) are loamy sand in texture with vegetation of Bushland, Woodland and Shrubland.

Interlevee lowland behind this dune is covered mainly with Grassland. Soils (gc) are loam or clay and slightly calcareous.

Mangrove flat frequently observed on the coastal area is covered with Forest (mangrove) or Grassland. Soils (oe) are sandy, strongly saline with humic materials.

Sand flat contiguous to the inland side of the mangrove flat is Barren land, where soils (ge) are strongly saline.

(e) Fundisa Hill

The Fundisa Hill is of Tertiary limestone, calcareous sandstone, and sandy clay. Vegetation is mainly Forest. In the area of limestone and calcareous sandstone, soils (bk) contain granules of limestone and are strongly sodic. Contrary to this, soils (lc) with sandy clay as parent material are slightly calcareous. And the soil texture is loam to silt, with good physical properties (air permiability and water retension) to make it good for Cropland.

(f) Ranching Project Area

The Ranching Project Area extending from the west of the Fundisa Hill is comprised mainly by Plateaus, Uplands, Dissected peneplains and Peneplains. Geologically, this is basically of Triassic and Jurassic sandstiones with covers of Pliocene and Pleistocene fluvial deposits in places. Vegetation is mainly Bushland or Bushed grassland and, in the middle to western part, Grassland and, in the east, Woodland are also observed. Soils (lc) in areas of Triassic and Jurassic sandstones are fairly suitable for agriculture, except for areas with shallow soil layers. But soils (so) derived from Pliocene and Pleistocene fluvial deposits are strongly sodic and not suitable for agriculture. Valley bottom lowland is observed along seasonal rivers developed in the Ranching Project Area. There are soils (vp) poorly draining and containing clay in large quantity (calcareous). Vegetation is Bushland or Bushed grassland. But the soil is reasonably suitable for grazing and irrigation. Soils of Residual hills in Dakadima, Dakawachu and Hoshingo are Lithosols.

IV. APPLICATIONS OF THEMATIC MAPS

IV. APPLICATIONS OF THEMATIC MAPS

Rational, systematic land use presupposes the availability of survey data collected from various angles of vision of national land use development. In Japan a variety of surveys are conducted for land use development plans formulated at national and prefectural levels, and the results are mostly compiled into reports that are usually accompanied by related maps and data. There are also cases where only maps are produced for multiple applications.

In the present survey, a total of five thematic maps were produced for multiple applications, three for the Tana River Delta Area ("Vegetation and Present Land Use Map", "Landform, Slope and Drainage Map" and "Surface Geology and Soil Map") and two for the Ranching Project Area ("Vegetation and Present Land Use Map" and "Landform and Drainage Map").

This section deals with the general utilization of these thematic maps and the details of land evaluation.

IV - 1 UTILIZATION OF THEMATIC MAPS

In a thematic map, the mapped area is represented according to the legend items determined to meet the purpose of its utilization. Accordingly, it clearly indicates the locations and extents of each individual legend item, and also makes it possible to see such locations and extents in relation to other legend items. For example, if one takes a look at a "Vegetation and Present Land Use Map", one can readily see where and in what extent the cultivated land is distributed in relation to vegetation and land use classification. Coral limestone is often used as aggregates for road repair work in Kenya, and then its distribution and occurrence areas can be readily seen from the relevant sheet of "Surface Geology and Soil Map". Such direct utilization based on legend items is the simplest way of utilizing thematic maps.

The thematic maps produced in the present survey are intended for multipurpose applications, so that their legend items were determined according to the generally adopted classification. Accordingly, there could be certain cases where such general legend items cannot be used directly. In such cases, it is necessary to modify the legend items by grouping some of them into of single, new item, or to devide them by introducing appropriate new items taken from other thematic maps or data.

All thematic maps are certainly correlated with each other especially in tems of natural conditions. Hence, combined utilization of the maps is far more effective than independent utilization of a single map in understanding the characteristics of an area under review and in meeting various other purposes of utilization.

Some examples of combined thematic map utilization are introduced below.

(1) Flood Potential Area

The lower reaches of the Tana River Delta Area are flooded frequently every year during the period from April – June (rain season) to July. Obtaining a good understanding of high flood potential areas is therefore an essential prerequisite to planning of the Delta Area development.

From the topography, flood potentiality is high in lowlying, flat, marshy areas along the mainstream and tributaries of the Tana. Seen from the vegetation, on the other hand, it is high in the grassland areas. Legend items representing such flood potential areas in the "Landform, Slope and Drainage Map" of the Tana River Delta Area are Flood plains (A), Valley bottom lowlands (V), Interlevee lowlands (Il), Bottom lands (B), Swamps (S) and Old river beds (Or). In the "Vegetation and Present Land Use Map", the flood potential area are represented by Grasslands. It is therefore possible to delineate areas with high flood potentiality by overlaying the two thematic maps mentioned above.

(2) Road Planning

Important factors in determining the road location suitability include amount of work, level of difficulty involved in work execution, areas to be avoided, and desirable route. If work load depends on the landform and slope, work volume can be approximated from the "Landform and Slope Map". Level of difficulty of work execution, if assumed to be influenced by hardness of rocks and volume of forest tress, can be determined from the "Surface Geology and Soil Map" and "Vegetation and Present Land Use Map". As for areas to be excluded from route selection, the distribution of vegetation types to be protected from environmental conservation can be obtained from the "Vegetation and Present Land Use Map", soft ground and fault zone from the "Surface Geology and Soil Map", and high flood potential areas unsuitable for road construction and maintenance from the "Landform Map". The desired route of the road can likely be determined from these thematic maps. The road location

The road location suitability based on natural conditions can thus be determined by checking each factor to be considered against the relevant thematic maps.

(3) Agricultural Land Use Planning

Agricultural land use planning requires consideration of many wide-ranging factors. This section discusses land evaluation among such factors as providing basis for agricultural land use planning.

In the initial preparatory step, kinds of land use to be assumed for land evalaution have to be defined. Basically they are determined according to purposes for which evalution is made. Kinds of land use are futher divided into 'major kinds of land use' and more detailed 'land utilization types'.

'Major kinds of land use' are made of agricultural land in terms of rainfed, irrigated, grassland, etc. This type of classification is good for quantitative and reconnaissance level evaluation. 'Land utilization types' are more detailed involving products, capital intensity, labour intensity, technology levels, etc. Specifically they can be defined, for example, as:

i) Small and sizes of individual ownership, rainfed/irrigated mixted agriculture, intermediate level of technology employed.

ii) Large scale, rainfed/irrigated mixed agriculture, high level of technology employed.

iii) Ranching

iv) Small scale, irrigated agriculture.

For each type of land utilization as above, land requirements are set in terms of climate, slope, vegetation, soil, etc.

From the findings of natural environmental surveys, maps are produced on the respective subjects of environmental conditions in the forms of Soil Map, Landform Map, Climate Data Map, Vegetation Map, etc. (i.e., thematic maps) which allows evaluation of the land area covered by the maps in terms of their land characteristics and land qualities.

Land characteristics refer to land attributes, that can be measured or estimated, such as slopes, rainfall, oil texture, organic contents of soils, to mention a few, while land qualities are defined in terms of complex characteristics that are known to be clearly relevant to a specific suitability associated with the land under consideration, such as productivity of vegetation, resistance to soil erosion, soil moisture storage capability, for example.

The land requirements and the land qualities (including land characteristics) as defined above are compared and diagnostic criteria are determined for a certain land use. More often than not, this process of criteria selection is repeated more than once as the land use initially targeted is changed or modified, or details are provided at a later stage. Types of evaluation that are required include land capabilities for possible improvement, environmental impacts as well as land suitability evaluation that incorporates social and economic analyses as well.

Typical applications of thematic maps as correlated according to purposes are summarized in Table IV-1.

Table IV-1 Applications of Thematic Maps for Evaluations

Thematic maps \ Evaluations		Hazard of flooding	Road	Irrigated agriculture	Ranching	Conservation	Silviculture
Landform, slope and drainage map	Landform	◎	◎	◎	○	○	○
	Slope	○	◎	◎	○	○	○
	Drainage		○	○		○	
Vegetation and landuse map	Vegetation	○	○	○	◎	◎	◎
	Landuse		○	○		○	○
Surface geology and soil map	Geology	○	◎			○	
	Soil	○		◎	◎	○	◎

Remark ◎ : More important
○ : Important

In utilizing thematic maps, attention should be given to the following points.

First of all, it must be noted that thematic maps are produced for various purposes of utilization, so that survey methods, compilation methods and map scales adopted for their preparation are diverse. For example, a Vegetation and Present Land Use Map prepared by photo interpretation alone is inferior in accuracy and quality to the one prepared by photo interpretation and field survey, even if the scale is the same for both maps. In case of Surface Geology and Soil Map, the accuracy is affected more by sampling rate than by scale. Accuracy corresponds to scale in most thematic maps, but there are cases where a thematic map prepared at a scale of 1/25,000 has an accuracy of 1/50,000.

In utilizing thematic maps, therefore, it is necessary to pay due attention to the relevant survey reports and annotation notes, and to obtain a thorough understanding of the survey methods and legends. Failure to exercise this caution will invite an error in the grouping or rearrangement of legend items, making it impossible to obtain the expected results from the combined utilization of thematic maps, and this could lead to an erroneous conclusion.

If the thematic map to be utilized is subject to annual changes like the "Vegetation and Present Land Use Map", it is very important to verify the dates of compilation, publication, field survey and aerial photography, and perform updating as necessary.

Thus, existing thematic maps are utilized either with or without correction, and they also serve as reference data for new surveys.

IV - 2 LAND EVALUATION AS ONE APPLICATION

Land evaluation was made using the thematic maps moduced in this project to illustrate an application of thematic maps. The land area covered by this evaluation and the evaluation index are given in Fig. IV-1.

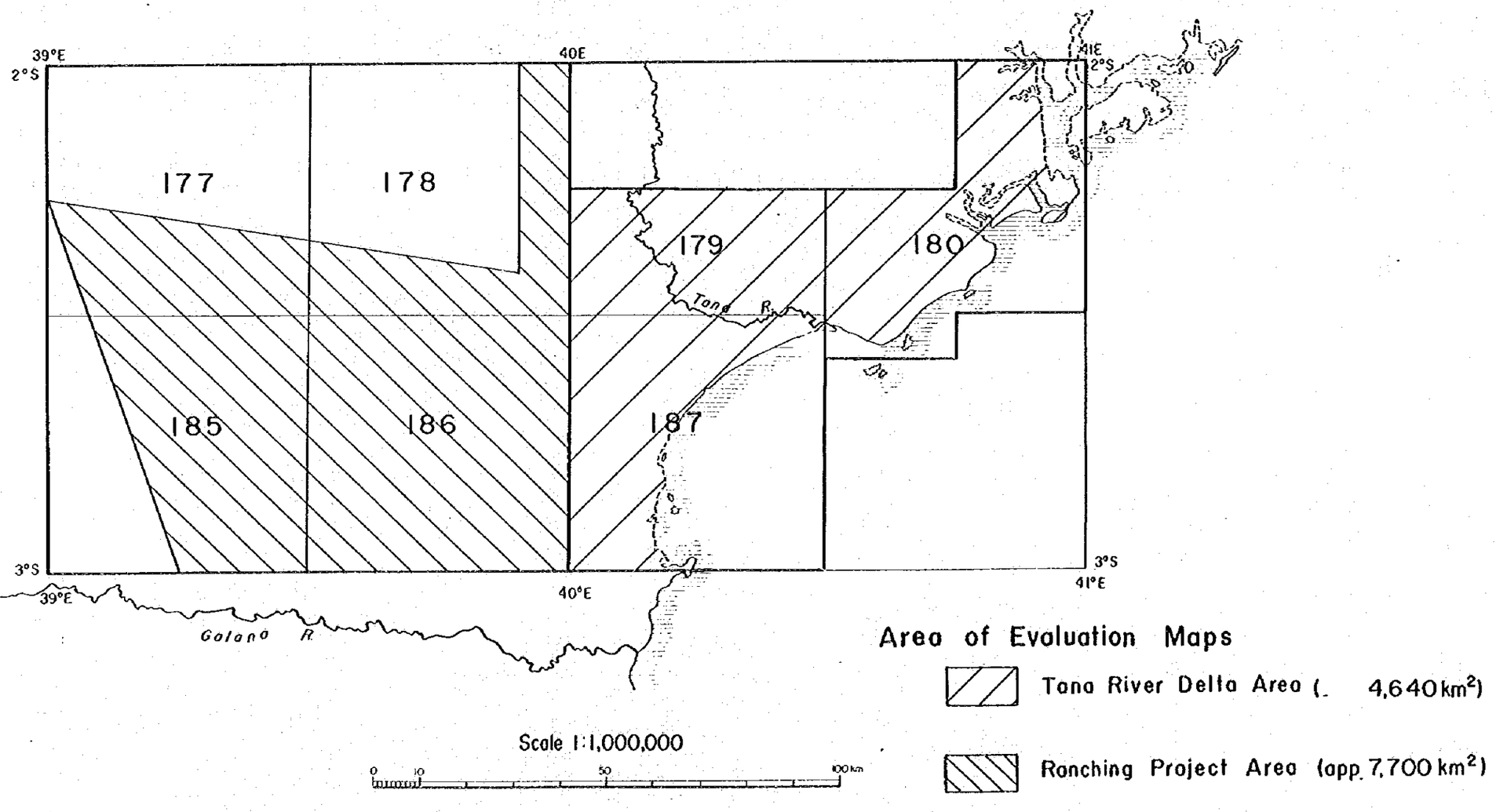


Fig. IV-1 Evaluation map index

IV - 2 - 1 METHODOLOGY AND PROCESS OF EVALUATION

As shown in Fig. IV-2, the land evaluation was conducted in a process comprising three steps of input, analysis and evaluation, with all data processed by a computer for the Tana River Delta Area and manually for the Ranching Project Area.

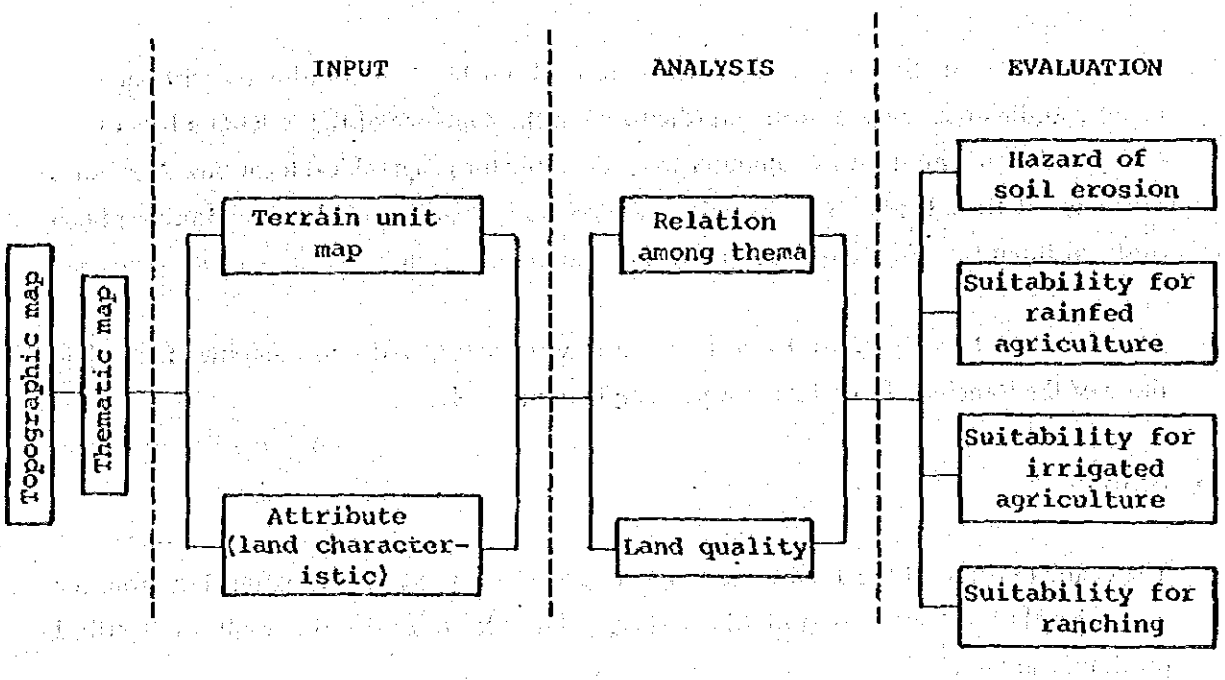


Fig. IV-2 Flow Chart of Evaluation

(1) Input

The following data were used for the evaluation.

Tana River Delta Area: Agro-climatic zone, landform, vegetation and present land use, slope, geology, and soil.

Ranching Project Area: Agro-climatic zone, vegetation and present land use, landform, drainage, soil.

For climate and agro-climatic zone, the data shown in Section II-2-4 are used, and other data were extracted from relevant thematic maps.

Thematic maps to be input into a computer are initially overlaid and integrated to make a base map for computer inputting. This map shows terrain units delineated by the boundaries of legend items and attributes associated with each of those terrain units. The terrain units are identified by serial numbers.

The boundaries of those terrain units then are read out by their coordinates with an automatic coordinate read-out instrument (digitizer) in the sequence of the serial numbers of the terrain units and input into a computer to create a file for geographical locations. Attributes associated with individual terrain units are also read according to the legend using punch cards for input to generate spatially identified data files.

All data related to the Tana River Delta Area were automated into computer files while those of the Ranching Project Area were compiled into tables.

(2) Analysis

The characteristics of the Tana River Delta Area were analyzed by correlating data from the respective thematic maps as stored in computer data files to obtain the results as described previously in III-5.

Land characteristics and land qualities as compound land characteristics were examined, and the evaluation criteria were reviewed on the basis of the criteria of the Kenya Soil Survey. The survey data were modified for compatibility where they did not fit with specified *accurancy or description.*

(3) Evaluation

A conversion table for determining land suitability was prepared from the land characteristics and land qualities obtained from analysis based on the evaluation criteria, and evaluation was made using the table.

The items on which evaluation was made are as follows.

Tana River Delta Area:	Soil erosion resistance. Suitability for rainfed agriculture. Suitability for irrigated agriculture.
Ranching Project Area:	Current suitability for ranching. Potential suitability for ranching.

The evaluation results were made into 1/100,000 maps.

IV - 2 - 2 LAND CHARACTERISTICS

Land characteristics are the individual attributes of land used as basic items of land evaluation. The land characteristics used in the present evaluation and their sources are as listed below.

1. Agro-climatic zone

   Data as listed II-2-4.

2. Landform

   Landform: Landform, Slope and Drainage Map, Landform and Drainage Map
   Drainage: – do –

3. Vegetation and land use

   Vegetation and land use: Vegetation and Present Land Use Map

4 Soil

Texture:	Surface Geology and Soil Map
Slope:	Landform, Slope and Drainage Map
Slope length:	Measured from Topographic Map
Soil depth:	Surface Geology and Soil Map
Drainage of Soil:	– do –
Consistency:	– do –

Physical characteristics: Surface Geology and Soil Map

Chemical characteristics: – do –

IV - 2 - 3 LAND QUALITIES

Land qualities are the complex land characteristics known to affect land suitability and used as basis for ranking in an evaluation of land. The land qualities and the land characteristics associated with them, used in the present evaluation, are as follows. These land characteristics are summarized in the Surface Geology and Soil Map and the descriptions of its legend made on the basis of field survey and soil analysis.

(1) Chemical fertility

(a) CEC (Cation exchange capacity)

(b) Available nutrients

(c) Mineral Reserve (Total mineral content)

(2) Salinity

ECe (Electric Conductivity of Saturation Extract)

(3) Alkalinity

ESp (Exchangeable Sodium Percentage)

(4) Resistance to Erosion

(a) Slope

(b) Agro-climatic zone

(c) Slope length

(d) Erodability

Organic Matter Content

Flocculation Index

Silt/Clay Ratio

Bulk-density

(5) Possibilities of Mechanization

(a) Slope

(b) Soil Texture and Soil Depth

(c) Workability

(d) Slope length

(6) Water-logging

Drainage of Soil

(7) Soil Moisture Storage Capacity

(a) Soil Texture

(b) Soil Thickness

IV - 2 - 4 LAND EVALUATION

Land evaluation was conducted for classification of land into Suitable Land (S) and Unsuitable Land (NS), and Suitable Land is further divided into the following three suitability classes.

Class S1, highly suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2, moderately suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land.
Class S3, marginally suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

Unsuitable Land (NS) refers to land that is not usable or unsuitable for a given purpose of land use. It includes land areas that cannot be utilized at present on reasons of environmental conservation/preservation.

Soil erosion resistance is evaluated in terms of land's resistance to sheet erosion and based on different criteria of evaluation from those for suitability evaluation.

Land evaluation is conducted for current suitability and for potential suitability. The current suitability evaluation is intended to determine the land suitability at the present time or possibly with some changes, and the potential suitability evaluation assumes changes of major proportions in the present land status.

In the present survey, the evaluation of soil erosion resistance was made in terms of sheet erosion after felling of trees. The suitability for rainfed agriculture and irrigated agriculture is current suitability whereas the suitability for ranching was evaluated for both current suitability and potential suitability. The changes considered in the potential suitability evaluation includes felling of trees and construction of dams for securing water supply.

Nature of impacts resulting from changes made on the land vary depending on the types of those changes.

Table IV-2 classifies changes to be made in the land in terms of levels of technical difficulty and costs as applied in Kenya. According to this table, forest tree cutting apparently falls in B and dam construction in D.

Table IV-2 Input Requirements Standard

Input	Technical Difficulty	Cost
A-low	low, may require some technical advisory services to the landowner.	low, can be borne by landowner.
B-moderate	moderate, requires important advisory services to the landowner.	moderate
C-high	high, specialists needed for planning and execution; special equipment needed.	high
D-very high	as for C.	very high

IV - 3 EVALUATION RESULTS

IV - 3 - 1 SOIL EROSION RESISTANCE

Evaluation of soil erosion resistance is intended to determine the resistance of land to sheet erosion. In the present survey, this evaluation was made on the assumption that the existing forest areas would be reduced to cut-over areas by clearing, and the conversion table shown in Table IV-3 was used. This conversion table was prepared on the basis of a report compiled in 1977 by H.M.H. Braun and R.F. van de Weg from the findings of their soil survey and land evaluation conducted in different parts of Kenya.

In this evaluation, slope class and erodability worked as predominant factors, and land resistance to sheet erosion was classified into the following five ranks.

R1: Very high resistance
R2: High resistance
R3: Moderate resistance
R4: Slight resistance
R5: Very slight resistance

Table IV-3 Land classification criteria

Rating of land quality : Resistance to erosion

subrating / land qualities	1	2	3	4	5
slope class	A, AB		B, BC, C		CD, D
agro-climatic zone	I, II	III	IV, V, VI, VII		
erodability	none	slight	moderate	strong	very strong
slope length (m)	< 50	50 - 200	>200		

final rating	summed subrating	
R 1	4 - 6	very high resistance
R 2	7 - 9	high resistance
R 3	10 - 12	moderate resistance
R 4	13 - 15	slight resistance
R 5	16 - 18	very slight resistance

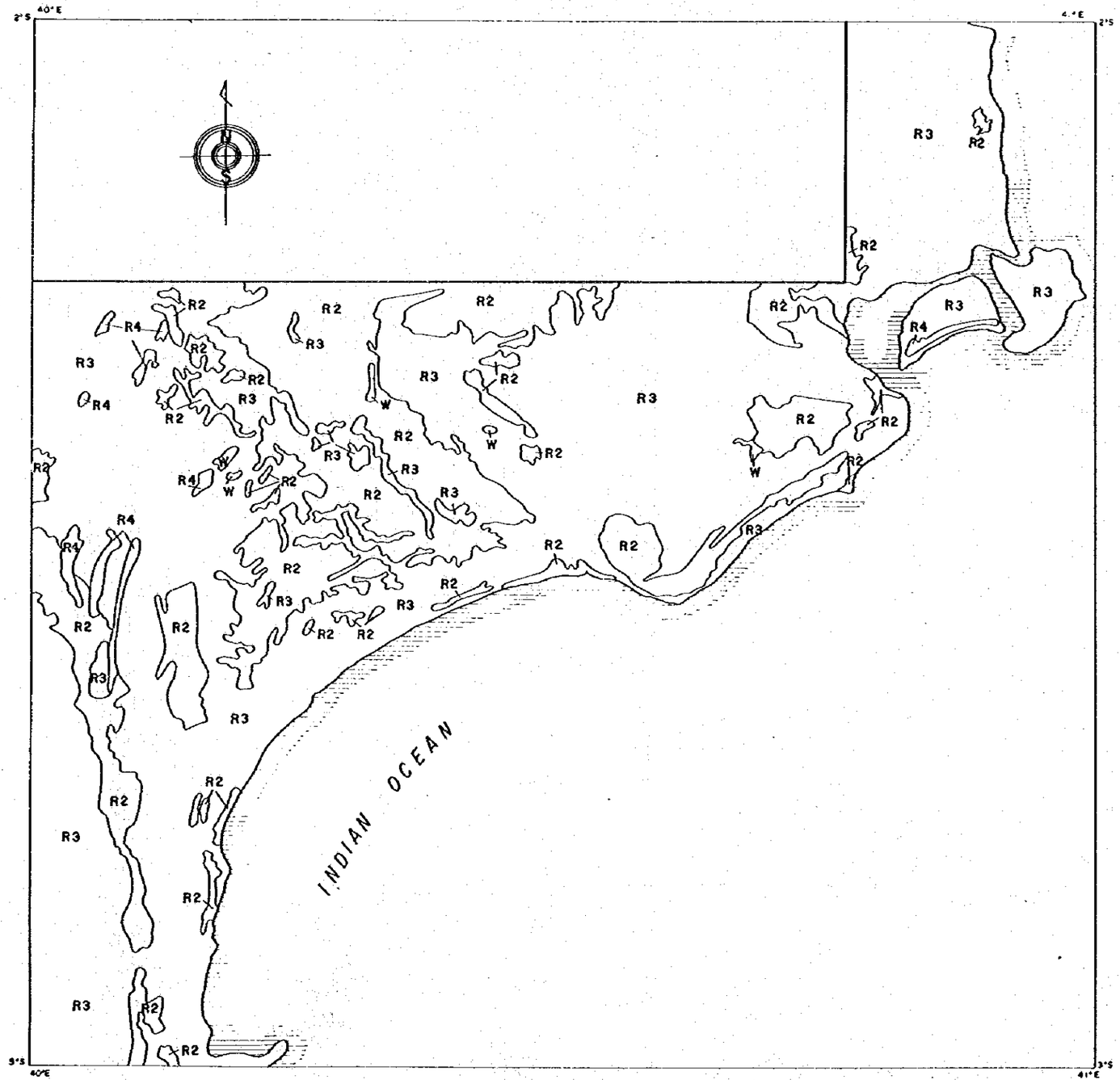
Note: For erodability, refer to Annex for relevant documents.

Final ratings were computed from values of the respective attributes according to the conversion table.

Fig. IV-3 is Schematic Map of Hazard of Soil Erosion.

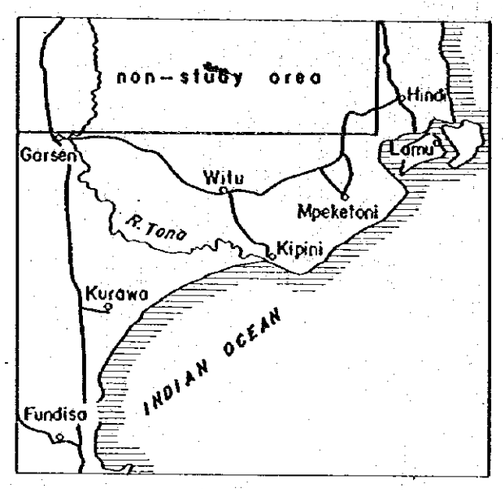
The area-wise distribution of the five ranks was as follows.

Rank	Area (km^2)	%
1	–	–
2	1,141.4	24.6
3	3,431.2	73.9
4	50.2	1.1
5	–	–
Water	17.2	0.4
Total	4,640.0	100.0



Scale 1 : 500,000

Study area of evaluation



Legend

Symbol	Class
R 1	Very high resistance
R 2	High resistance
R 3	Moderate resistance
R 4	Slight resistance
R 5	Very slight resistance
W	Water

Fig.IV-3 Schematic map of hazard of soil erosion

The Tana River Delta Area has a nearly flat topography, with slopes of more than 5% found in very few localities, and, therefore, the evaluation relates in a larger measure to erodability as one characteristic of soil. Flat land with distribution of Canbisols, Vertisols, Luvisols, tend to be Rank 2 (high resistance). Rank 2 areas account for about 1/4 of the total area, the rest being mostly Rank 3 areas (moderate resistance) covering terraces with Solonetz and Arenosols. Dunes with slopes of more than 5% are rated as Rank 4 (slight resistance) but with limited occurrance.

IV - 3 - 2 SUITABILITY FOR RAINFED AGRICULTURE

Suitability for small-scale mixed agriculture based only on rainfall as a water source was evaluated using the conversion table shown in Table IV-4. The conversion table was prepared by referring to the "Conversion Tables for Land Suitability Rating" by R.F. van de Weg published in 1978.

This suitability evaluation was made not by summing up the subrating as in the case of soil erosion resistance evaluation, but on the basis of the lowest rating given to any of the land qualities used.

The results were made in the following classes.

- S1: Highly suitable
- S2: Moderately suitable
- S3: Marginally suitable
- NS: Unsuitable

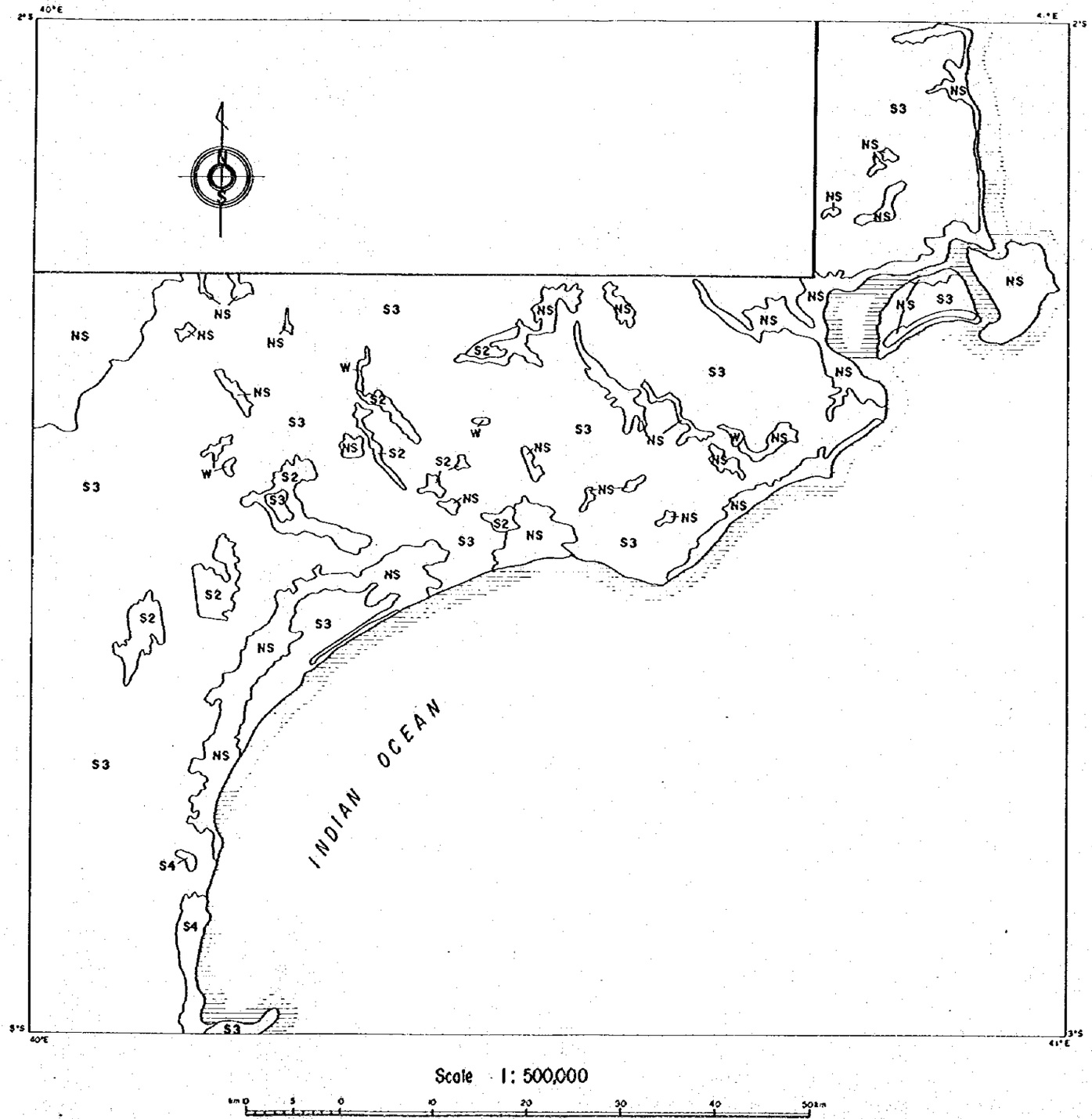
Table IV-4 Land classification criteria

Land utilisation type: Small holder rainfed, mixed farming (cashew, maize, etc.)

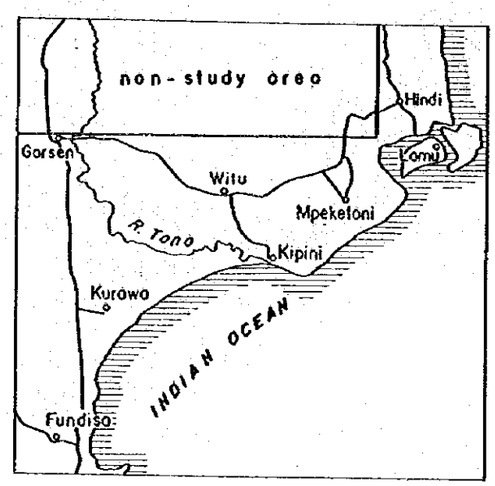
suitability class / land qualities	S 1 Highly suitable	S 2 Mod. suitable	S 3 Marg. suitable	N S Unsuitable
agro-climatic zone	I, II, III	IV	V	VI, VII
soil moisture storage capacity	very high, high	moderate	low, very low	
chemical soil fertility	very high to moderate	low	very low	
resistance to erosion	very high, high	moderate	slight	very slight
possibilities of mechanisation	very good, good	very good, good	moderate	poor, very poor
drainage class	excessively to well	moderately well	imperfectly	poorly, very poorly

Note 1: Refer to relevant documents listed in Annex for ranking soil moisture storage capacity, chemical soil fertility, possibilities of mechanization.

Note 2: For resistance to erosion, the results given in the preceding section are applied.



Study area of evaluation



Legend

Symbol	Suitability class
S 1	Highly suitable
S 2	Moderately suitable
S 3	Marginally suitable
N S	Unsuitable
W	Water

Fig.IV-4 Schematic map of suitability for rainfed agriculture

The area-wise distribution of the four ranks was as follows.

Rank	Area (km^2)	%
S1	–	–
S2	133.9	2.9
S3	3,701.9	79.8
NS	787.0	16.9
Water	17.2	0.4
Total	4,640.0	100.0

As described in Section II-2 Climate, evaporation surpasses rainfall annually in the greater part of the Tana River Delta Area. As a consequence, the suitability rating for the "agro-climatic zone", the most important factor in rainfed agriculture, was very low resulting in no "highly suitable" area. "Moderatly suitable" rating occurs in areas with distributions of Cambisols and Fulvisols, accounting for about 3%, with about 80% of the total area rated as "Marginally suitable".

"Unsuitable" occurs in the coastal area accounting for about 17%.

IV - 3 - 3 SUITABILITY FOR IRRIGATED AGRICULTURE

Suitability for irrigated agriculture to be operated mainly for rice production was evaluated, using the conversion table shown in Table IV-5. The conversion table was prepared by referring to "Proposed Criteria for Land Suitability Classification for Irrigation" reported by F.N. Muchena in 1981, with "slope length" introduced as a substitute for "micro relief" which requires field survey. It is to noted that accessibility to water supply was disregarded in this evaluation.

The results were made in the following classes.

S1: Highly suitable
S2: Moderately suitable
S3: Marginally suitable
NS: Unsuitable

Fig. IV-5 is Schematic Map of Suitability for Irrigated Agriculture.

The area-wise distribution of the four ranks was as follows.

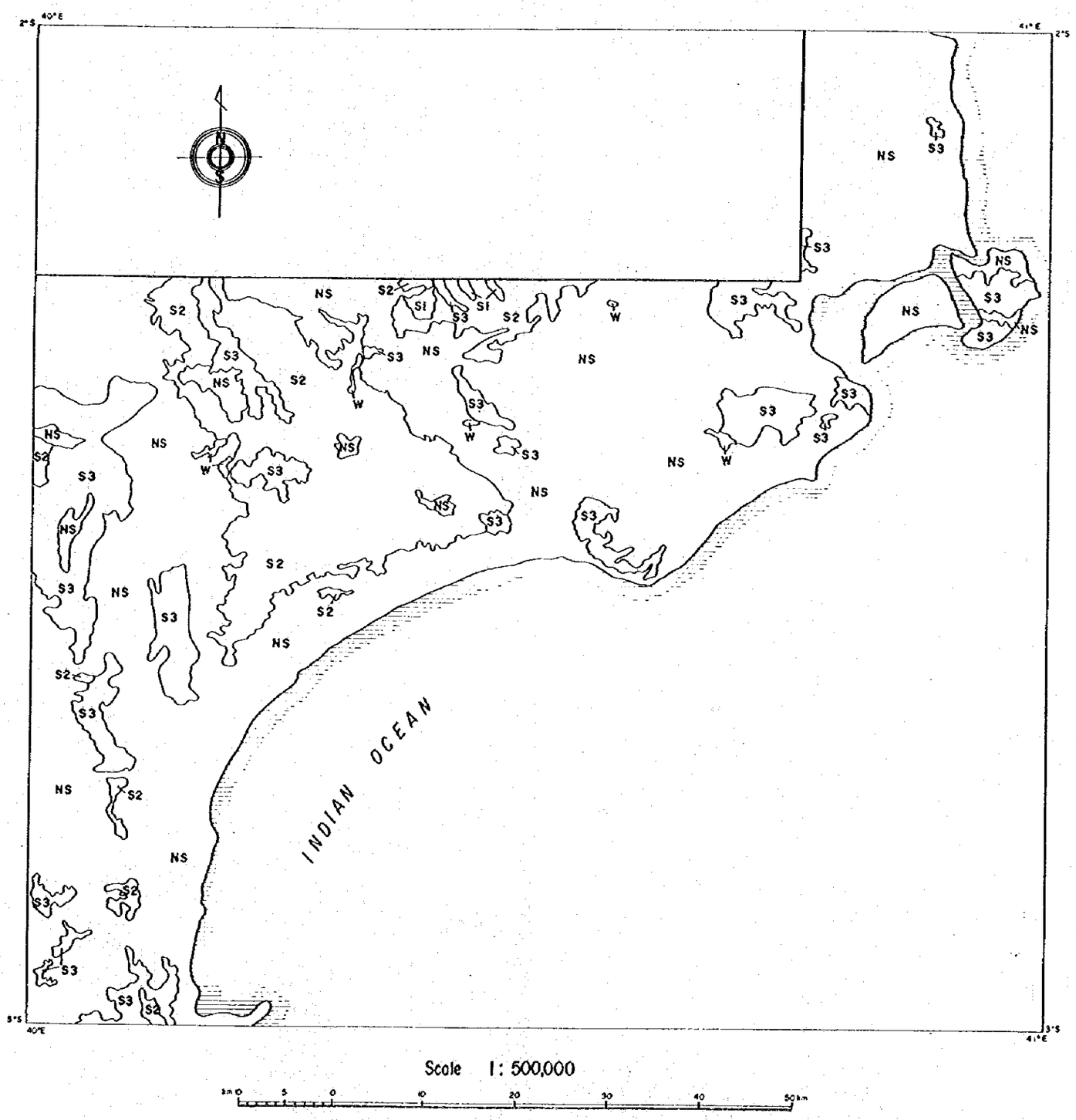
Rank	Area (km^2)	%
S1	18.9	0.4
S2	646.0	13.9
S3	631.4	13.6
NS	3,326.5	71.7
Water	17.2	0.4
Total	4,640.0	100.0

Table IV-5 Land classification criteria

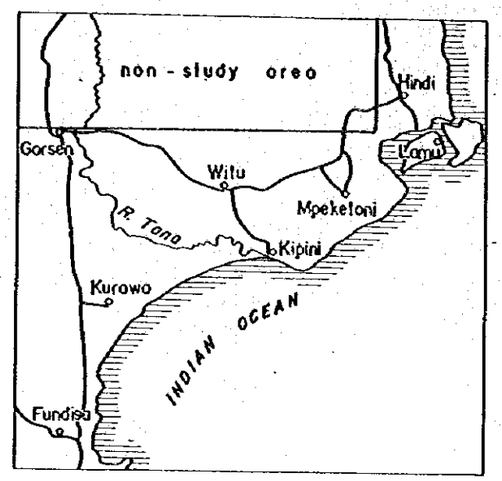
Land utilisation type: Irrigated agriculture (Mainly rice)

suitability class / land qualities	S 1 Highly suitable	S 2 Mod. suitable	S 3 Marg. suitable	NS Unsuitable
texture top	loam to clay	loam to clay	sand to sandy loam	
texture sub	silty clay to clay	loam to clay loam	sandy loam	sand to loamy sand
alkalinity: ESP (%)	< 15	15 - 30	15 - 30	> 30
salinity: ECe (mmho)	< 4	4 - 8	4 - 8	> 8
soil depth (cm)	> 80	50 - 80	25 - 50	
drainage class	well to imperfectly	poorly	poorly	excessively, somewhat excessively, very poorly
vegetation coverage (%)	0 ~ 20	20 ~ 40	40 ~ 80	> 80
slope length (m)	> 200	50 - 200	50 - 200	< 50
slope (%)	< 1	< 1	1 - 2	> 2

Note: For alkalinity and salinity, refer to Annex for relevant documents.



Study area of evaluation



Legend

Symbol	Suitability class
S 1	Highly suitable
S 2	Moderately suitable
S 3	Marginally suitable
N S	Unsuitable
W	Water

Fig.IV-5 Schematic map of suitability for irrigated agriculture

The suitability rating in the above evaluation was greatly influenced by soil conditions because water supply conditions were not considered. Specifically, about 70% of the total delta area was rated as "Unsuitable", about 14% as "highly suitable/moderately suitable" and another 14% as "marginally suitable".

IV - 3 - 4 SUITABILITY FOR RANCHING

Suitability for ranching was evaluated for the Ranching Project Area for both current and potential suitabilities. The current suitability was evaluated on the basis of the present conditions and existing water supply facilities, and the potential suitability was evaluated assuming such changes to be made by forest tree cutting and dam construction for securing water supply.

Suitable class of ranching suitability is divided into four subratings with "Submarginally suitable" added below S3: "Marginally suitable".

(1) Current Suitability

The conversion table used in the current suitability evaluation, shown in Table IV-6, was prepared by referring to a table proposed by R.F. van de Weg (1978). However, soil qualities such as soil moisture capacity, chemical soil fertility, resistance to erosion and hazard of water-logging could not be applied because no soil survey was conducted. For this reason, land suitability as estimated from its relationship with landform and geology and from available reference data was used as one of the land qualities.

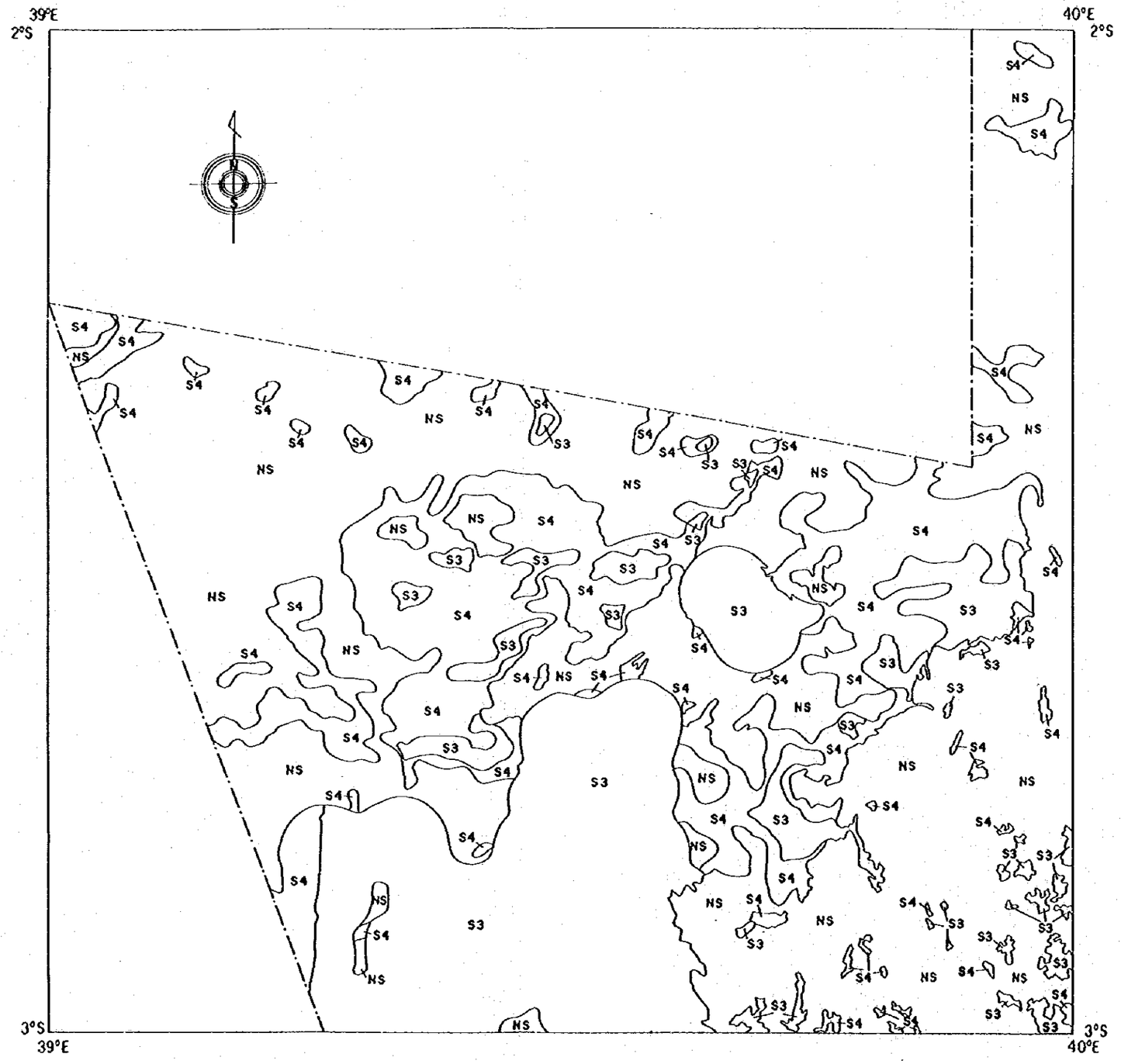
Availability of water was divided into five classes according to the densities of river systems and water holes as well as distances from the existing dams, tanks and springs, and was applied to the relevant suitability class. A higher density of river systems or of water holes makes suitability higher in ranking. This applies also when there ia a dam, a tank or a sping within a distance of 5 km.

Fig. IV-6 is Schematic Map of Current Suitability for Ranching. The evaluation disclosed that there were no "highly suitable" area, and "marginally suitable" and "Submarginally suitable" areas are found only in the neighborhood of existing water supply facilities, and sizeable areas of "Unsuitable" land are distributed in the eastern and north-western parts of the Ranching Project Area. This is because o the forests in the eastern part and the agro-climatic zone and availability of water in the north-western part.

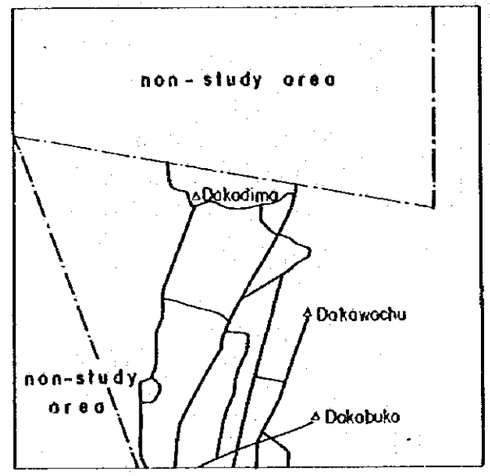
Table IV-6 Land classification criteria

Land ulilisation type : Ranching (current suitability)

suitability class / land qualities	S 1 Highly suitable	S 2 Moderately suitable	S 3 Marginally suitable	S 4 Submarginally suitable	N S Unsuitable
agro-climatic zone	I, II, III	IV, V	VI	VII	
vegetation	G-1·2, Fa	BG-1·2·3	B-1·2 WB-1·2		F-2·3, WBt-1, Cr, Co, C_2, Pm, P_2, V, Ag, Bt
landform	Pn, U, Ud, L, Y, A, Pt 1·2	B, V, Pf	Dz, H, F	C	O, Hr, Hs, W, S
soil	vp, lc, bk	xk	qf, so		i
availability of water	5	4	3	2	1



Study area of evaluation



Legend

Symbol	Suitability class
S 1	Highly suitable
S 2	Moderately suitable
S 3	Marginally suitable
S 4	Submarginally suitable
N S	Unsuitable

Scale 1:500,000

10 5 0 10 20 30 40 50km

Fig.IV-6 Schematic map of current suitability for ranching

(2) Potential Suitability

If ranching suitability of the Ranching Project Area is to be improved by reforming its natural conditions, forest tree cutting and dam construction would serve the purpose. Accordingly, the evaluation was intended to determine the suitability for ranching that can be expected by clearing forest trees and constructing dams. For this purpose, 23 candidate dam sites were selected along the fourth order river systems at necks of valleys with no two sites occurring within a distance of 5 km for the same river system. Thus, "dam site potentiality" was added as one of the land qualities. The area to be served by such a dam is assumed within a radius of 5 km of the site.

The dam site potentiality and the water availability evaluation used for the current evaluation were compared and whichever was better was defined as "potential availability of water" and applied for suitability evaluation. The conversion Table used is given in Table IV-7.

Table IV-7 Land classification criteria

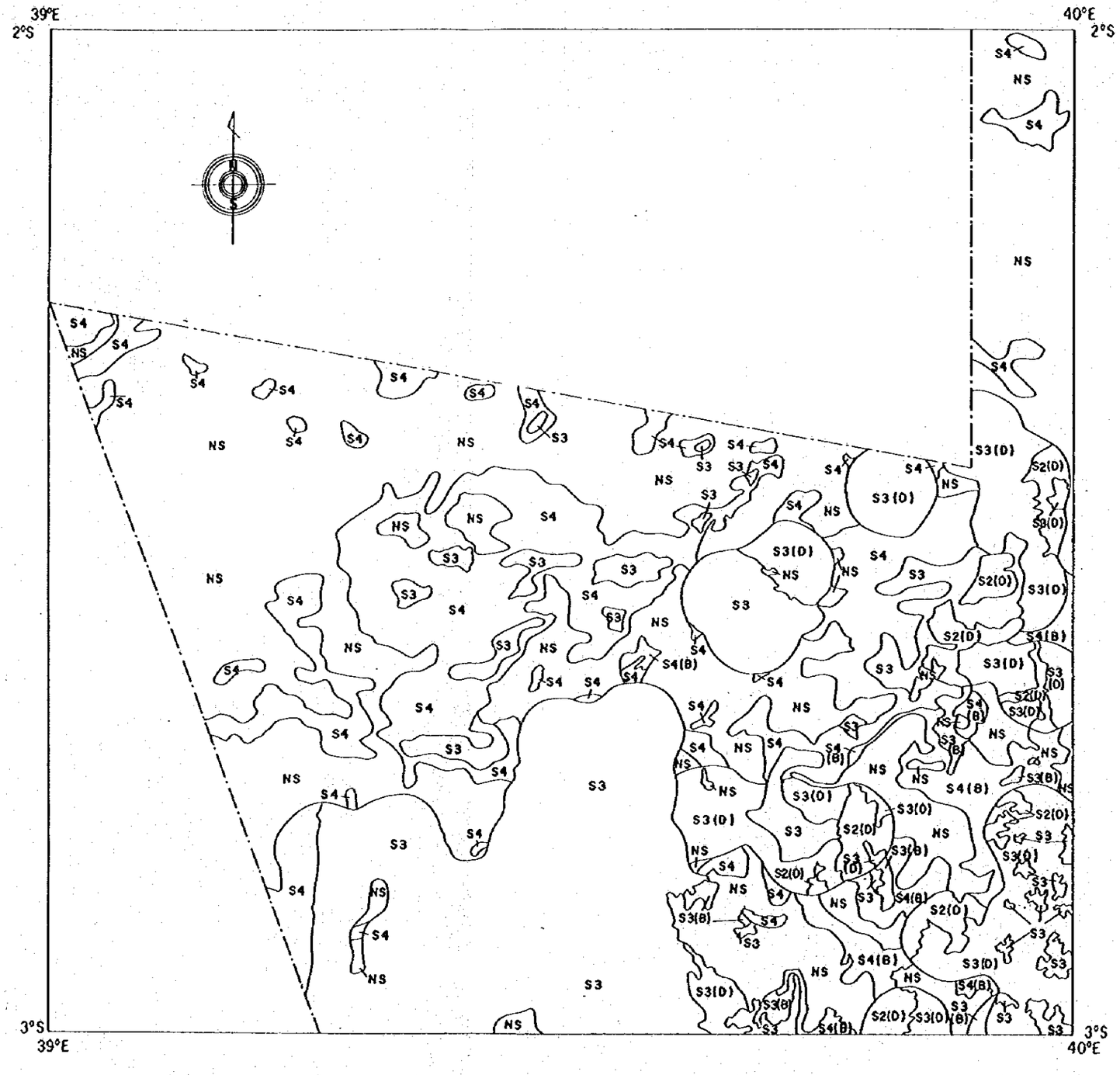
Land utilisation type : Ranching (potential suitability)

suitability class / land qualities		S 1 Highly suitable	S 2 Moderately suitable	S 3 Marginally suitable	S 4 Submarginally suitable	N S Unsuitable
agro-climatic zone		I, II, III	IV, V	VI	VII	
landform		Pn, U, Ud L,Y, A, Pt t.2	B, V, Pf	Dz, H, F	C	O, Hr, Hs W, S
soil		vp, lc, bk	xk	qf, so		i
potential availability of water	availability of water	5	4	3	2	1
	dam site potential	1	1	1	1	0

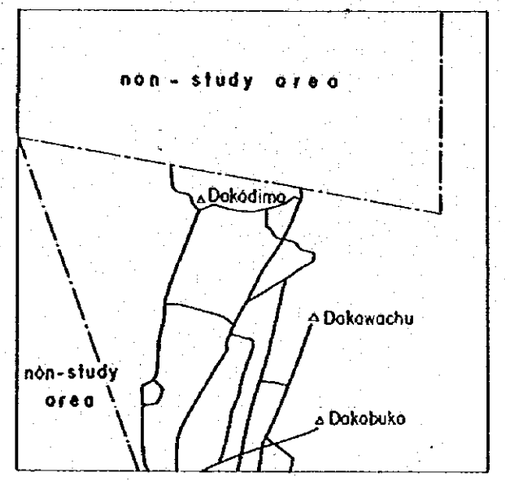
Fig. IV-7 is Schematic Map of Potential Suitability for Ranching.

In the potential suitability map, S2 (D) and S3 (B), for example, denote that suitability increases only when such changes as made by forest tree cutting (difficulty level B) and dam construction (difficulty level D) respectively are to take place. On the other hand, when there is no improvement expected in potential suitability from such changes in the present land, that particular land is represented by current potentiality.

The evaluation shows that there will be some "Moderately suitable" areas though in small in size, created near where dams are sited. Some of the "Unsuitable" areas in the current suitability were upgraded to either "Marginally suitable" or "Submarginally suitable". One major reason for that low suitability is there is little suitable area for dam siting due to the agro-climatic zone and the underdeveloped river systems.



Study area of evaluation



Legend

Symbol	Suitability class
S 1	Highly suitable
S 2	Moderately suitable
S 3	Marginally suitable
S 4	Submarginally suitable
N S	Unsuitable

Input requirements

(A)	Low
(B)	Moderate
(C)	High
(D)	Very high

Scale 1:500,000

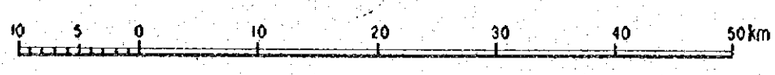


Fig. IV-7 Schematic map of potential suitability for ranching

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V. REFERENCES

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