2.2 Physical Geography

2.2.1 Topography

(1) Topographic Classification

The main topographic features of Zambia are represented by a series of gently undulating and flat plateau with isolated hills and low ranges, as shown in Figure 2-7. Broad shallow depressions can often be found in the plateau forming swamps and flats. The western part of the country is covered with loose sediment delivered by the Zambezi river which forms a wide flat plain. The plateau are abruptly broken by steep linear escarpments running in a NE-SW direction along the Luangwa river and Zambezi river in the south western peripheral area of Zambia. The plateau has an average elevation of 1300m above sea level, varying from a maximum of 2164m in the east to a minimum of 325m at the Zambezi river. The majority of the country lies between 900m and 1500m and the main cities are mainly situated on the gentle undulating plateau. Topography of Zambia is classified in detail by satellite imagery interpretation as shown in Table 2-14 and Figure 2-7.

Table 2-14 Classification of Topography of Zambia (km^2)

	Montane Zone	Degraded Plateau	Aggraded Plateau	Escarpment Zone	Rift Trough	Escarpment Zone
Lusaka	0	8,435	0	8,430	5,229	22,094
Copperbelt	0	31,217	0	0	0	31,217
Central	0	80,898	295	7,096	6,395	94,684
Northwestern	0	76,324	48,957	0	0	125,280
Western	0	2,084	125,259	0	0	127,344
Southern	0	19,446	44,656	11,709	9,387	85,199
Luapula	0	38,319	0	3,002	8,274	49,594
Northern	323	106,831	0	12,586	27,552	147,292
Eastern	160	22,862	0	24,082	22,043	69,146
All Zambia	483	189,542	169,915	51,379	67,256	751,851

<u>Montane Zone</u>

Montane Zone means mountain regions, and this unit consists of land at an elevation of more than 1,850m. This unit includes Montane Plateau (elevation of more than 2,000m) and Montane Escarpment. The distribution of the Montane Zone is limited to Northern Province.

<u>Central African Plateau</u>

Most parts of Zambia are classified as Central African Plateau. The elevation of the plateau ranges from 1,850 to 600m. The highest parts of the plateau are located in the north and north west of Zambia. The elevation gradually reduces toward the southwest/south to the Zambezi river. In general the plateau is gently undulating in all places. Central African Plateau is subdivided into two major sub units, that are Degraded Plateau and Aggraded Plateau. The surface of Degraded Plateau is made by erosion and traversed by network of rivers. The relief of the plateau is dominated by drainage density. Swamps, lakes, floodplains and isolated hills are included in degraded plateau. The surface of Aggraded Plateau is made by sediments and characterised by very gently undulating plains with widely spaced river lines and by sand dunes and pans made by wind . The distribution of aggraded plateau is limited to Western Province and North Western Province.

Zambia

Geomorphology

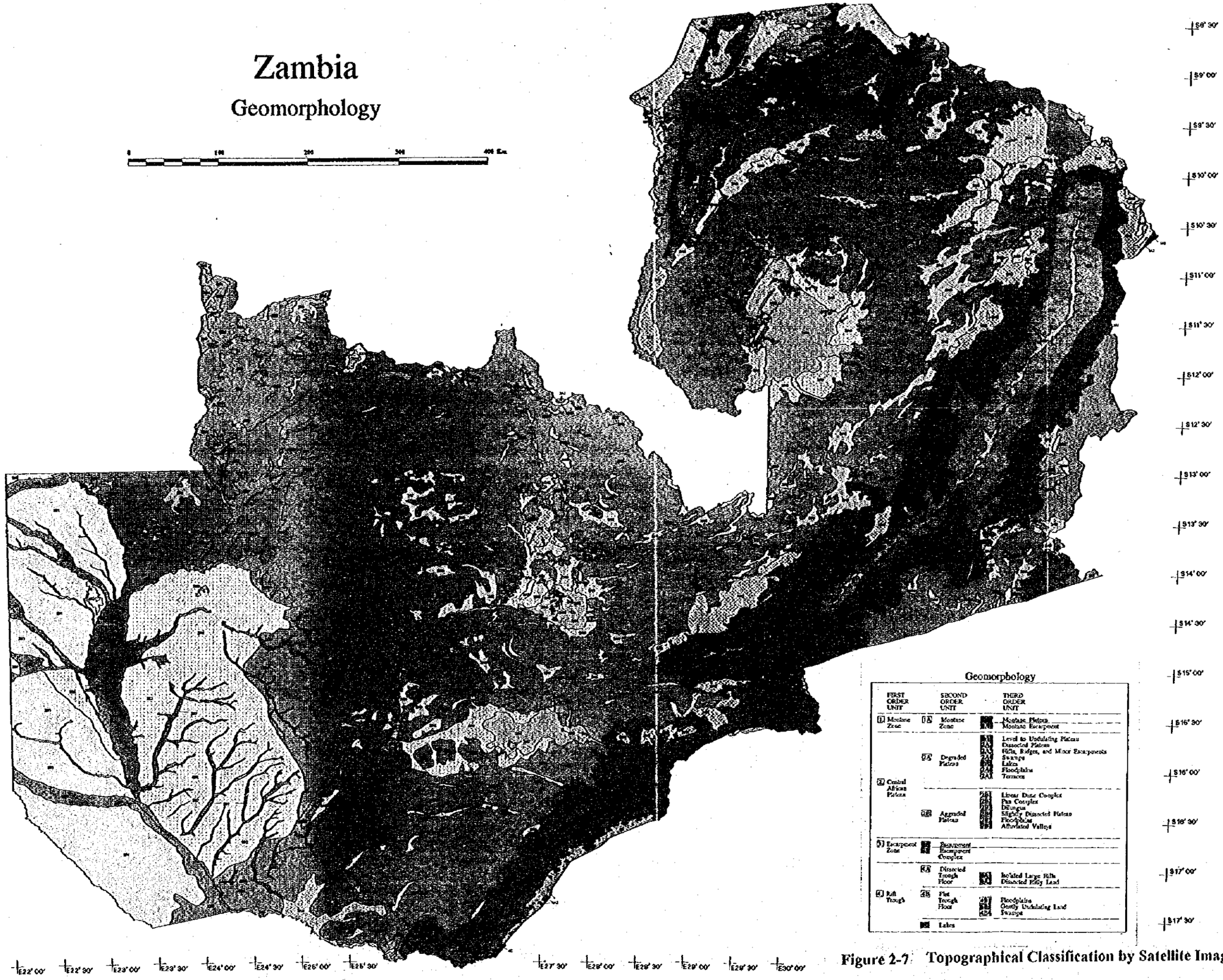


Figure 2-7 Topographical Classification by Satellite Imagery Interpretation

Zambia

Geomorphology

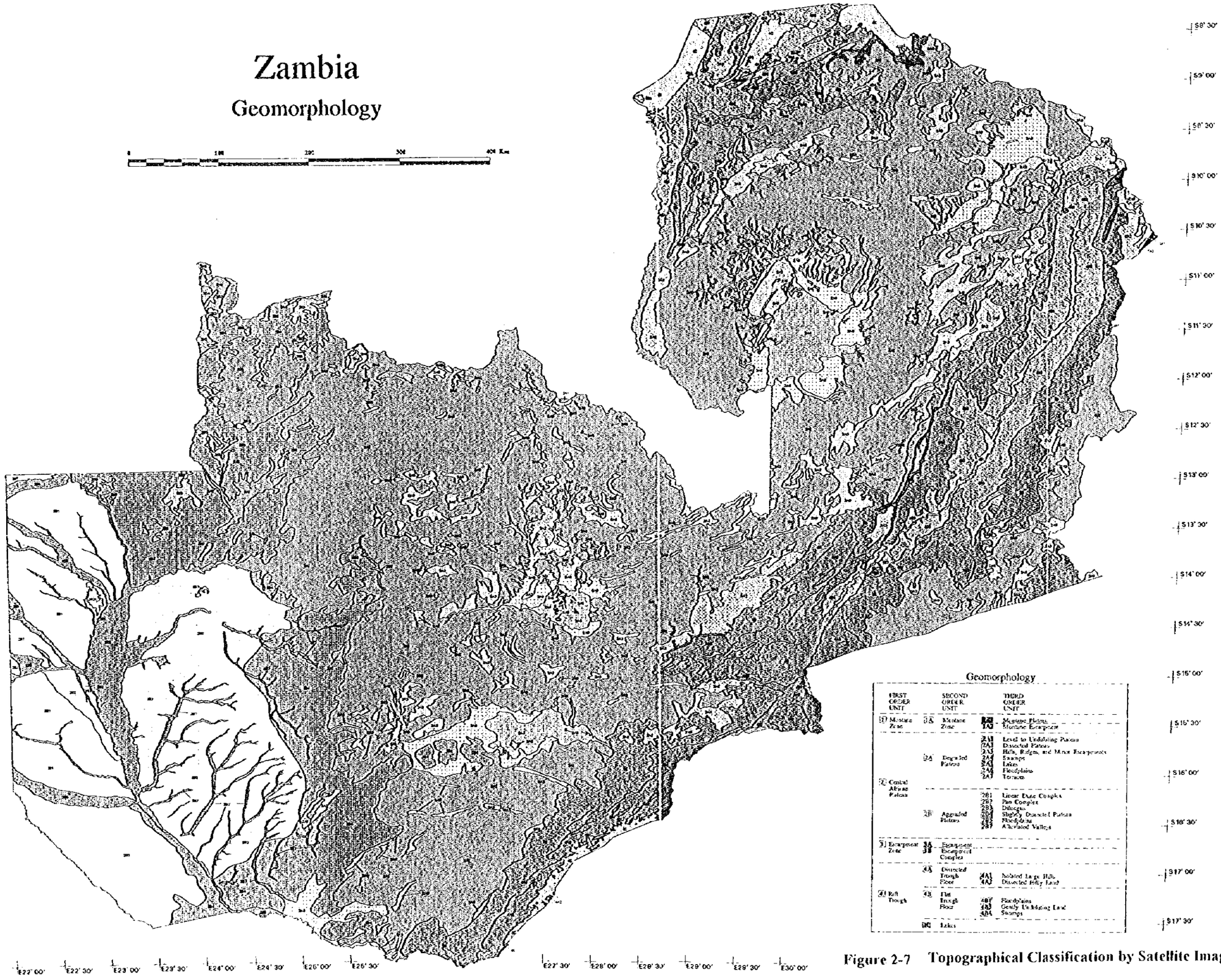


Figure 2-7 Topographical Classification by Satellite Imagery Interpretation

Zambia

Geomorphology

Figure 2-7 Topographical Classification by Satellite Imagery Interpretation

Escarpment Zone

Escarpment Zone exists between the Central African Plateau and Rift Troughs, and is characterised by a steep escarpment. The Escarpment was made by major faulting and subsequent erosional processes and abruptly breaks the African Plateau. This zone is very clear along the Luangwa River.

Rift Troughs

Rift Troughs are located in the floors of large valleys which have been made by major faults. The main Rift Trough in Zambia exists along the Luangwa river and the elevation generally ranges from 325m up to 650m.

2.2.2 Geology

The geology of Zambia comprises various rocks and layers dating from over 1,000 million years ago (Precambrian era) to more recent times. These rock formations consist of igneous, sedimentary and metamorphic rocks. The stratigraphy of Zambia is summarised in Table 2-15.

Table 2-15 Stratigraphy of Zambia

Geological Age		Super Groups	Groups or Formation	Rocks and Sediments
Cenozoic Era	Quaternary Tertiary	Cenozoic Super Group	Alluvium	Alluvium sands, Gravels with clay near lakes
			Kalahari Group	Fine sands, Sandstones with clay
Mesozoic Era	Cretaceous	Mesozoic Super Group	Lower Cretaceous Formation	Mudstones, Siltstones
	Jurassic Carboniferous	Karroo Super Group	Upper Karroo Group	Basalt, Interbedded sandstones, Sandstones, Mudstones, Siltstones
			Lower Karroo Group	Mudstones with coal measure, Siltstones, Sandstones, Conglomerates
Paleozoic Era	Silurian Ordovician	Lower Paleozoic Super Group		Quartzites, Shales, Sandstones
	Early Paleozoic Precambrian	Metanga Super Group	Kundelung Group	Carbonate rocks with shales, Shales, Siltstones, Sandstones
Precambrian Era			Upper Roan Group	Dolomites, Argillites
			Lower Roan Group	Quartzites, Argillites, Dolomites, Conglomerate, Mine series shales
		Basement and Muva Super Group	Muva Group	Shales, Mudstones, Sandstones
			Basement Complex	Basement gneisses, Migmatites, Schists
Various age mainly older Precambrian		Intrusive and Metamorphic Rocks		Basic-igneous rocks, Meta-igneous rocks, Amphibolites, Metasediments, Metavolcanics

Basement Complex

The oldest system in Zambia is known as Basement Complex which is dated to be over 1,000 million years old (Lower Precambrian). The Basement Complex consists of highly deformed gneiss, schists, quartzites, conglomerates, crystalline limestone, migmatites and granites. The Basement Complex mainly outcrops in the east and south-eastern part of Zambia and its

distribution areas mostly coincide with the "Bangweulu Block" as shown in Figure 2-8. The Basement Complex is overlain by undeformed Precambrian to Lower Paleozoic sediment known as the Plateau Series and Muva Group.

Katanga Super Group

The age of the Katanga Super Group ranges from late Precambrian to Cambrian (100 to 500 million years old). The Katanga Super Group comprises shale, sandstone, dolomites, quartzites, limestones and conglomerates. The Katanga Super Group is distributed in the northern and central parts of Zambia, and almost coincides with "Katanga System" shown in Figure 2-8.

Lower Paleozoic Super Group

The Katanga Super Group is overlain by sedimentary rocks such as shales, quartzites and arkose sandstones. They are grouped as Lower Paleozoic Super Group and are extremely limited. Its existence is only evident in the western part of Zambia and the mid-Zambezi Valley by drilling investigations.

Karroo Super Group

The Karroo Super Group is composed of tillites (fluvo-glacial origin), coal seams, mudstones, marls, conglomerates and basalt. The Karroo Super Group corresponds to the Carboniferous to Jurassic Systems. The Karroo Super Group is distributed along the Luangwa river and western part of Zambia, as shown in Figure 2-8.

Mesozoic Super Group

The basalt of the Karroo Super Group is overlain by mudstones along the Zambezi river and to the west of Zambia. These layers have been judged to be Cretaceous in age based on the discovery of certain fossils and are named the Mesozoic Super Group. The thickness of the Mesozoic Super Group has been estimated as up to 100m thick. The distribution area of the Mesozoic Super Group is shown in Figure 2-8 as "Cretaceous System".

Cenozoic Super Group

The Mesozoic Super Group is overlain in a large part of the extreme west of Zambia (Barotse Basin) by tertiary sandstone and quaternary consolidated sand layers (duricrusts) and clay layers. These layers have been named the Cenozoic Super Group and they are divided into two formations; namely the Zambezi Formation of the lower part and the Barotse Formation of upper part. The so-called "Kalahari Sandstone" is a member of the Zambezi Formation.

Intrusive Rocks

Intrusive rocks of varying age and type mainly intrude the Precambrian rocks. The majority consist of granite rocks and the remainder are gabbros, dolerites, syenites, etc.

Zambia

Geology

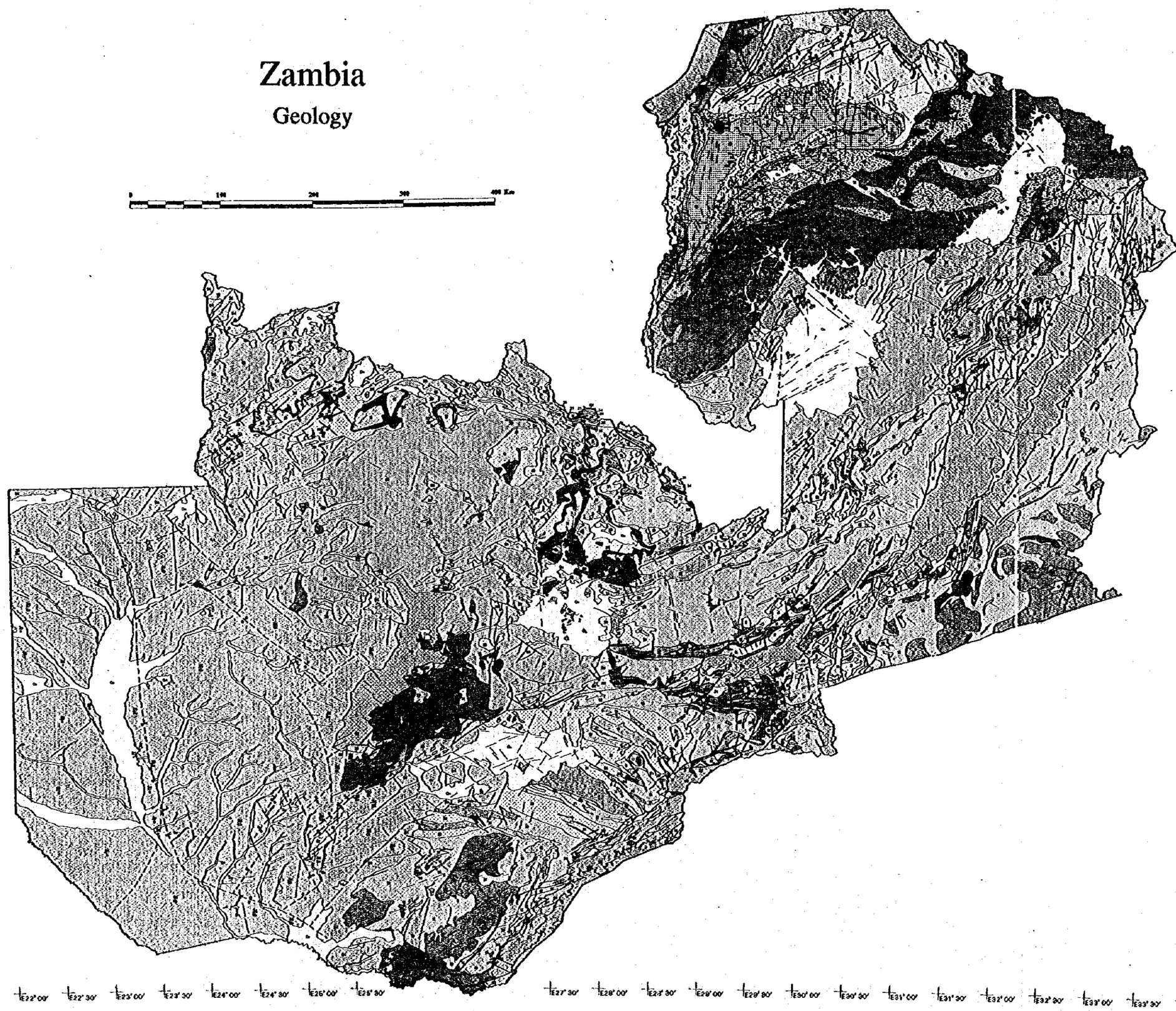
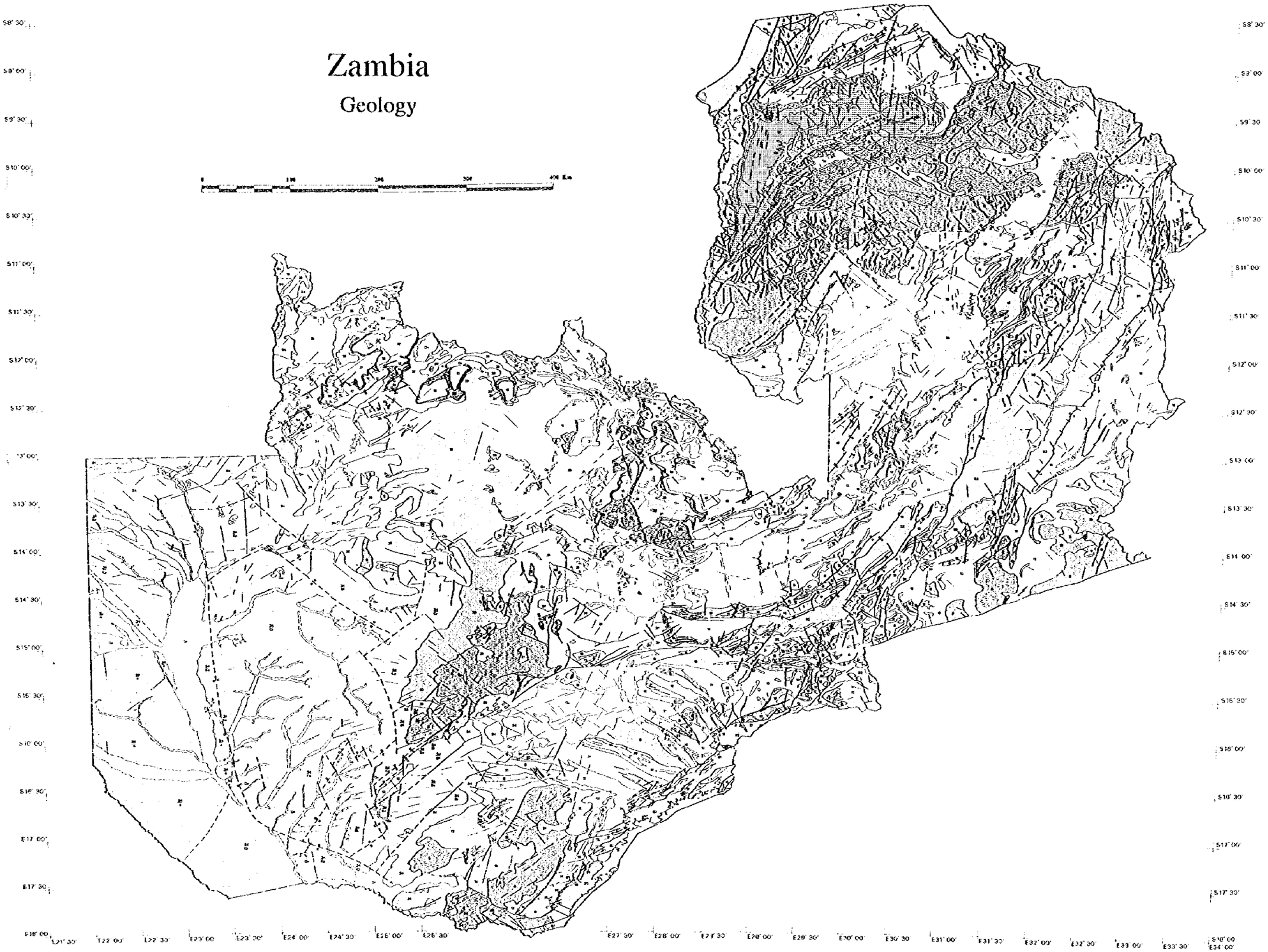


Figure 2-8 Geological Classificat

Zambia

Geology



Geologic Sy

All symbols dashed where u

Thrust or R

Fault U/D

movement
of strike sl

Fault Mo

Lineament

Stratigraphic

Foliation

Anticlinal ax

Synclinal ax

Dome

Lithologic Sy

Alluvium, colluvium, laterite

Kalahari Group with fossil soil zones

unconformity

Basalts

Upper Karroo (Zambezi Valley), Karroo

Lower Karroo, undifferentiated

Basal Formation and Coal Measure

unconformity

Upper Kundelungu Shales (Lusaphe Prov

Kundelungu psammite and mafite formatio

Kundelungu undifferentiated, may include

includes Petit Conglomerat in Lusaphe Pr

Lower Kundelungu Shales (Lusaphe Prov

Kundelungu carbonate rocks; may be Mp

Kundelungu undifferentiated, may include

Pe. lommanity shales, siltstones, sandstone

Mwashia - typically carbonaceous shale a

Upper Roan - Typically dolomitic argillite

Lower Roan with basal conglomerate, do

Includes quartzites, conglomerates, arg

Mine Series(sic)-Undivided, Upper Roan

province and at western end of Copperbe

Upper Roan around Luswishi Dome, Sout

unconformity

Upper shales

Upper quartzite

Lower shales

Lower quartzite

Quartzites, phyllites

Schists and banded pelitic quartzite pelite and

associated meta-carbonate and meta-volca

Mporokoso group, Kasama group and Mi

unconformity

Pre Katanga schists, undifferentiated, inclu

foot classified gneiss and schists and various

Provinces.

Granulite facies rocks (excluding ch

Undifferentiated Basement Complex, contai

some granite

Vol. stasis and meta volcanics

Meta-carbonate rocks of various age

Calc-silicate rocks undifferentiated

Meta-quartzites of various ages

Quartz veins

Mylonite and blastes chlorite

Granite

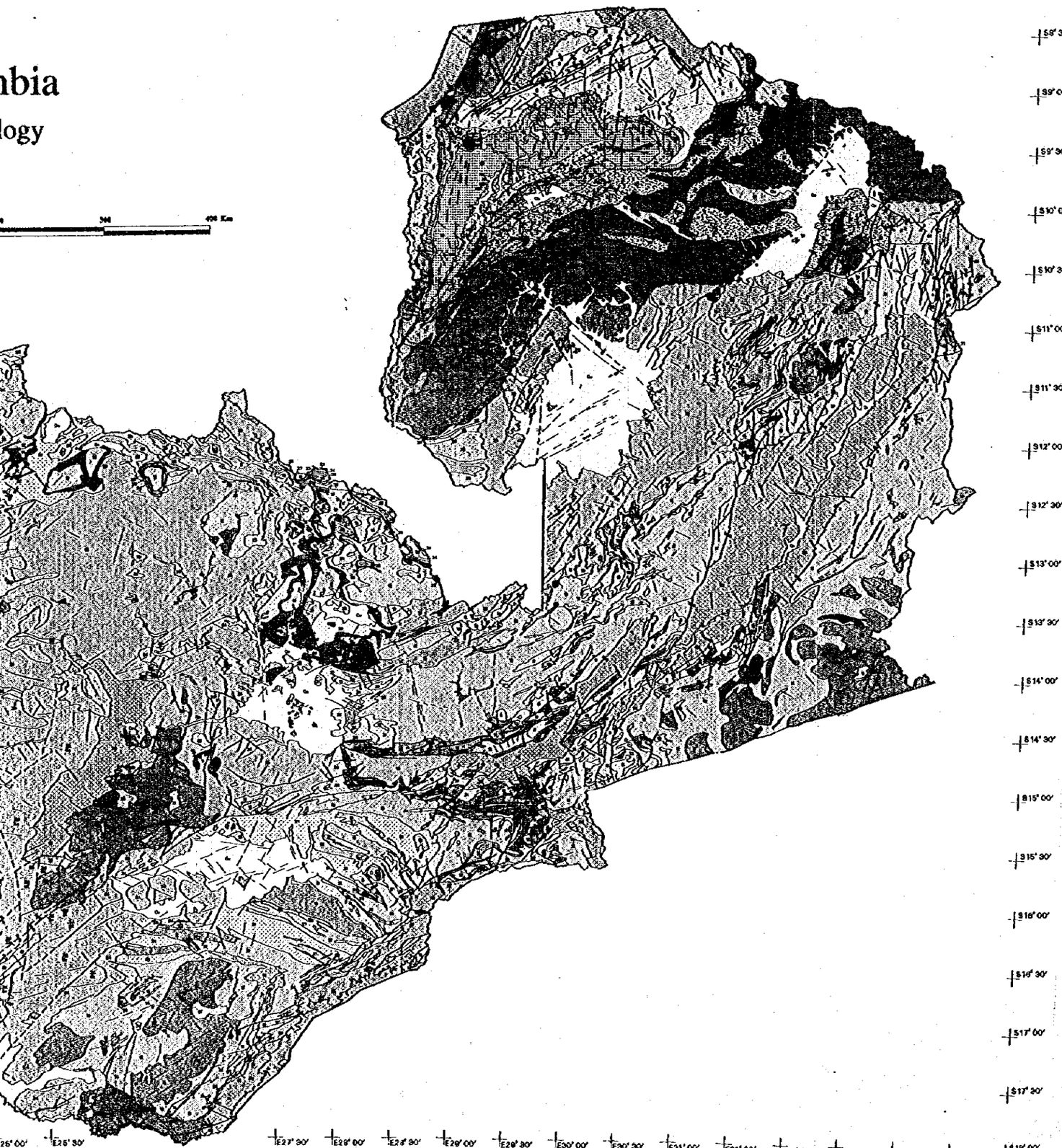
Syenite, syenodiorite, dunite and metaso

Basic igneous and meta-igneous rocks, an

Carbonatite

Kimberlite

Figure 2-8 Geological Classifica



Geologic Symbols

All symbols dashed where indefinite or concealed

- Thrust or Reverse fault. Triangles are on the upper plate.
- Fault. U/D on faults where sense of vertical movement is identified. Arrows show direction of strike-slip movement.
- Fault. Movement unspecified.
- Lineament. May indicate a fault or a fracture.
- Stratographic break.
- Foliation.
- Anticlinal axis.
- Synclinal axis.
- Dome

Lithologic Symbols

Alluvium, colluvium, laterite Kalahari Group with fossil seif dunes	Sub-crop of solid geology underlying these groups shown as follows: c-Cretaceous, Kb-Karroo Basalt, Kc-Karroo Clastics, BK-Basement, and Katanga System	TERTIARY TO RECENT
unconformity		
Basalts Upper Karroo (Zambezi Valley); Karroo undifferentiated (elsewhere) Lower Karroo, undifferentiated Basal Formation and Coal Measure		KARROO (Upper Carboniferous to Jurassic)
unconformity		
Upper Kundelungu Shales (Luapula Province) Kundelungu psammite and rudite formations (includes Petit Conglomerat in Luapula Province) Lower Kundelungu Shales (Luapula Province) Kundelungu carbonate rocks; may be Mwashia in part in some areas Kundelungu undifferentiated; may include some Mine 'Series' in the northwest. Predominantly shales, siltstones, sandstones and mixtites. Mwashia - typically carbonaceous shale and argillite Upper Roan - Typically dolomite argillite Lower Roan with basal conglomerate; the main copper-bearing unit. Includes quartzites, conglomerates, argillites, arkoses, and some dolomite Mine 'Series' undifferentiated. Upper Roan plus Mwashia in Northwestern province and at western end of Copperbelt; probably Lower and Upper Roan around Luswishi Dome. Status uncertain south of Copperbelt.		KATANGA (Late Precambrian and (?) Lower Paleozoic)
unconformity		
Upper shales Upper quartzite Lower shales Lower quartzite	Luapula and Northern Provinces	MUVA
Quartzite-pelite sequences		
Metamorphosed pelite, quartzite-pelite and psammite sequences, some with associated meta-carbonate and meta-volcanic rocks. Includes Chisamba Formation, Mpanshya group, Sasare group and Mwami group. Probably coeval in part.		PRECAMBRIAN ROCKS OF UNCERTAIN AGE: POSSIBLLY MUVA
unconformity		
Pre-Katanga schists, undifferentiated. Includes Lufubu Schists of Copperbelt (interlayered gneiss and schist) and various groups in Southern and Northwestern Provinces. Granulite facies rocks (excluding charnockites) Undifferentiated Basement Complex; mainly granitic gneisses and migmatites with some granite. Volcanics and meta-volcanics		PROBABLY LARGELY OLDER PRECAMBRIAN
Meta-carbonate rocks of various ages Calc-silicate rocks undifferentiated Meta-quartzites of various ages Quartz veins Mylonite and blastomylonite Granite Syenite, syenodiorite, diorite and metamorphic equivalents Basic igneous and meta-igneous rocks, amphibolites Carbonatite Kimberlite		LITHOLOGICAL UNITS OF VARIOUS AGES

Figure 2-8 Geological Classification by Satellite Imagery Interpretation

2.2.3 Hydrogeology

(1) Classification of Aquifers

From a hydrogeological view point, the classification of geology of Zambia is simplified into the following groups and component rocks, as shown in Table 2-16.

Table 2-16 Classification of Aquifers

Litho Stratigraphic Unit		Main Aquifer Lithology	Productivity of Groundwater	% of the Whole Country (%)
Cenozoic Super Group	Alluvium	Sand , Gravel	Medium-High	11.9
	Kalahari	Sand	Medium-High	23.8
Karroo Super Group	Upper Karroo	Basalt	Low	0.5
		Sandstone	Medium-High	4.5
	Lower Karroo	Mudstone	Low	0.7
Katanga Super Group	Kundelungu	Carbonate Rock	High	2.0
	Undifferential Kundelungu	Shale	Low	12.9
	Upper Roan	Dolomite	High	0.4
	Lower Roan	Quartzite, Dolomite	Medium-High	0.8
	Mine Series	Quartzite, Shale	Low-Medium	3.7
Muva Super Group		Shale	Low	9.4
Basement Complex		Gneiss, Migma-tites, Schist	Low-Medium	14.2
Granite		Granite	Low-Medium	15.2
Other Igneous Rocks		Basic-Igneous Meta-Igneous	Low	
Metamorphic Rocks		Metasediment, Metavolcanics	Low	

[Source]: Hydrogeological Map of Zambia (scale 1:1,500,000)
Groundwater Resources Inventory of Zambia (Chenov, 1978).

(2) Types of Aquifer

Groundwater occurs in secondary developed features such as weathered zones, joints, fractures, faults or solution features within consolidated hard rocks. The weathered zones usually form shallow aquifers which are shallower than 20m in depth. Fracture zones have been developed under weathered zones and usually extend to around 30m-40m in depth and often extend to more than 90m in depth. The thickness and permeability of aquifers are closely related to the original rock type. The aquifers in Zambia are classified into three types as shown in Figure 2-9.

<u>Aquifers where intergranual groundwater flow is dominant</u>
The alluvial formations, Kalahari Group and Karroo Group are included in this category. This type of aquifer is distributed mainly in the western half of Zambia, in Western Province and parts of North-Western Province and Southern Province as shown in Figure 2-9. However, in the eastern half of Zambia, this aquifer is also distributed around Chambeshi river and lake Bangweulu in Luapula and Northern Province and along Luangwa river in Eastern and Northern Province.

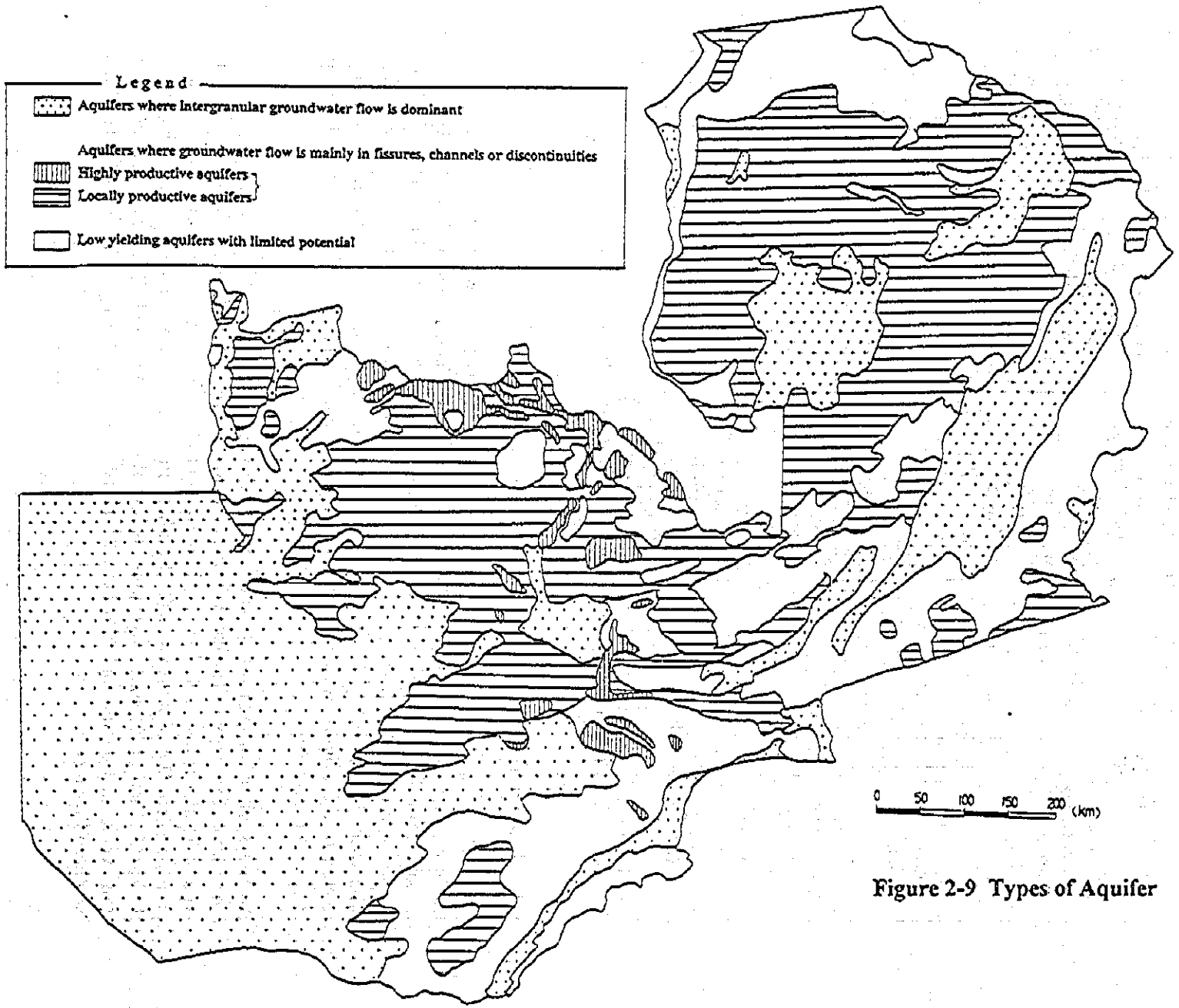


Figure 2-9 Types of Aquifer

Aquifers where groundwater flow is mainly in fissures, channels or discontinuities
The type of this aquifer is subdivided into two types.

Highly productive aquifers
The Upper Roan dolomite and Kundelungu limestone are included in this category. Limestone, dolomites and dolomitic-limestones are often the most productive aquifers in Zambia. This type of aquifer is distributed in Copperbelt, Lusaka, North-Western and Central Province. The area of distribution is limited and very narrow, but some large cities are located around this type of aquifer.

Locally productive aquifers
The Lower Roan Quartzite, Muva sediments, granites and undifferential Kundelungu formations are included in this category as locally productive. These aquifers are distributed largely in Northern, Luapula, Central, North-Western, and Copperbelt Province.

Low yielding aquifers with limited potential
This category includes the major part of argillaceous formations, Karroo basalts and the older Basement Complex. This type of aquifer is distributed in almost half of Eastern, Southern and Lusaka Province, and parts of Northern, Luapula, Central, Copperbelt and North-Western Province.

2.2.4 Land Use

Land use is divided into eight(8) categories, namely Forest, Savanna, Grassland, Barren, Agriculture, Wetlands, Urban and Water. Land use map made by Satellite Imagery Interpretation is shown in Figure 2-9. Land use of each province is shown in Table 2-17.

Table 2-17 Land Use of Zambia (km^2)

	Forest	Savanna	Grassland	Barren	Agriculture	Wetlands	Urban	Water	Total
Lusaka	5,250	3,790	12,261	14	255	255	173	97	22,094
Copperbelt	7,462	3,951	18,641	44	700	69	312	37	31,217
Central	17,823	16,769	55,093	65	2,781	1,744	97	312	94,684
Northwestern	21,838	26,801	75,802	49	435	175	83	97	125,280
Western	13,345	18,830	93,689	486	279	372	25	318	127,344
Southern	11,381	10,590	56,684	4	2,624	1,086	108	2,721	85,199
Luapula	5,931	10,232	25,447	52	451	2,626	91	4,764	49,594
Northern	17,644	47,547	74,878	266	520	2,040	133	4,264	147,291
Eastern	5,022	12,462	48,103	29	3,463	11	45	11	69,146
Total	105,699	150,972	460,599	1,009	11,507	8,379	1,065	12,621	751,851
(%)	(14)	(20)	(61)	(>1)	(2)	(1)	(>1)	(2)	(100)

Outline of Land Use in Zambia is as follows.

Forest
Forest areas occupy 14.1% of Zambia. Distribution area of forest is relatively large in Northern, Copperbelt and Lusaka Province where forests occupy 24% of each province. On the contrary, distribution area is just 7% in Eastern Province. In general, area of the distribution is in proportion to annual rain fall. However, this trend does not always hold in Zambia.

Savanna
Savanna area is widely distributed and occupies 20.1% of Zambia. Distribution of savanna is largest in Northern Province and occupies 32% of the province. The smallest is 12 % in Southern Province. Savanna area exists between forest and grassland in elevation.

Grassland
Grassland areas occupy 61.3% of Zambia and are the most common land use in Zambia. High distribution areas are Western province (75%), Southern province (68%) and Eastern province (70%). These province have less rain than other provinces. The distribution area of grassland is more than 50% in all provinces and the lowest is 51% in Luapula Province. Grasslands are distributed over most low elevation areas especially along Luangwa and Zambezi River.

Wetlands
Wetlands occupy 1.1% of Zambia. Large distribution area of wetlands are limited to Kafue Floodplain, southern part of Lake Bangweulu, Lukanga swamp and southern part of Lake Mweru. On the other hand, wetlands which are distributed along many rivers are usually small and narrow. Wetland distribution is relatively large in Central Province (2%) , Lusaka (1%) and Northern (1%).

Water
Water areas occupy 1.7% of Zambia. This category includes lakes like Lake Tanganyika, Lake Mweru, Lake Mweru Wantipa, Lake Bangweulu, Lake Kariba and Lake Itezhi-Tezhi. The distribution is the largest in Luapula province where water occupies 10% of the province.

Barren
Barren areas occupy only 0.1% of Zambia and distribution is very small and limited. A relatively large barren area exists in the upper stream region of Luangwa River in Eastern province and many small barren areas are scattered on the right side of Zambezi River in Western province.

Agriculture
Agriculture areas occupy only 1.5% of Zambia. Most agriculture areas are small and scattered. In particular, agriculture is distributed along the main road and railway from Livingstone to Copperbelt. Therefore, ratio of agriculture area is high in Southern Province, Lusaka Province, Central Province and Copperbelt Province. Eastern Province also has a relatively high ratio. On the other hand, small scale agriculture areas are distributed along the road from Lusaka to Mongu, upper area of Zambezi River and parts of Northern Province and Luapula Province. Distribution of agriculture area does not appear elsewhere on the satellite imagery interpretation map with scale of 1: 1,500,000.

Urban area
Urban areas occupy 0.1% of Zambia. Most cities, municipalities and large townships are clearly shown on the satellite imagery interpretation map. However, small town ships and villages are too small to appear on the satellite imagery interpretation map with scale of 1: 1,500,000.

Zambia

Land Cover

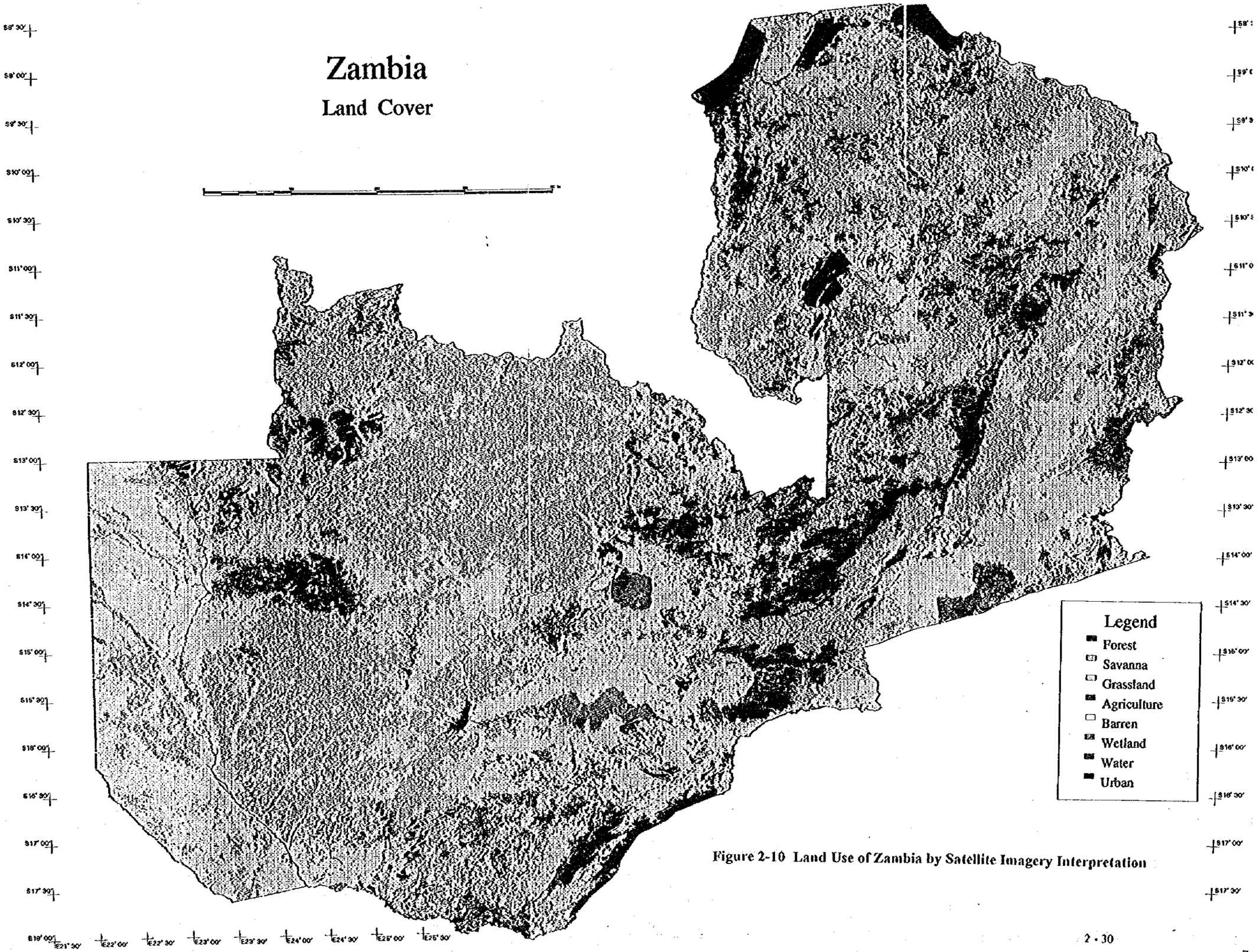


Figure 2-10 Land Use of Zambia by Satellite Imagery Interpretation

2.3 Climate

2.3.1 General Climatic Conditions

For a land-locked tropical country, Zambia enjoys an enviably pleasant climate. Temperatures are remarkably moderate and this is mainly due to the altitude. The rainfall is not heavy and floods are rare. Winds are generally light and damage to life and property due to high winds is practically unknown. Cases of tropical cyclone storms from the Indian Ocean crossing the East Coast of Africa and reaching as far as Zambia are rare.

Over Zambia, annual mean temperature ranges from 19.3 °C to 24.5 °C, and is 21.0 °C on an average. The annual rainfall ranges from 700 mm in the extreme southwest to 1,400 mm in the north, and is 1,001 mm on an average. Lusaka, the capital city of Zambia, is located almost in the centre of the country at an elevation of 1,280 metres above sea level (Lusaka City Airport). The mean daily maximum and minimum temperature is 30.1°C in October and 9.1°C in July. The mean annual rainfall is 858 mm.

In general, a year in Zambia can be divided into two distinct halves, a dry half from May to October and a wet half from November to April. However, from the synoptic point of view it is more convenient to divide a year into 4 unequal seasons as follows :

1) Winter season : June to August
2) Pre-rainy season : September to October
3) Rainy season : November to March
4) Post rainy season : April and May

The equatorial low and the Inter Tropical Convergence Zone (ITCZ) move north and south in the tropics, with the apparent movement of the sun in the different months of the year. The positions of the ITCZ over Africa in July and January are shown in Figure 2-12. Whereas the ITCZ in July is almost a straight line extending from west to east at about 15° North, the ITCZ in the month of January takes a "Z" shape with 2 curvatures ABC and DEF. One end AB is at 7° North and the other end EF is at 17° South. Zambia is in the bend DE. It is this crooked shape of the ITCZ in January that explains and controls the rainfall over Zambia.

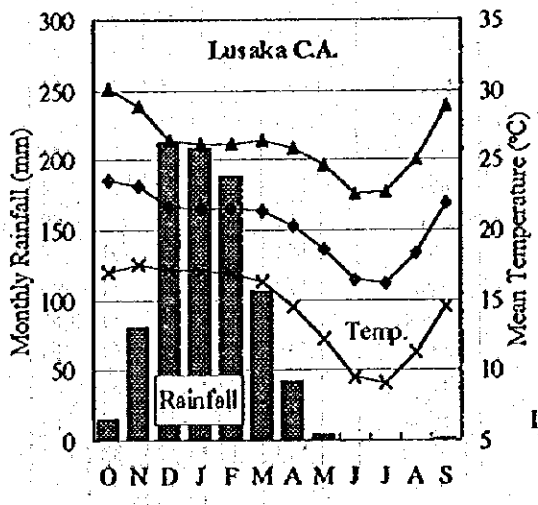


Figure 2-11
Monthly Climate in Lusaka

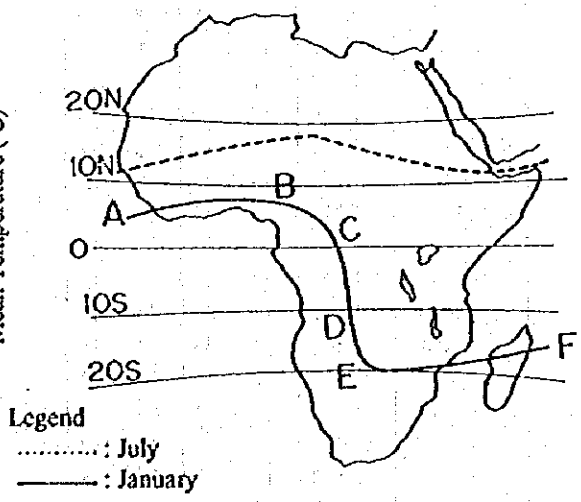


Figure 2-12
Inter Tropical Convergence Zone (ITCZ) in July and January

2.3.2 Network of Meteorological Stations

Meteorological data in Zambia is observed, collected and archived mainly by the Department of Meteorology (DOM), Ministry of Transport and Communication (MOTC) and is available to the public. There are currently 36 stations forming the meteorological station network of DOM. Such meteorological items as rainfall, temperature, relative humidity, pressure, daily weather, wind speed, sunshine hours, cloud cover and pan-evaporation are observed at these stations. In terms of rainfall only stations, there are 825 registered voluntary stations, operated by volunteers and various organisations. The number of meteorological stations and voluntary rainfall stations by the basin and the province is presented in Table 2-18. The registered total stations are numerous amounting to 861 stations but the operated number is 394 stations, only 46% of the total registered. The geographical information of the 36 meteorological stations are shown in Table 2-19 and the location of both meteorological and voluntary stations are shown in Figure 2-13.

Table 2-18 Number of Meteorological and Voluntary Stations

River Basin	Station Registered	Meteoro-logical Station	Voluntary Station	Total	Province	Meteoro-logical Station	Voluntary Station	Total
Zambezi	248	13	78	91	Lusaka	3	21	24
Kafue	190	7	109	116	Copperbelt	2	44	46
Luangwa	157	8	60	68	Central	4	44	48
Chambeshi	92	3	44	47	Northwestern	5	23	28
Luapula	149	4	60	64	Western	5	24	29
Lake Tanganyika	25	1	7	8	Southern	4	50	54
-		-	-	-	Luapula	3	34	37
-		-	-	-	Northern	6	85	91
-		-	-	-	Eastern	4	33	37
Total	861	36	358	394	Total	36	358	394

Table 2-19 Geographical Information of Meteorological Stations

Province	Station	Altitud	Latitude		Longitud		Province	Station	Altitud	Latitude		Longitud	
		(EL.m)	Deg	Min	Deg	Min			(EL.m)	Deg	Min	Deg	Min
Lusaka	Lusaka C.A.	1,280	15	25	28	19	Southern	Choma	1,267	16	51	27	4
	Lusaka I.A.	1,154	15	19	28	27		Kafue	978	15	46	27	55
	Mt.Makulu	1,213	15	33	28	15		Livingstone	987	17	49	25	49
Copper-belt	Kafironda	1,242	12	36	28	7		Magoye	1,018	16	8	27	38
	Ndola	1,270	13	0	28	39	Luapula	Kawambwa	1,324	9	48	29	5
Central	Kabwe	1,207	14	27	28	28		Mansa	1,259	11	6	28	51
	Kabwe	1,165	14	24	28	30		Samfya	1,172	11	21	29	32
	Mumbwa	1,218	14	59	27	4	Northern	Isoka	1,360	10	10	32	40
	Serenje	1,384	13	14	30	13		Kasama	1,384	10	13	31	8
North-Western	Kabompo	1,026	13	36	24	12		Mbala	1,672	8	51	31	20
	Kasempa	1,235	13	32	25	51		Mfuwe	573	13	16	31	56
	Mwinilunga	1,362	11	45	24	26		Misamfu	1,536	10	11	31	13
	Solwezi	1,333	12	11	26	23		Mpika	1,402	11	54	31	26
	Zambezi	1,078	13	32	23	7	Eastern	Chipata	1,032	13	33	32	35
Western	Kalabo	1,051	14	57	22	42		Lundazi	1,143	12	17	33	12
	Kaoma	1,152	14	48	24	48		Msekera	1,025	13	39	32	34
	Mongu	1,053	15	15	23	9		Petauke	1,036	14	15	31	17
	Senanga	1,027	16	7	23	16							
	Sesheke	951	17	28	24	18							

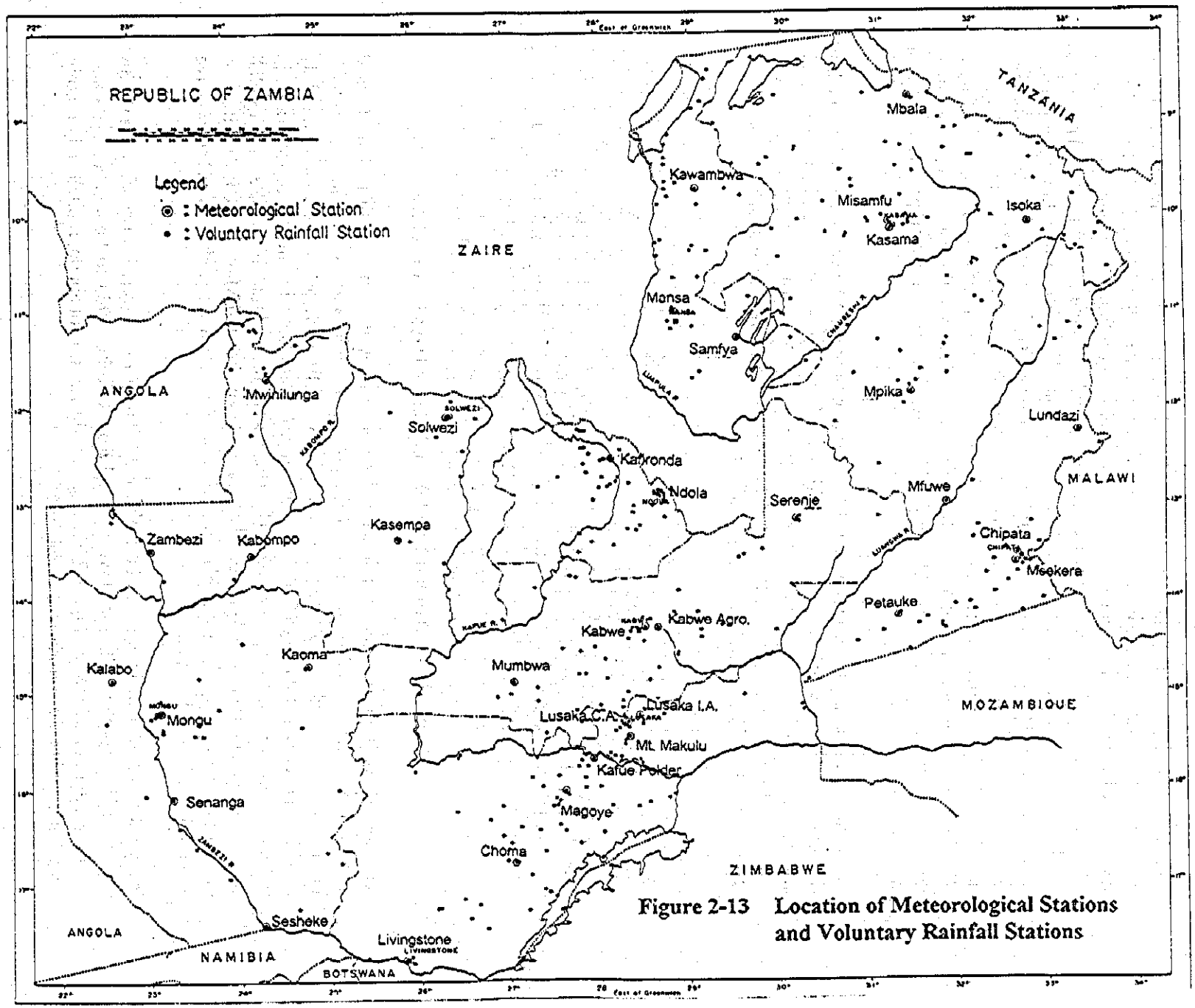


Figure 2-13 Location of Meteorological Stations and Voluntary Rainfall Stations

2.3.3 Rainfall

(1) Annual Rainfall and Monthly Rainfall

Based on the daily rainfall data, annual rainfall and annual number of rainy days for the 36 meteorological stations have been compiled and are summarised in Table 2-20. The 30 years averages of annual rainfall and rainy days in the all meteorological stations are graphically shown in Figure 2-14. The annual rainy days are according to the annual rainfall. The figures of the annual rainy days are about one by ten of the annual rainfall figures. In terms of annual rainfall and annual rainy days at the provinces, Luapula Province has most annual rainfall, 1,259 mm and 123 days on an average, and Southern Province has least annual rainfall, 737 mm and 74 days on an average. The city with the most annual rainfall is Mwinilunga City in Northwestern Province amounting to 1,402 mm and 142 days, and the least is Sesheke City in Southern Province, amounting to 657 mm and 73 days. The Zambian averages are 1,001 mm and 97 days.

In addition, comparing the average annual rainfalls during the last 10 years and during the last 30 years, the last 10 years averages are less than the last 30 years average. The former on an Zambian average is less by 27 mm than the latter and is 97 % of the latter. Especially in Luapula, Southern and Western Province, the last 10 years average annual rainfalls are 93-95 % of the last 30 years average annual rainfall.

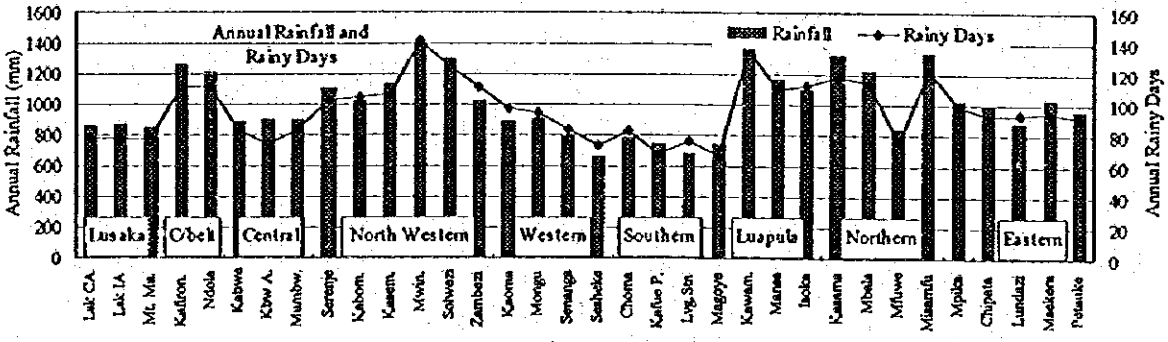


Figure 2-14 Annual Rainfall and Rainy Days by Province

The annual variation of monthly rainfall and monthly rainy days in the all meteorological stations have been compiled and these at the provincial capitals are shown in Figure 2-15. From May to September in Zambia it scarcely rains and from November to March, monthly rainfall ranges from 100 mm to 250 mm. More than 90 % of annual rainfall is concentrated in the rainy season from November to March. The 8 % of the residual 10 % of annual rainfall comes down on October and April, and the 2 % on September and May. There is definitely no rain from June to August in Zambia. The three months from December to February have about 65 % of annual rainfall.

Isohyetal maps of annual rainfall and monthly rainfall for Zambia were drawn based on the 36 meteorological stations with the 30 year period from October 1963 to September 1993 and are shown in Figure 2-16 and Figure 2-17. Regional distribution of annual rainfall and monthly rainfall in Zambia are summarised as follows :

Annual Rainfall Distribution

- In the west of Zambia, isohyetal lines are almost parallel from west to east and annual rainfall of the northernmost area is about1,400 mm and the southernmost area is about 700 mm.
- In the east of Zambia, isohyetal lines are more complicated. The trend that the north has much rain and the south has less is the same as the west side of Zambia. However annual rainfall of Eastern Province ranges from 900 mm to 1,000 mm even in the north of the province.
- Northern Province and Northwestern Province have most rainfall in Zambia and the annual rainfall ranges from 1,100 mm to 1,400 mm.
- Southernmost area of Zambia, such as the area around Sesheke and Livingstone, is the least rainfall area and its annual rainfall is under 700 mm.

Monthly Rainfall Distribution

- September passing, it begins to rain in the north area of Zambia and monthly rainfall on October is 50 - 90 mm in these area. In the South area on October, monthly rainfall is less than the north, 20 - 40 mm. October rainfall is least around Lundazi in Eastern Province, and is about 10 mm.
- On November, monthly rainfall is 120 - 210 mm in the north area and is 70 - 110 mm in the south area.
- In the core of rainy season on December, January and February, monthly isohyetal line looks similar each other. Zambia could be divided into following four categories. The most rainfall area, Area I, is the north of Copperbelt Province, the south of Luapula Province, the next, Area II, is the northwest, northeast area and Central Province and Lusaka Province, then Area III is around Eastern Province, the least rainfall area, Area IV, is the south area of Zambia. The monthly rainfall in these area is as follows :

Month	Area I	Area II	Area III	Area IV
December	270 - 300 mm	200 - 260 mm	180 - 190 mm	140 - 190 mm
January	280 - 310 mm	210 - 270 mm	200 - 230 mm	150 - 200 mm
February	240 mm	180 - 230 mm	180 - 210 mm	140 - 170 mm

- On March the north area still has 170 - 250 mm of monthly rainfall, but the south area is starting to be less rainfall area, amounting to 90 - 160 mm.
- On April, monthly rainfall in the north area is also starting to be less, 50 - 120 mm, and is very little in the south area, amounting to 20 - 50 mm. May coming, dry season has started from the south area day by day to the north and finally rain stops in the whole Zambia at the beginning of June, and no rain until the end of August in Zambia.

Table 2-20 Annual Rainfall and Annual Rainy Days

Unit: RF:mm; RD: days

Province	Station Name	Altitude (EL.m)	Average Annual Rainfall (RF)			Average Annual Rainy Days (RD)			Maximum Annual		Minimum Annual	
			10yrs.	20yrs.	30yrs.	10yrs.	20yrs.	30yrs.	RF	RD	RF	RD
Lusaka	Lusaka C.A.	1280	832	887	858	74	79	78	1366	112	483	49
	Lusaka I.A.	1154	810	894	865	72	76	77	1299	109	530	49
	Mt. Makulu	1213	883	899	848	77	77	77	1288	102	569	45
	Average	1216	842	893	857	74	77	77	1318	108	527	48
Copperbelt	Kafironda	1242	1248	1282	1256	106	111	111	1748	139	895	89
	Ndola	1270	1183	1229	1205	109	111	111	1756	136	439	79
	Average	1256	1216	1256	1231	108	111	111	1752	138	667	84
Central	Kabwe	1207	823	891	886	81	84	83	1451	111	619	59
	Kabwe Agro.	1165	833	902	897	72	75	74	1313	110	499	50
	Mumbwa	1218	873	931	900	80	85	84	1324	98	438	60
	Serenje	1384	1114	1100	1105	106	105	103	1585	151	708	66
	Average	1244	911	956	947	85	87	86	1418	118	566	59
North-western	Kabompo	1026	1050	1028	1016	104	104	105	1338	125	593	74
	Kasempa	1235	1110	1151	1131	102	107	107	1559	136	654	76
	Mwinilunga	1362	1318	1375	1402	135	140	142	1761	167	1043	108
	Solwezi	1333	1263	1330	1300	124	127	125	1575	146	985	91
	Zambezi	1078	1026	1045	1017	110	112	111	1346	136	720	87
	Average	1207	1153	1186	1173	115	118	118	1516	142	799	87
Western	Kalabo (*1)	1051	877	(last 7 yrs.)		95	(last 7 yrs.)		1084	104	617	77
	Kaoma	1152	843	913	882	95	99	97	1311	118	240	71
	Mongu	1053	851	914	903	86	92	94	1357	117	382	43
	Senanga	1027	745	800	791	77	82	84	987	97	463	64
	Sesheke	951	630	692	657	72	76	73	1546	112	379	48
	Average	1046	767	830	808	83	87	87	1300	111	366	57
Southern	Choma	1267	744	800	779	82	86	83	1187	116	423	46
	Kafue Polder	978	694	753	744	63	66	68	1192	106	460	44
	Livingstone	987	617	688	679	67	75	76	1402	103	420	49
	Magoye	1018	694	753	744	62	65	67	935	76	461	49
	Average	1063	687	749	737	69	73	74	1179	100	441	47
Luapula	Kawambwa	1324	1277	1349	1358	136	135	136	1758	154	865	114
	Mansa	1259	1125	1162	1159	107	109	110	1573	131	800	81
	Samfya (*2)	1172	1490	1445	-	109	108	-	2065	128	937	79
	Average	1292	1201	1256	1259	122	122	123	1666	143	833	98
Northern	Isoka	1360	1062	1097	1094	109	109	112	1334	135	876	83
	Kasama	1384	1284	1337	1323	115	115	118	1888	146	801	92
	Mbala	1672	1190	1202	1219	105	109	114	1745	148	469	54
	Mfuwe	573	814	842	840	72	74	75	1062	89	495	42
	Misamfu	1536	1336	1345	1331	107	110	123	1751	127	1097	88
	Mpika	1402	1040	1054	1018	97	99	99	1498	127	644	71
	Average	1321	1121	1146	1138	101	103	107	1546	129	730	72
Eastern	Chipata	1032	959	992	990	88	90	92	1471	115	656	70
	Lundazi	1143	983	906	878	96	92	93	1415	120	495	68
	Msekera	1025	992	1026	1024	90	92	94	1179	101	753	76
	Petauke	1036	965	981	951	86	91	91	1381	120	597	71
	Average	1059	975	976	961	90	91	93	1362	114	625	71
Total Average		1187	977	1016	1001	93	96	97	1432	122	616	68

Remarks :

(*1), (*2) : These station are excluded in calculating the average.

▒▒▒ : The data was calculated by using the record near the station

Average period : 10yrs.(1983/84-92/93), 20yrs.(1973/74-92/93), 30yrs.(1963/64-92/93)

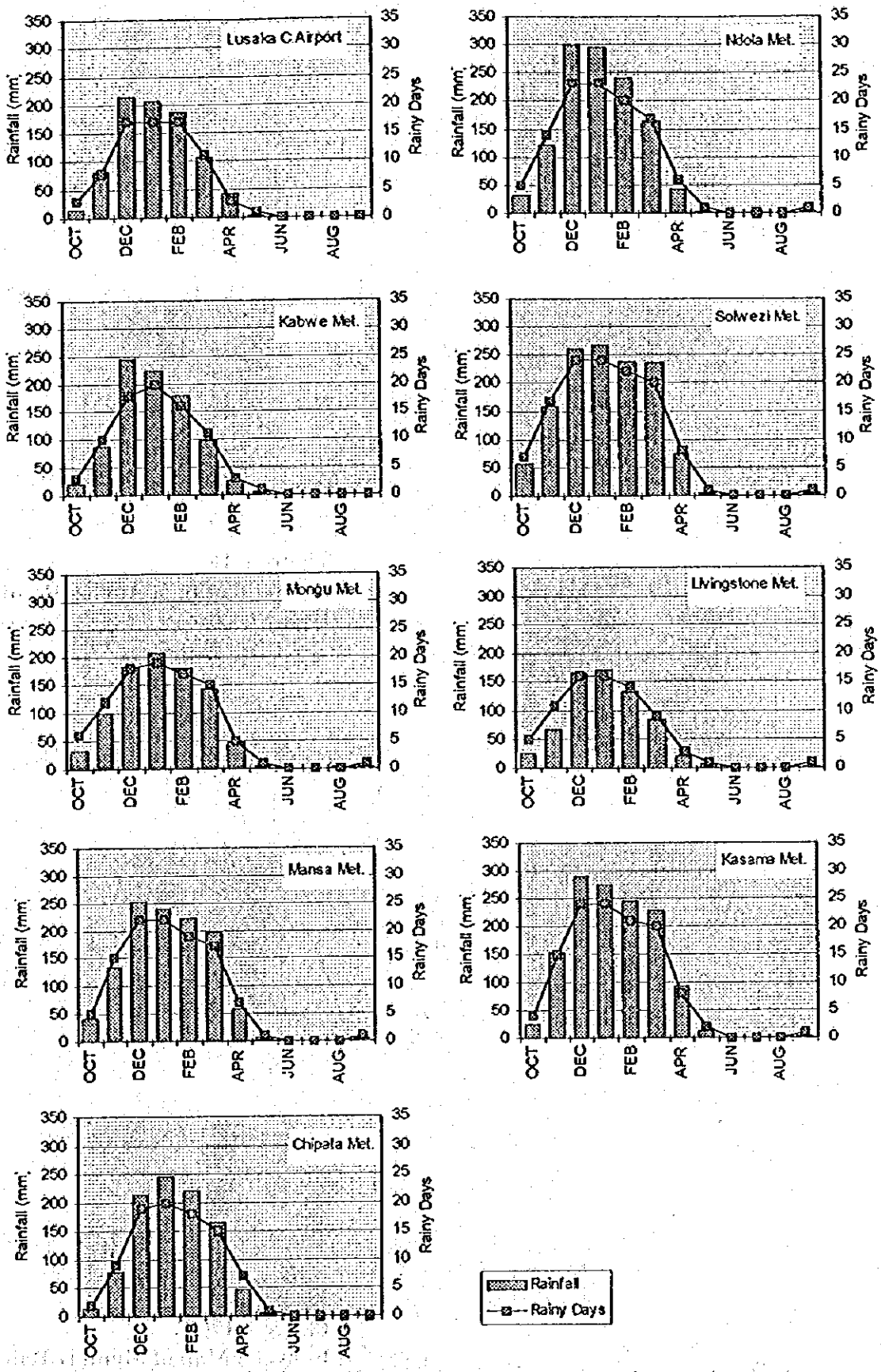


Figure 2-15 Monthly Rainfall and Rainy Days at the Provincial Capitals

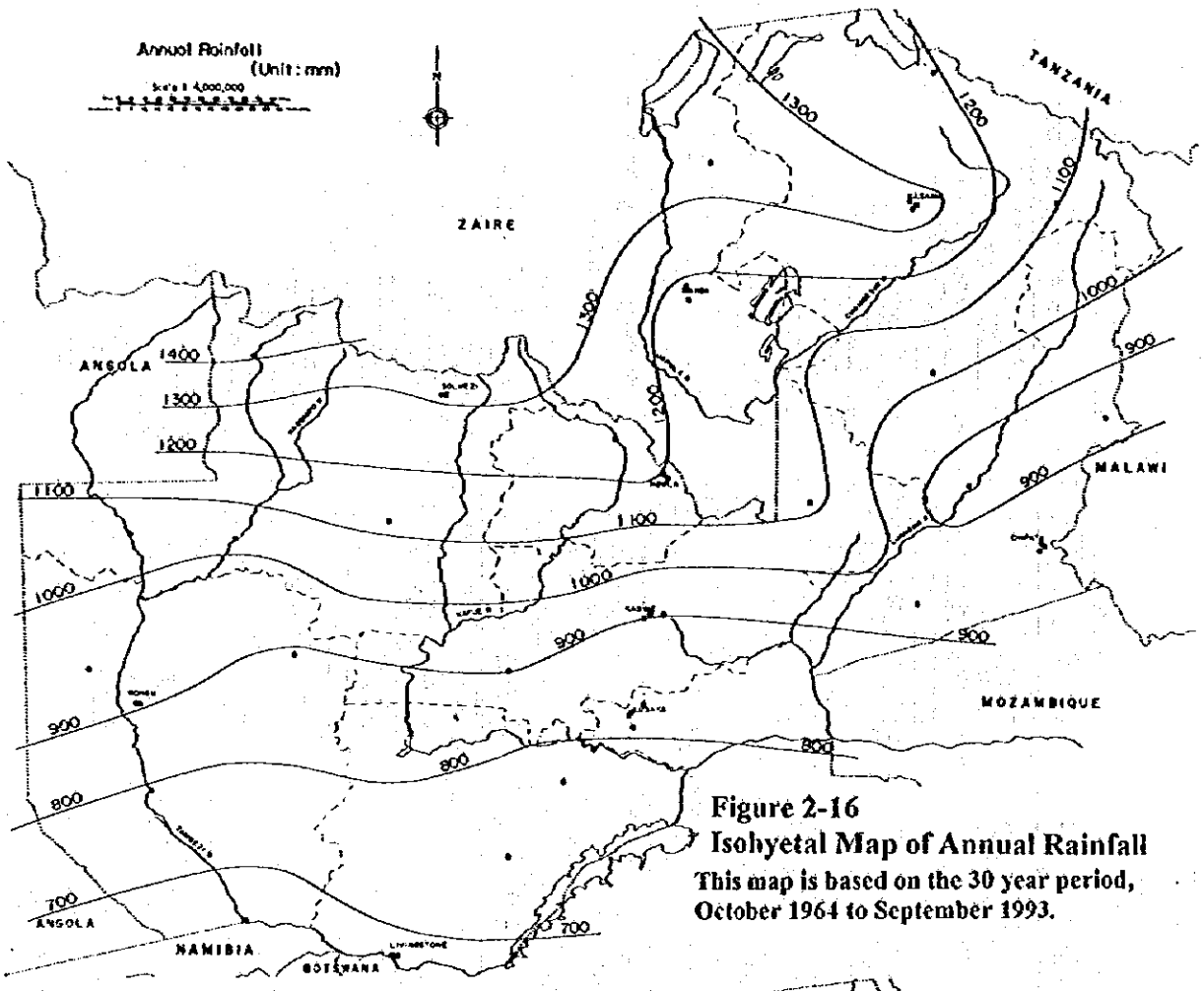


Figure 2-16
Isohyetal Map of Annual Rainfall
This map is based on the 30 year period, October 1964 to September 1993.

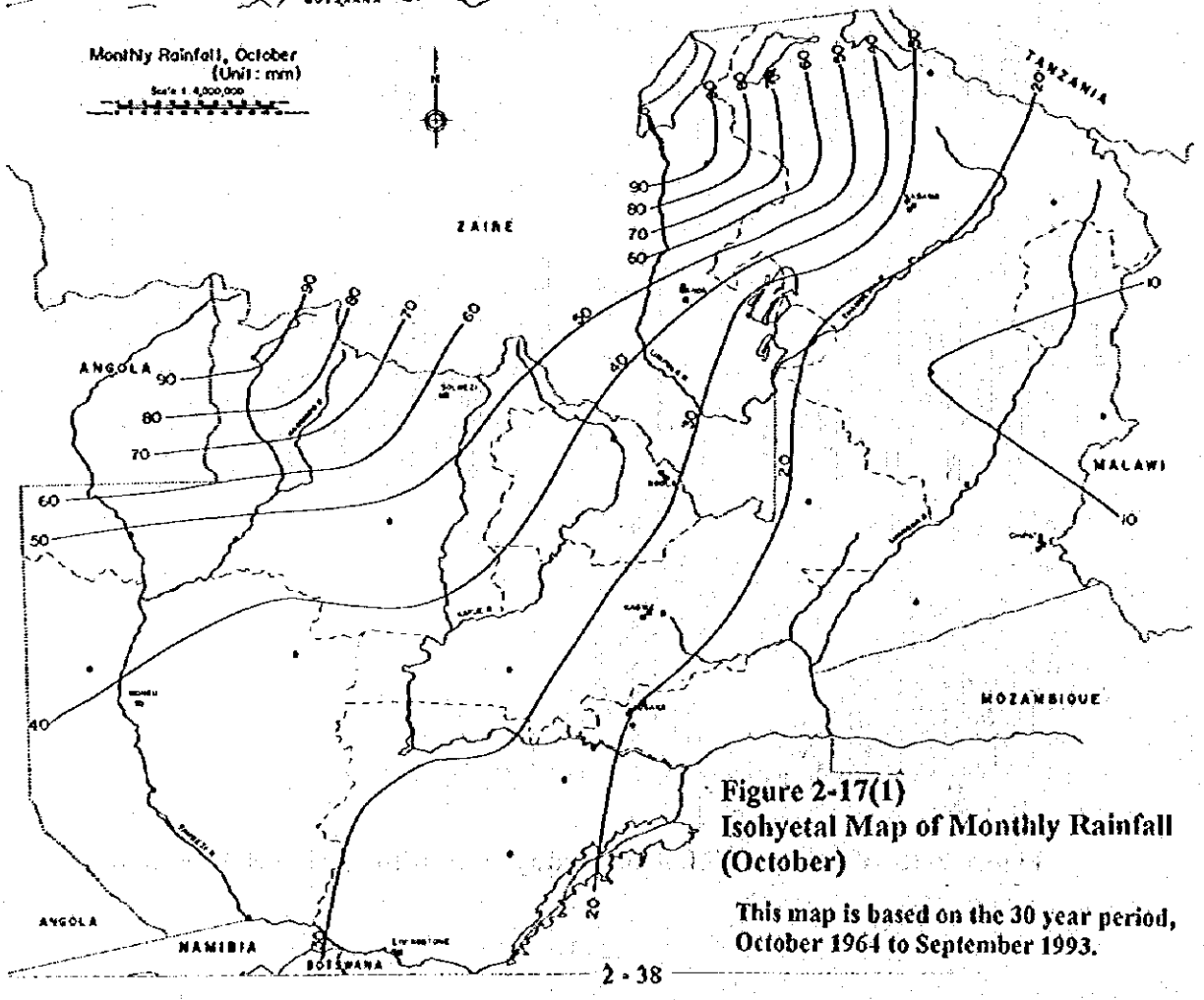


Figure 2-17(1)
Isohyetal Map of Monthly Rainfall (October)

This map is based on the 30 year period, October 1964 to September 1993.

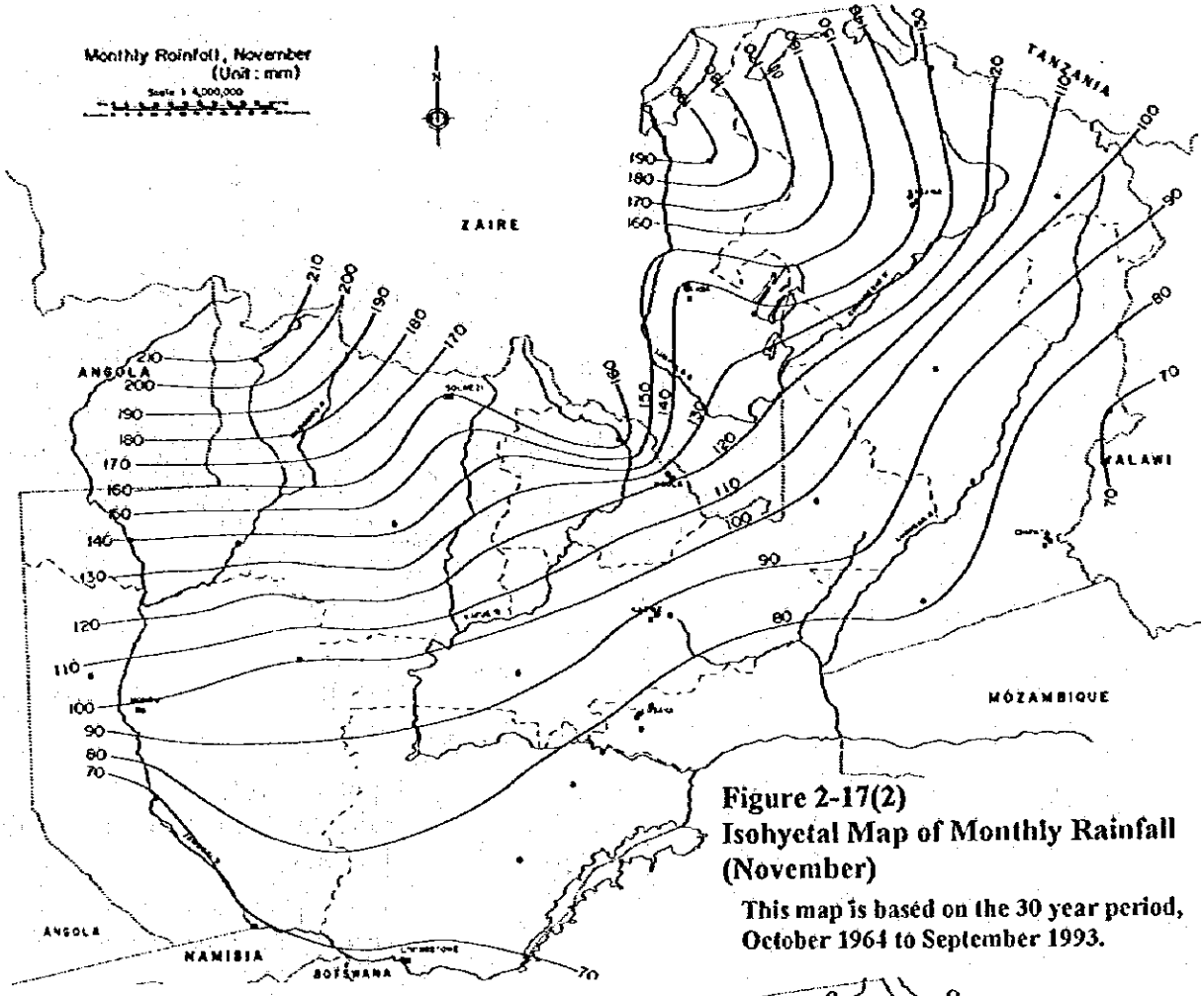


Figure 2-17(2)
Isohyetal Map of Monthly Rainfall (November)

This map is based on the 30 year period, October 1964 to September 1993.

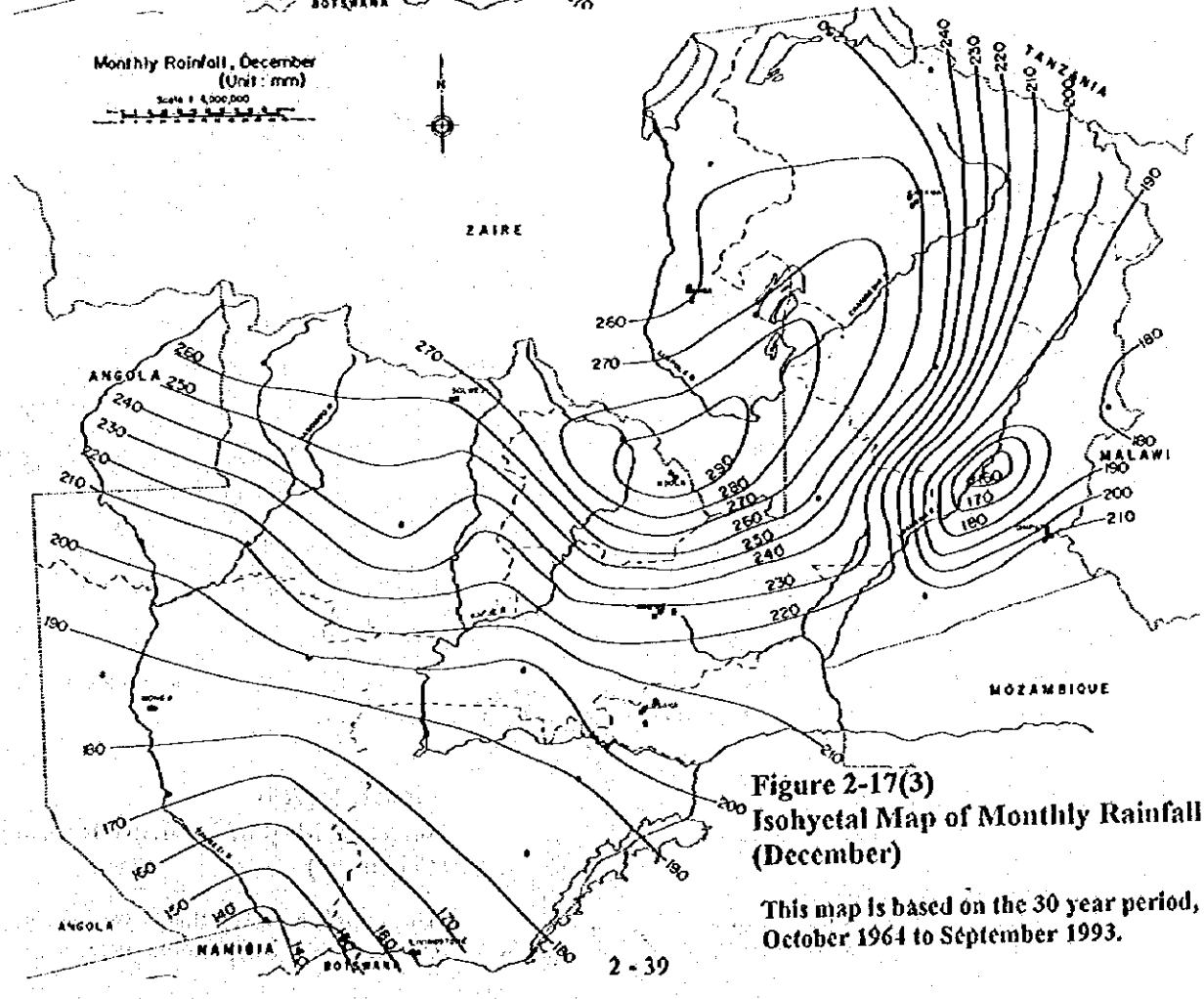


Figure 2-17(3)
Isohyetal Map of Monthly Rainfall (December)

This map is based on the 30 year period, October 1964 to September 1993.

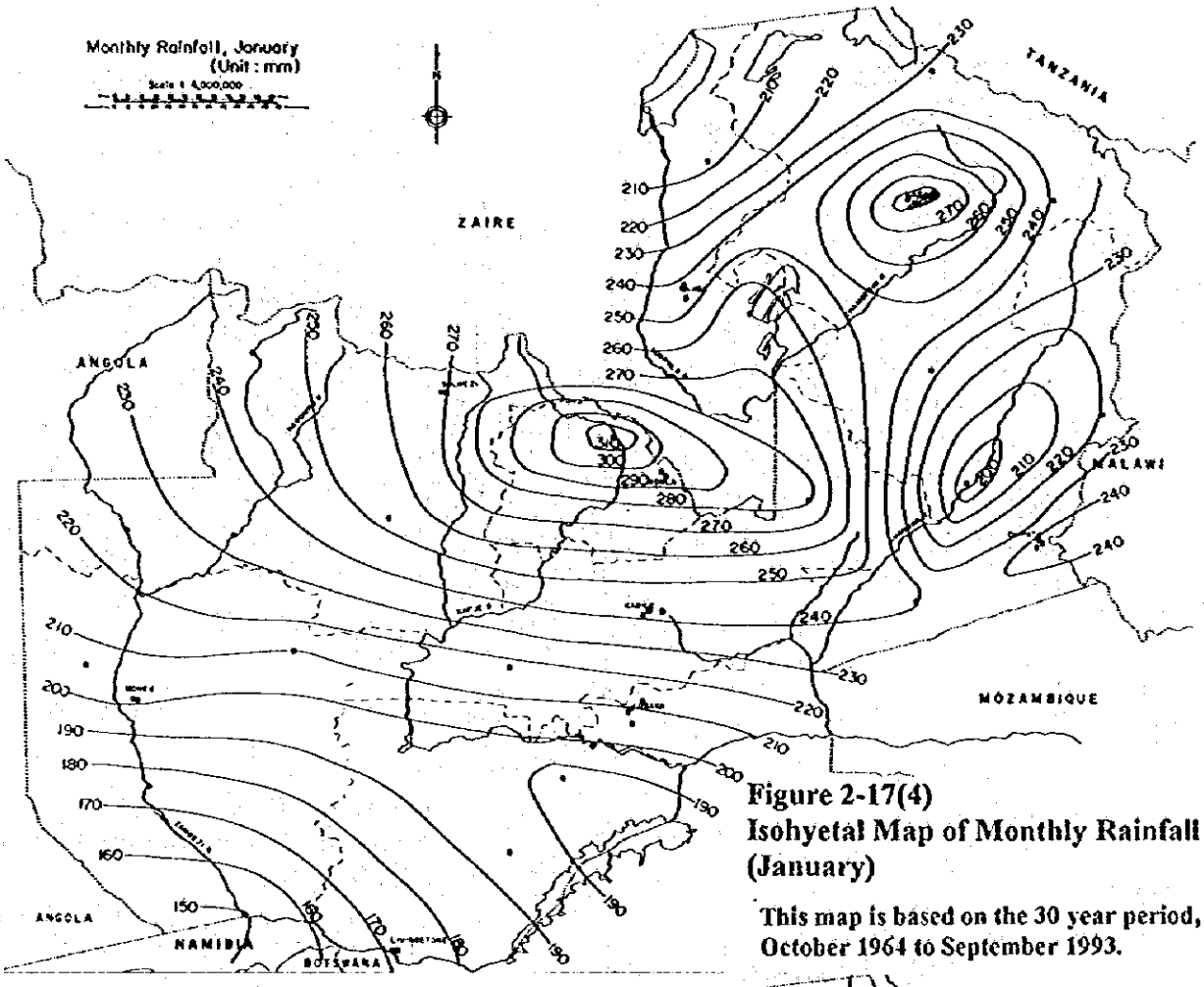


Figure 2-17(4)
Isohyetal Map of Monthly Rainfall (January)

This map is based on the 30 year period, October 1964 to September 1993.

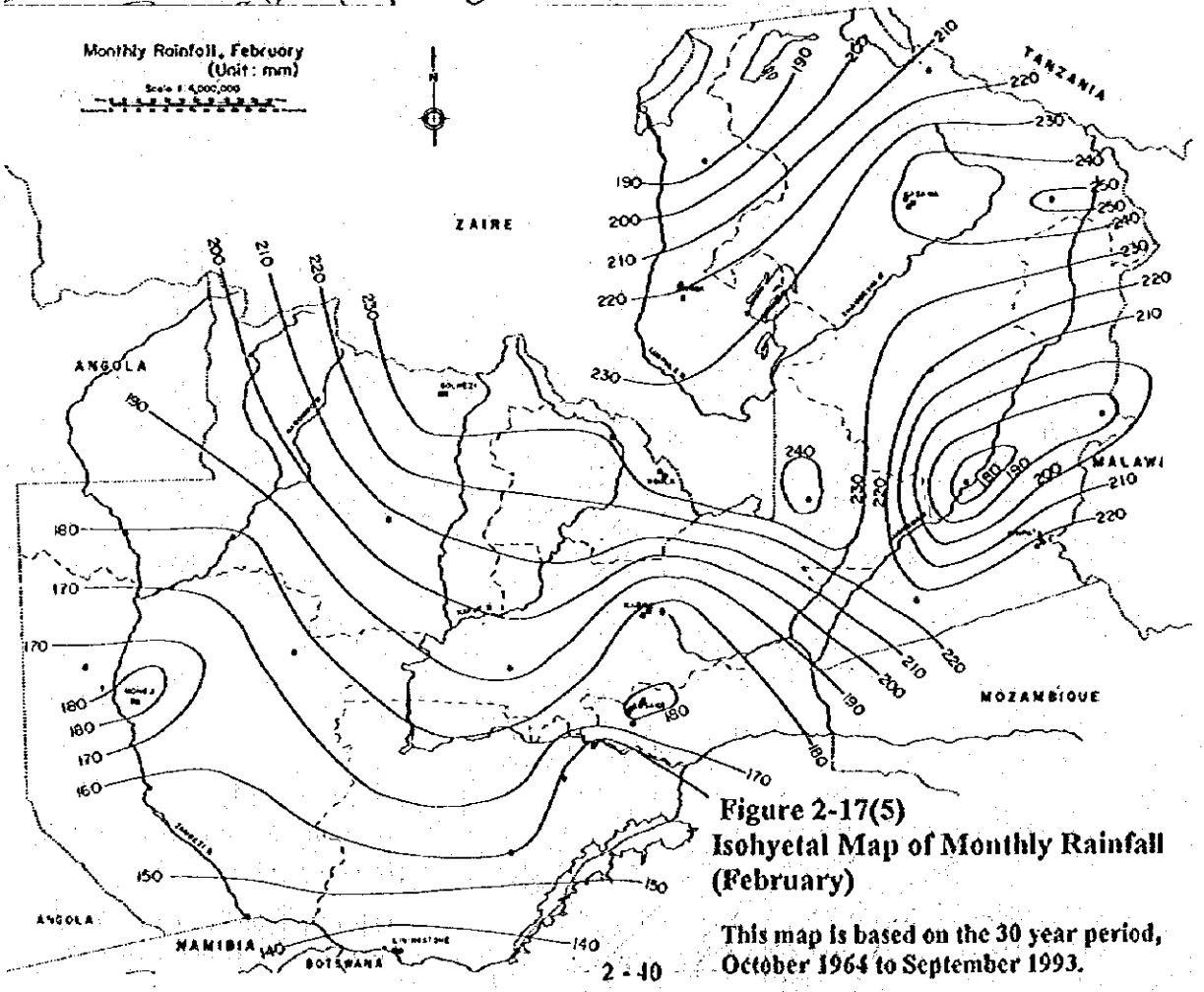


Figure 2-17(5)
Isohyetal Map of Monthly Rainfall (February)

This map is based on the 30 year period, October 1964 to September 1993.

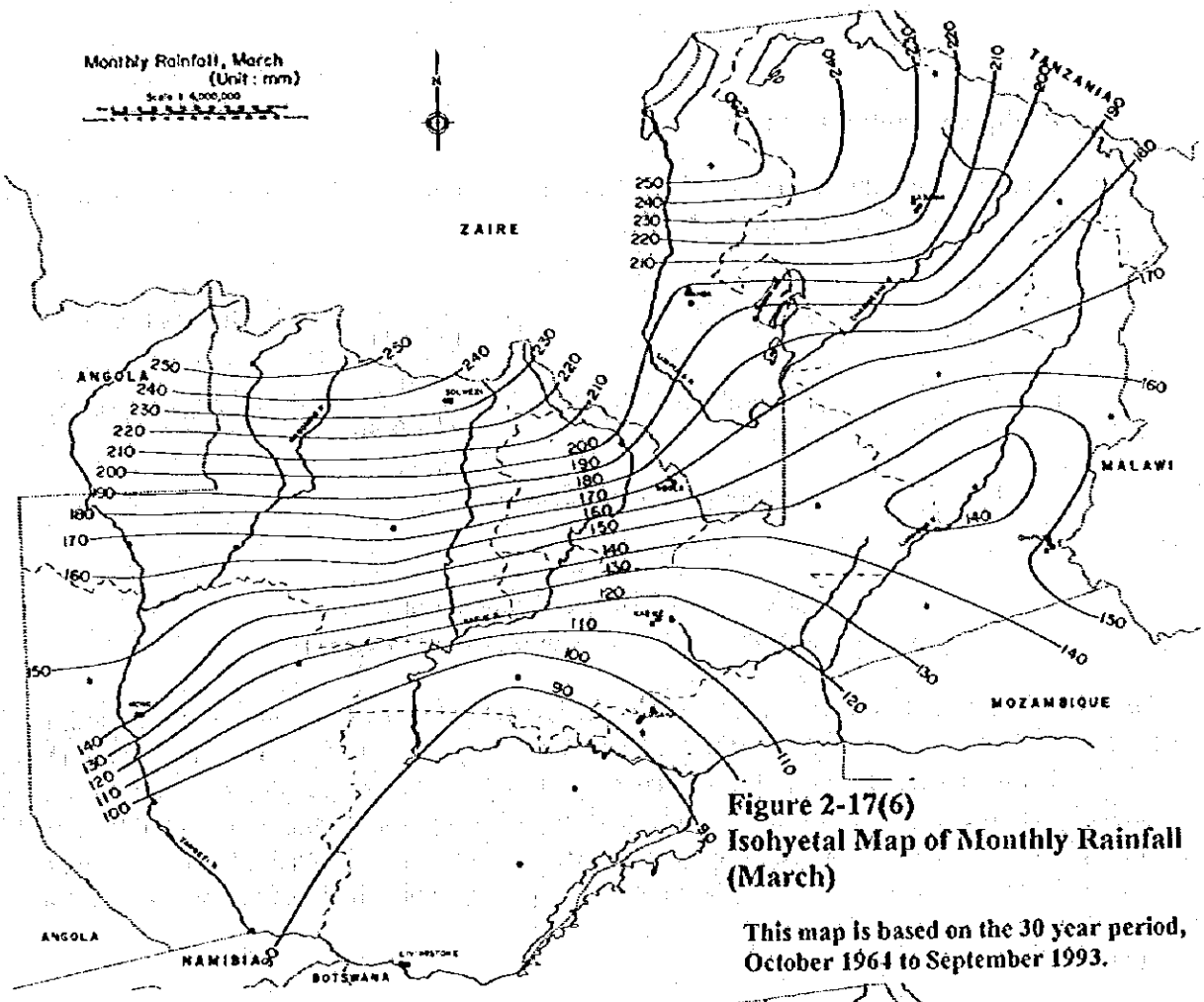


Figure 2-17(6)
Isohyetal Map of Monthly Rainfall (March)

This map is based on the 30 year period, October 1964 to September 1993.

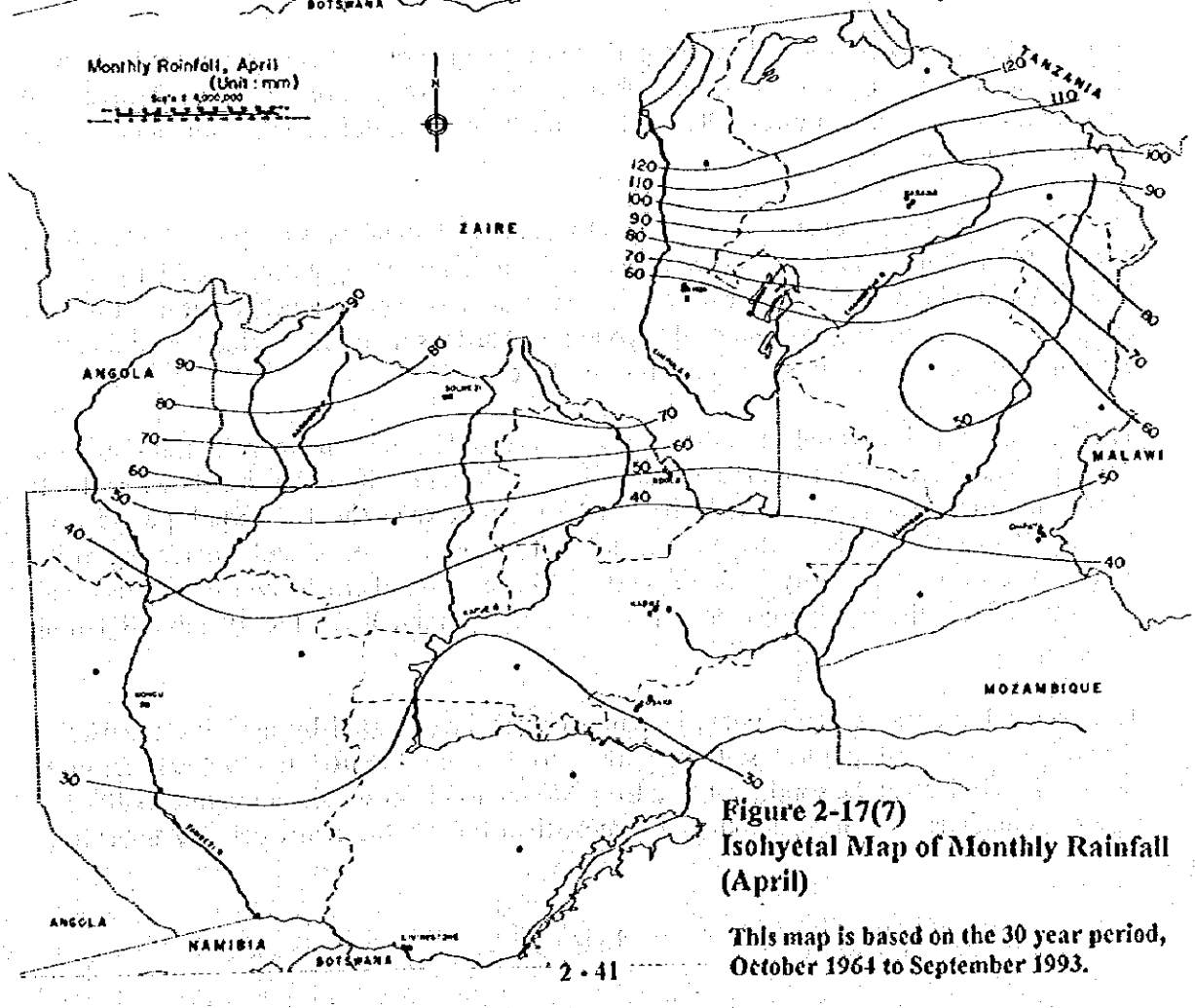


Figure 2-17(7)
Isohyetal Map of Monthly Rainfall (April)

This map is based on the 30 year period, October 1964 to September 1993.

(2) Probable Annual Rainfall

Return period (probability of exceedance) of each annual rainfall is calculated by using the following four equations of order statistics :

$W = \frac{(2i-1)}{2N}$: Hazen (1930)

$W = \frac{i}{(N+1)}$: Thomas (1938)

$W = \frac{i-0.3}{N+0.4}$: Chegodayov (1955)

$W = \frac{i-0.31}{N+0.38}$: Jankinson (1969)

Where, W : probability of exceedance

T : return period ($T = \frac{1}{W}$)

i : order from maximum or minimum

N : sample size (number of observation years)

In these four equation, Hazen equation has the largest value under a same return period, the second is Jankinson equation, the third is Chegodayov equation, and the Thomas equation has the smallest value. The probable annual rainfalls at all the meteorological stations were calculated corresponding to many return periods. Maximum and minimum probable annual rainfall with 10, 30, 50 and 100 year return period are shown in Table 2-21. These figures in the table were estimated by using the Jankinson equation which had been adopted by WMO.

(3) Drought Analysis

A drought is usually considered to be a period in which the rainfall consistently falls short of the climatically expected amount, such that the natural vegetation does not flourish and agricultural crops fail. Low rainfalls more seriously affect water supplies for industry and domestic purposes.

"The technique for the evaluation of drought from rainfall data" was proposed by Herbst in 1966 in South Africa. This method confines the definition of droughts specifically to periods in which rainfall deficits were in excess of average deficits. Thus sequences of months with extremely dry conditions are identified beyond the shortfalls in monthly rainfall amounts that are normally experienced in some months of each year.

The Herbst method was applied to the long-rainfall record at all the meteorological stations in Zambia. The top ten droughts ranked according to their severity index are shown in Table 2-22. The drought severity is the highest at Livingstone over the 107 month period from January 1979 to November 1987, but the drought intensity is not so high comparing to the others. The drought intensity is the highest at Mbala in Northern Province, and this high intensity reflects the low percentage, 42%, of average rainfall for the 19 months during drought.

The regional variations of droughts in Zambia were investigated by applying the Herbst method to 24 meteorological stations with records from 1963/64 to 1992/93. Drought severity is very high in the southwest area from Mongu to Livingstone, amounting to 80 - 160 and is also high near Lundazi, amounting to more than 100. On the centre belt of Zambia from

Table 2-21 Maximum and Minimum Probable Annual Rainfall

Unit : mm

Province	Station Name	Maximum Probable Annual Rainfall					Minimum Probable Annual Rainfall				
		Return Period					Return Period				
		5yrs.	10yrs.	30yrs.	50yrs.	100yrs	5yrs.	10yrs.	30yrs.	50yrs.	100yrs
Lusaka	Lusaka C.A.	1,424	1,729	2,112	2,264	2,453	671	582	470	426	370
	Lusaka I.A.	1,456	1,763	2,148	2,301	2,492	685	589	468	420	361
	Mt. Makulu	1,415	1,712	2,086	2,234	2,419	650	547	419	368	304
Copperbelt	Kafironda	2,109	2,526	3,049	3,258	3,516	959	774	543	451	336
	Ndola	1,965	2,363	2,862	3,061	3,308	956	827	665	600	520
Central	Kabwe	1,538	1,856	2,255	2,414	2,611	725	618	483	429	363
	Kabwe Agro.	1,556	1,900	2,332	2,504	2,718	747	668	569	530	481
	Mumbwa	1,454	1,772	2,172	2,331	2,529	681	595	488	455	392
	Serenje	1,878	2,263	2,746	2,938	3,177	891	761	597	532	450
North-western	Kabompo	1,641	1,962	2,364	2,524	2,723	761	621	446	376	289
	Kasempa	1,838	2,197	2,647	2,827	3,049	871	724	539	466	374
	Mwinilunga	2,198	2,614	3,138	3,346	3,604	998	788	524	420	289
	Solwezi	2,035	2,416	2,894	3,084	3,321	922	722	470	370	246
	Zambezi	1,676	2,004	2,415	2,579	2,782	776	633	455	383	295
Western	Kalabo	1,518	1,854	2,275	2,443	2,651	665	554	415	359	290
	Kaoma	1,483	1,791	2,178	2,332	2,523	729	642	533	490	436
	Mongu	1,555	1,873	2,273	2,432	2,629	768	676	559	513	455
	Senanga	1,216	1,466	1,780	1,905	2,060	574	488	382	339	286
	Sesheke	1,246	1,526	1,877	2,016	2,190	593	530	452	421	382
Southern	Choma	1,361	1,648	2,008	2,151	2,330	675	604	514	479	435
	Kafue Polder	1,280	1,547	1,882	2,015	2,181	608	523	417	375	322
	Livingstone	1,240	1,514	1,857	1,994	2,164	597	535	456	425	386
	Magoye	1,168	1,406	1,705	1,824	1,972	530	434	314	267	207
Luapula	Kawambwa	2,096	2,483	2,969	3,162	3,402	939	721	448	339	204
	Mansa	1,854	2,209	2,656	2,883	3,054	837	661	440	352	243
	Samfya(*1)	2,397	2,889	3,507	3,753	4,059	1,112	933	708	618	507
Northern	Isoka	1,703	2,021	2,420	2,578	2,776	722	527	282	185	64
	Kasama	2,037	2,426	2,914	3,108	3,349	938	752	519	427	312
	Mbala	1,972	2,357	2,840	3,032	3,271	920	755	548	466	364
	Mfuwe	1,348	1,624	1,969	2,107	2,278	625	522	393	342	279
	Misamfu	2,112	2,514	3,018	3,218	3,467	910	682	397	283	142
	Mpika	1,685	2,025	2,451	2,620	2,831	802	680	527	466	390
Eastern	Chipata	1,655	1,989	2,410	2,577	2,785	790	673	525	467	394
	Lundazi	1,490	1,805	2,201	2,358	2,554	704	609	489	442	382
	Msekera	1,595	1,909	2,304	2,461	2,655	697	542	348	271	174
	Petauke	1,604	1,930	2,339	2,502	2,705	767	657	517	462	393

[Note] The calculation results in the table are based on the Jankinson equation.

east to west, drought severity is middle, amounting to 60 - 80, and in the northward, drought severity is low, amounting to less than 60. Besides the Zambian average of the severest droughts at each station during 1963/64-1992/93 is obtained as follows :

- Drought Duration : 58 month
- Drought Intensity : 1.36
- Drought Severity : 68.7
- Percentage of Mean Rainfall during Drought : 78.2 %

Table 2-22 Ten Maximum Droughts in Zambia

No.	Station Name	Province	Period	Duration (month)	Intensity	Severity	% of Mean Rain
1	Livingstone	Southern	79/01-87/11	107	1.54	165.3	84.4
2	Kasama	Northern	48/11-55/10	84	1.64	137.4	83.2
3	Mongu	Western	81/04-88/12	93	1.26	117.5	81.6
4	Lundazi	Eastern	69/01-77/11	107	1.02	108.6	80.6
5	Mpika	Northern	89/06-94/09	64	1.54	98.7	77.5
6	Kasempa	N/western	80/12-85/12	61	1.40	85.7	82.6
7	Zambezi	N/western	81/04-87/08	77	1.09	83.7	82.8
8	Kabwe	Central	86/11-92/10	72	1.13	81.6	77.5
9	Kasama	Northern	56/05-61/10	66	1.10	72.6	89.1
10	Kafironda	Copperbelt	85/03-90/12	70	1.01	70.4	85.4

2.3.4 Temperature

Annual mean temperature and the maximum and the minimum of monthly mean temperature for the 36 meteorological stations were compiled and are shown in Table 2-23 and Figure 2-18. The average annual mean temperature in Zambia ranges from 19.3 °C to 24.2 °C and the Zambian average is 21.0 °C. Western Province is hottest, 22.1 °C on an average, and Copperbelt Province is coldest, 20.3 °C on an average. Northern Province is also very cold, 20.0 °C on an average excluding Mfuwe at the southernmost of Northern Province. July is the coldest season and its minimum temperature is 3.6-12.0 °C (8.1 °C on an average). September and October (mainly October) are the hottest season and its maximum temperature is 27.7-36.5 °C (31.8 °C on an average). The hottest place in Zambia is Mfuwe and the maximum and minimum temperature are 36.5 °C, 10.3 °C and the annual mean is 24.2 °C. One of the coldest places in Zambia is Kafironda and the maximum and minimum temperature are 32.0 °C, 3.6 °C and the annual mean is 19.8 °C.

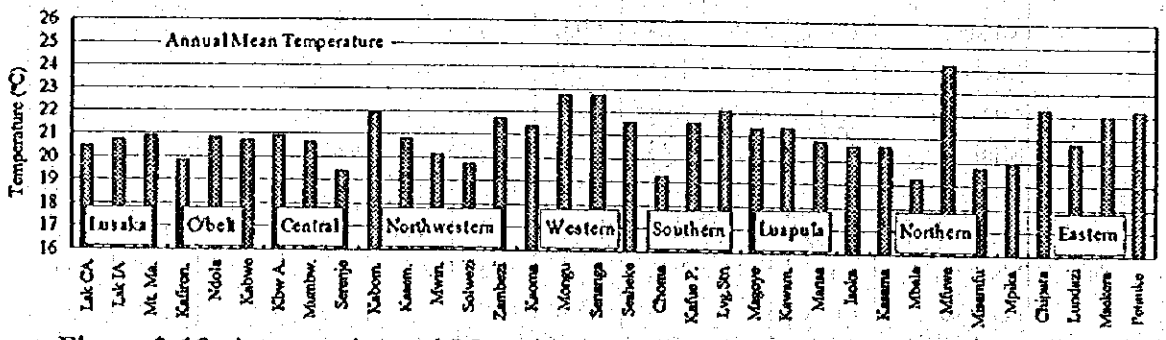


Figure 2-18 Average Annual Mean Temperature at the Meteorological Stations

Table 2-23 Average Annual Mean Temperature, Maximum and Minimum of Monthly Mean Temperature

(Unit : ℃)

Province	Station Name	Altitude (EL.m)	Annual Mean	Monthly Maximum		Monthly Minimum		(Max - Min)
				Month	Temp.	Month	Temp.	
Lusaka	Lusaka C.A.	1280	20.4	Oct.	30.1	Jul.	9.1	21.0
	Lusaka I.A.	1154	20.7	Oct.	31.6	Jul.	7.3	24.3
	Mt. Makulu	1213	20.9	Oct.	31.3	Jul.	8.7	22.6
	Average	-	20.7	-	31.0	-	8.4	22.6
Copperbelt	Kafironda	1242	19.8	Oct.	32.0	Jul.	3.6	28.4
	Ndola	1270	20.8	Oct.	31.4	Jul.	7.7	23.7
	Average	-	20.3	-	31.7	-	5.7	26.1
Central	Kabwe	1207	20.7	Oct.	31.1	Jul.	8.6	22.5
	Kabwe Agro.	1165	20.9	Oct.	31.7	Jul.	7.3	24.4
	Mumbwa	1218	20.6	Oct.	31.1	Jul.	7.1	24.0
	Serenje	1384	19.4	Oct.	30.3	Jul.	7.5	22.8
	Average	-	20.4	-	31.1	-	7.6	23.4
North-western	Kabompo	1026	21.9	Sep.	33.6	Jul.	7.3	26.3
	Kasempa	1235	20.8	Oct.	31.8	Jul.	6.7	25.1
	Mwinilunga	1362	20.1	Sep.	31.0	Jul.	6.5	24.5
	Solwezi	1333	19.7	Oct.	30.5	Jul.	5.6	24.9
	Zambezi	1078	21.7	Sep.	33.5	Jul.	6.4	27.1
	Average	-	20.8	-	32.1	-	6.5	25.6
Western	Kalabo (*1)	1051	-	Oct.	33.8	Jul.	9.7	24.1
	Kaoma	1152	21.4	Oct.	33.0	Jul.	5.8	27.2
	Mongu	1053	22.7	Oct.	33.7	Jul.	9.6	24.1
	Senanga	1027	22.7	Oct.	33.7	Jul.	8.7	25.0
	Sesheke	951	21.6	Oct.	34.2	Jul.	4.4	29.8
	Average	-	22.1	-	33.7	-	7.6	26.0
Southern	Choma	1267	19.3	Oct.	30.8	Jul.	4.6	26.2
	Kafue Polder	978	21.6	Oct.	32.8	Jul.	7.1	25.7
	Livingstone	987	22.1	Oct.	33.9	Jul.	6.4	27.5
	Magoye	1018	21.3	Oct.	32.8	Jul.	6.9	25.9
	Average	-	21.1	-	32.6	-	6.3	26.3
Luapula	Kawambwa	1324	21.4	Sep.	30.5	Jul.	10.8	19.7
	Mansa	1259	20.8	Oct.	31.2	Jul.	8.5	22.7
	Samfya (*2)	1172	-	Oct.	30.0	Jul.	10.4	19.6
	Average	-	21.1	-	30.6	-	9.9	20.7
Northern	Isoka	1360	20.6	Oct.	31.5	Jul.	9.9	21.6
	Kasama	1384	20.6	Oct.	30.9	Jul.	9.2	21.7
	Mbala	1672	19.3	Oct.	27.7	Jul.	10.5	17.2
	Mfuwe	573	24.2	Oct.	36.5	Jul.	10.3	26.2
	Misamfu	1536	19.7	Oct.	30.5	Jul.	7.1	23.4
	Mpika	1402	19.9	Oct.	29.7	Jul.	9.0	20.7
	Average	-	20.7	-	31.1	-	9.3	21.8
Eastern	Chipata	1032	22.3	Oct.	32.2	Jul.	11.8	20.4
	Lundazi	1143	20.8	Oct.	30.9	Jul.	8.0	22.9
	Msekera	1025	22.0	Oct.	31.5	Jul.	10.7	20.8
	Petauke	1036	22.2	Oct.	32.4	Jul.	12.0	20.4
	Average	-	21.8	-	31.8	-	10.6	21.1
Total Average		-	21.0	-	31.8	-	8.1	23.7

Remarks :
(*1, *2) : This station is excluded in calculating the provincial average.

2.3.5 Evaporation and Evapotranspiration

Based on the daily pan-evaporation, annual and monthly pan-evaporation for the 36 meteorological stations were compiled. Also potential evapotranspiration was calculated by using the revised Penman equation. The annual pan-evaporation and the potential evapotranspiraion are shown in Figure 2-19 and Table 2-24. Moreover an annual pan-evaporation isopleth map and a potential annual evapotranspiration isopleth map have been drawn and are shown in Figure 2-21. Based on these table and figures, regional distribution and annual variation are summarised as follows:

Pan-evaporation

The average annual pan-evaporation in Zambia ranges from 1,666 mm to 2,814 mm and the Zambian average is 2,061 mm. Annual pan-evaporation is low, 1,700 - 2,000 mm in the north, and is very high in the east, 2,200 -2,600 mm, and is average in the centre, the west and the south. Copperbelt Province has the lowest annual pan-evaporation, 1,865 mm on an average and Eastern Province has the highest, 2,211 mm on an average. Monthly pan-evaporation is high from August to November at 200 - 300 mm per month, and is low from December to July at 100 - 200 mm per month. These figures indicate that evaporation is high in areas/months with little rainfall and is low in areas/months with higher rainfall.

Potential Evapotranspiration

The average annual potential evapotranspiration in Zambia ranges from 1,394 mm to 1,892 mm and the Zambian average is 1,574 mm. Areas with highest potential evapotranspiration are the southwest of Zambia and the area along the Luangwa River near Mfuwe, amounting to 1,700-1,800 mm/year. Potential evapotranspiration in the central area of Zambia is 1,500-1,600 mm/year, and in the northwest and northeast is 1,400-1,500 mm/year. Potential evapotranspiration is larger than precipitation in Zambia. This means that Zambia is in a hydrological condition of precipitation deficit, which amounts to -100 mm/year to -1,100 mm/year, compared with potential evapotranspiration.

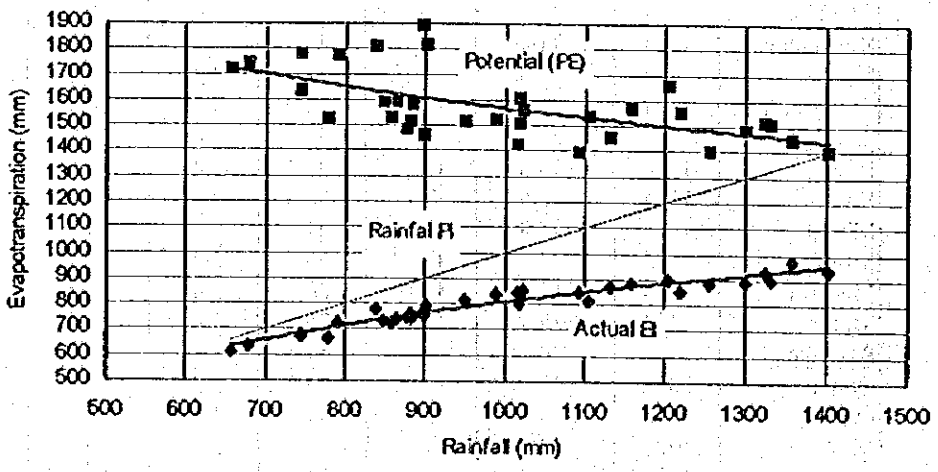


Figure 2-19 Actual and Potential Evapotranspiration

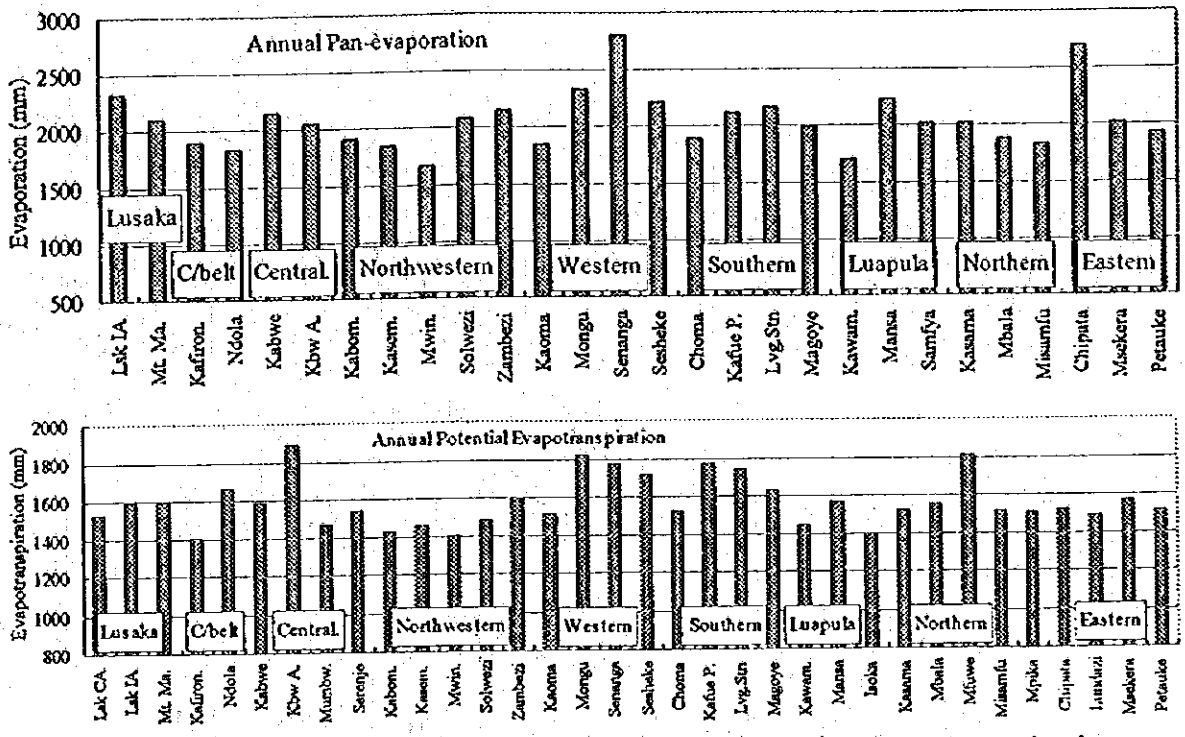


Figure 2-20 Annual Pan-evaporation and Annual Potential Evapotranspiration

Table 2-24 Annual Pan-evaporation and Annual Potential Evapotranspiration

Province	Station Name	Pan-evaporation (mm)	Potential Evapo-transpiration (mm)	Province	Station Name	Pan-evaporation (mm)	Potential Evapo-transpiration (mm)
Lusaka	Lusaka C.A.	-	1,533	Southern	Choma	1,902	1,522
	Lusaka I.A.	2,331	1,590		Kafue Polder	2,122	1,776
	Mt. Makulu	2,104	1,591		Livingstone	2,166	1,745
	Average	2,218	1,571		Magoye	1,991	1,634
Copperbelt	Kafironda	1,892	1,407		Average	2,045	1,669
	Ndola	1,838	1,659	Luapula	Kawambwa	1,698	1,445
	Average	1,865	1,530		Mansa	2,237	1,571
Central	Kabwe	2,158	1,586		Samfya(*1)	2,015	-
	Kabwe Agro.	2,051	1,892		Average	1,983	1,508
	Mumbwa	-	1,467	Northern	Isoka	-	1,394
	Serenje	-	1,538		Kasama	2,018	1,518
	Average	2,105	1,621		Mbala	1,873	1,555
North-western	Kabompo	1,912	1,426		Mfuwe	-	1,808
	Kasempa	1,847	1,455		Misamfu	1,829	1,511
	Mwinilunga	1,666	1,406		Mpika	-	1,507
	Solwezi	2,080	1,485		Average	1,907	1,549
	Zambezi	2,155	1,603	Eastern	Chipata	2,689	1,524
	Average	1,932	1,475		Lundazi	-	1,488
Western	Kalabo	-	-		Msekera	2,024	1,565
	Kaoma	1,845	1,513		Petauke	1,920	1,514
	Mongu	2,324	1,816		Average	2,211	1,531
	Senanga	2,814	1,773	Total Average		2,061	1,574
	Sesheke	2,215	1,718				
	Average	2,300	1,705				

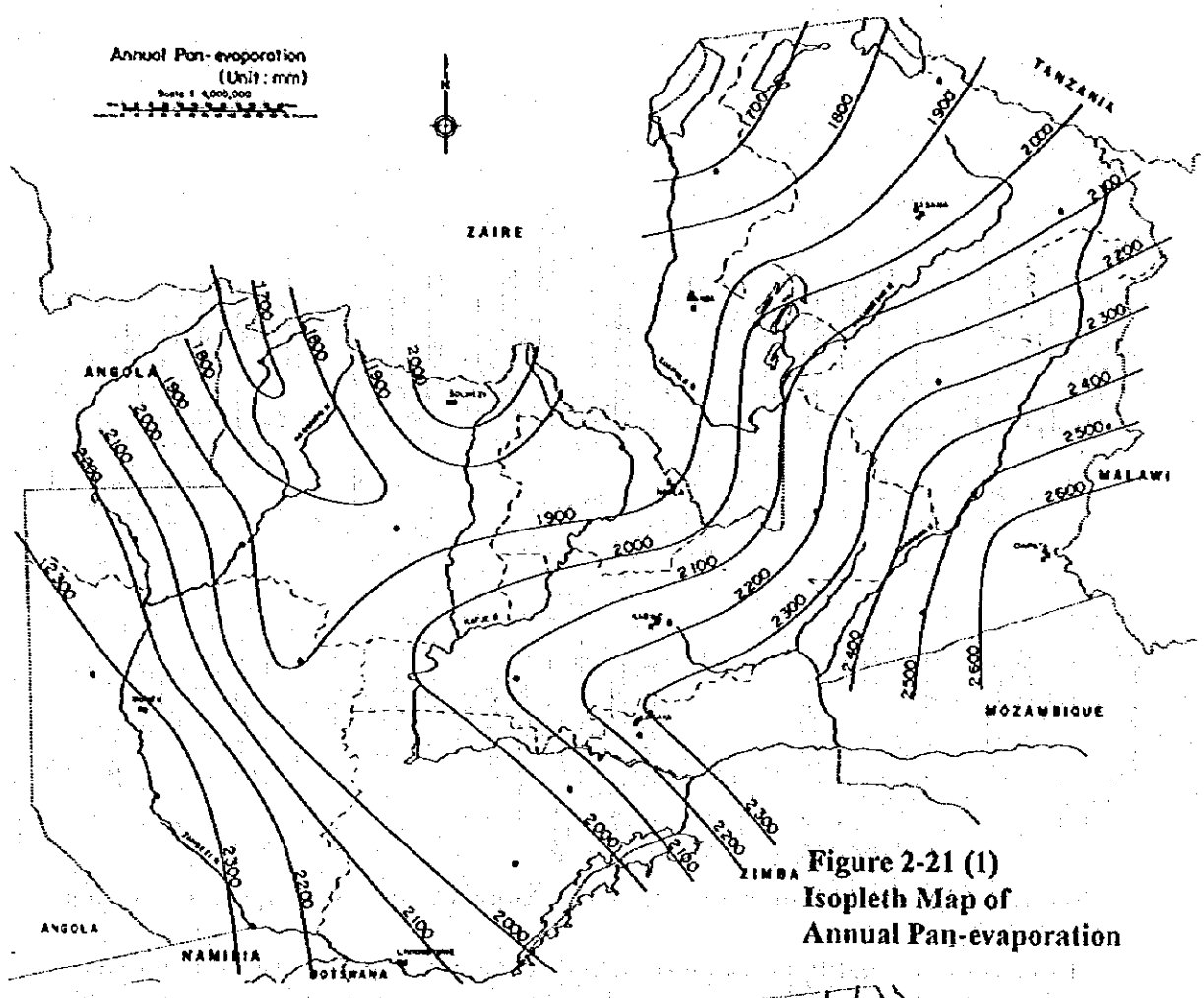


Figure 2-21 (1)
Isopleth Map of
Annual Pan-evaporation

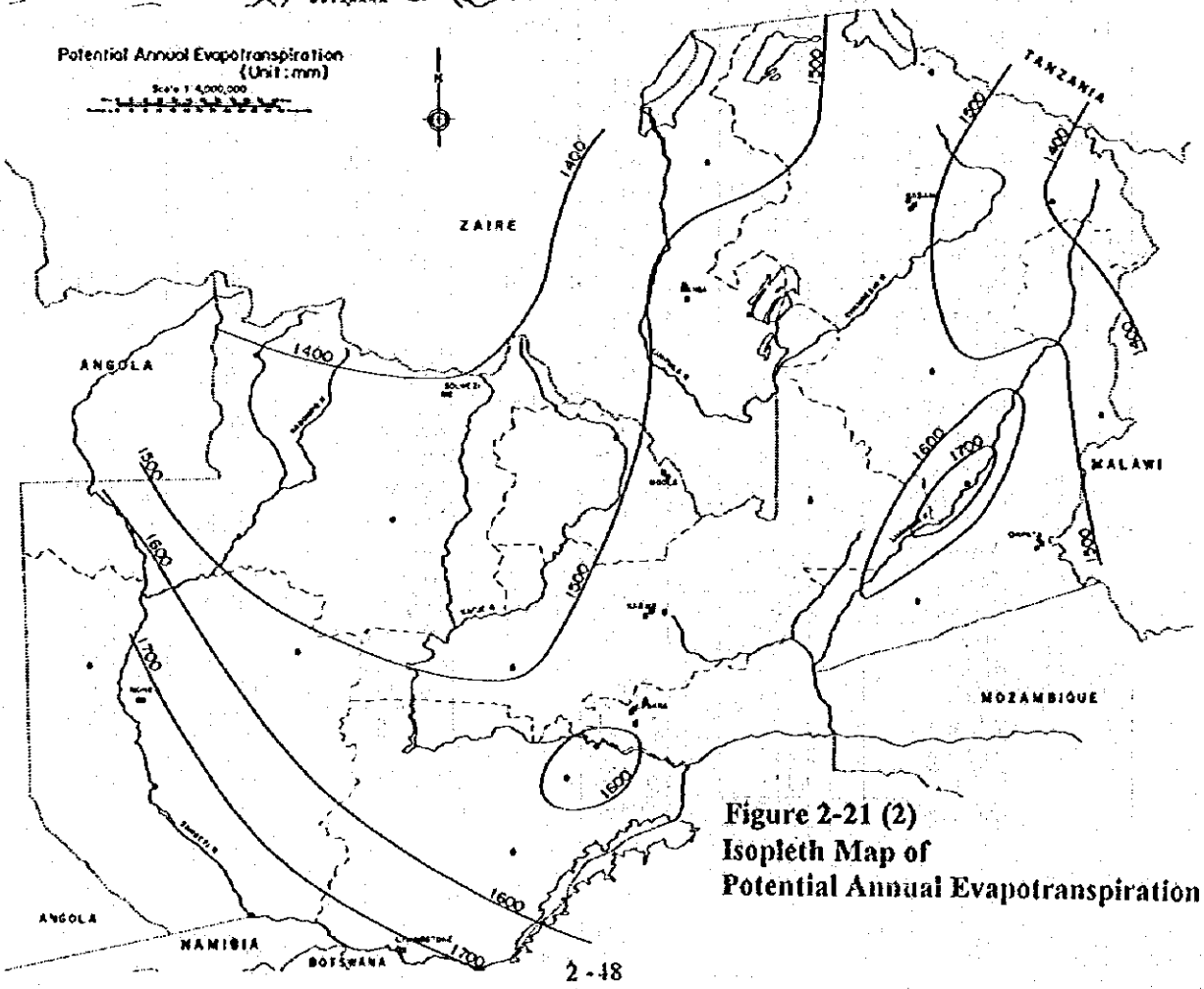


Figure 2-21 (2)
Isopleth Map of
Potential Annual Evapotranspiration