UNITED REPUBLIC OF TANZANIA

MINISTRY OF WATER, ENERGY AND MINERALS

FEDERAL REPUBLIC OF GERMANY

GERMAN AGENCY FOR TECHNICAL COOPERATION LTD.

TANGA WATER MASTER PLAN

TANGA REGION

VOLUME VI

AGRICULTURE

AGRAR- UND HYDROTECHNIK GMBH
ESSEN · FEDERAL REPUBLIC OF GERMANY
1976

This volume is part of Tanga Water Master Plan which, in total, consists of the following volumes:

vol.	I a	Main Report, Text
vol.	I b	Main Report, Maps
vol.	II	Geography, Climate, Hydrology
vol.	III	Groundwater Resources
vol.	IV	Soils
vol.	V	Socio-Economics
vol.	VI	Agriculture
vol.	VII	Water Engineering

Furthermore, the following Technical Reports are also part of Tanga Water Master Plan:

TR	1	Addendum to Boreholes Catalogue Tanga Region, March 1975
TR	2	The Prospects of Sisal
TR	3	Market and Price Prospects of Synthetic Fertilizer
TR	4	Hydrological and Meteorological Data of Tanga Region, 2 vols.
TR	5	Proposals for the Extension of the Hydrological, Meteorological and Hydrogeological Observation Network of Tanga Region
TR	6	Rural Settlements of Tanga Region and their Water Supply Situation (Socio-Economic Results of the Village Survey)
TR	7	The Present Central Places Pattern of Tanga Region
TR	8	Climate, Evaporation, Irrigation and Livestock Water Requirements in Tanga Region
TR	9	Agricultural Statistics of Tanga Region
TR	10	Wells Finished Until December 31st, 1975
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TR	12	Wells Finished Until July 31st, 1976
TR	13	Present Production Costs of Selected Industrial Products
TR	14	Suggestions for a Central Places Strategy for Tanga Region
TR	15	Storage Reservoirs
TR	16	Meteorological and Hydrological Stations Installed in the Tanga Region by T.W.M.P.
TR	17	Rainfall Probabilities for Selected Stations in the Tanga Region
TR	18	Daily Rainfall Figures from Selected Stations in the Tanga Region, 2 vols.
TR	19	Analysis of Drought in Tanga Region
TR	20	Miscellaneous Agricultural Notes

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ABBREVIATIONS

RH	Relative humidity
AEZ (A-E zone)	Agro-economic zone
USBR	United States Bureau of Reclamation
O/M	Operation and Maintenance

1 INTRODUCTION

Irrigated agriculture may, in the medium term, play a considerable role in Tanga Region's economy [1]. It was therefore necessary to make this water using subsector the subject of a detailed study to assess its prospects and its potential water requirements. The same holds true, though perhaps to a lesser extent as far as its present economic importance is concerned, for animal husbandry.

For both subsectors, therefore, data on all factors relevant for water utilization, as far as they were obtainable, were collected and processed. The results of these efforts and the conclusions to be drawn from them are presented in this volume.

1) See e.g. TANZANIA / AHT: Reconnaissance Study of the Lower Pangani Valley, 2 vols. and DTO: Reconnaissance Study of the Lower Mkomazi Valley, 2 vols., all Essen 1976

2 PRESENT SITUATION

2.1 CLIMATE

2.1.1 General

The climate of East Africa is predominantly governed by the atmospheric circulation in the intertropical convergence zone (equatorial pressure trough). The great solar heating in this zone causes low pressure and ascending air movements (saturation, condensation, cloud formation). Winds from the adjacent high pressure belts (generally dry and warm areas) blow towards the equatorial trough (convergence zone).

The three pressure zones oscillate north and south annually, the intertropical convergence zone following the earth position of the sun at its zenith with a time lag of about 5 weeks.

At the time when the convergence zone lies over the equator (twice a year) the converging winds blow from a prevailing easterly direction (south-east at the southern hemisphere), also called "trade winds". These air currents pick up moisture from the Indian Ocean and cause the double rainfall seasons (generally from October till December and from March till June).

During the northern summer the heating of the Asian Continent increases the pressure gradient towards the intertropical convergence zone, by then positioned over these land masses, and resulting in a cross equatorial flow of air, with prevailing south to south east dry winds on the southern hemisphere and the SW-monsoon at the northern hemisphere.

A similar development during the southern summer (December till March) when the convergence zone lies over the southern subtropical belt, causes winds which are blowing from a prevailing northeast to east direction (also called "kaskazi" winds).

The easterly trade winds affect the area with an intensity which gradually decreases inland. Local differences in altitude, ground heating and vegetation may give rise to separate shower clouds or thunderstorm. Ascending air at the windward side of the Usambara mountains causes heavy rains and significant dry areas in the rain shadow zones (Föhn).

Although it sometimes rains out of season and dry spells occur during the rainy seasons, the fact remains that, when averages are considered, wet seasons emerge in the Tanga Region which may be looked upon as the interaction of the passage of the intertropical convergence zone and of the various local rain producing features.

The average macro-climate in Tanga corresponds to a tropical savanah climate (A_W) according to Köppen - Geiger's classification:

Average temperature of coldest month: 18°C
Rainfall index: 2
Rainfall in driest month: 60 mm.

2.1.2 Evapotranspiration

Meteorological data from 8 stations have been presented in Technical Report No. 4, volume I. Five stations are located in the Tanga Region, whereas 3 stations lies in adjacent regions. Data from six meteorological stations (Tanga, Mombo, Amani, Mlingano, Same and Kalimawe) allowed the calculation of one or more potential evapotranspiration reference values. For comparison both the formulae of Blaney-Criddle and Thornthwaite have been applied to all stations. Data from Mlingano Station only were sufficient to enable the calculation of evaporation from an open water surface according to Penman's formula (E_o).

Class "A" Pan evaporation values are available for four stations, but however are seldom very useful, since they have to be adjusted for the influence of advection over the water surface ("Oasis" effect), for which purpose the so-called pan coefficients have to be known.

The Blaney-Criddle values obtained are in all cases extremely high, mainly because the formula does not allow for high relative humidity (Formula was developed for arid climates).

Since it is rather difficult to convert Thornthwaite's reference values into real potential evapotranspiration figures for various crops or vegetation types, an attempt was made to find the correlation between Thornthwaite and Penman values. The Penman method is generally accepted as the best way to obtain reliable evaporation estimates and in addition has the advantage that the evaporation figures can be easily converted into consumptive use values for different crops (see chapt. 3.6). In Fig. AG 2-1 the monthly evapotranspiration reference values, calculated according to Penman, Thornthwaite and Blaney-Criddle from the Mlingano data, are shown for the years 1950 till 1974. The monthly precipitation from a rainfall station nearby is also presented in order to show the relatively high seasonal variability.

Correlation between Penman and Thornthwaite values seems to be adequate on a first sight, the calculated correlation coefficients however were found to be very poor, as can be seen in Table AG 2-1.

Table AG 2-1: LINEAR REGRESSION OF THORNTHWAITE'S AND BLANEY-CRIDDLE'S E_p ON PENMAN'S E_o FOR MLINGANO STATION

	Period	$r_{x.y}$ 1)	Standard Deviation		Linear Regression Coefficients		Standard error of y about regression line
			s_x (mm/day)	s_y (mm/day)	a	b	$S_{y.x}$ (mm/day)
Thornthwaite (x) on Penman (y)	OCT-MAR	0.57	0.60	0.62	0.58	2.73	0.58
	APR-SEP	0.35	0.63	0.51	0.29	3.13	0.42
	OCT	0.39	0.42	0.46	0.43	3.34	0.38
	MAR	0.36	-	-	-	-	-
	JUN	0.43	-	-	-	-	-
Blaney-Criddle (x) on Penman (y)	OCT-MAR	0.23	0.25	0.61	0.55	2.23	0.54
	APR-SEP	0.61	0.16	0.48	1.81	-5.4	0.63
	OCT	0.38	0.11	0.45	1.55	-3.65	0.45
	MAR	0.25	-	-	-	-	-
	JUN	0.36	-	-	-	-	-

1) Sample estimates of correlation coefficient

Since 22 years of simultaneous Penman and Thornthwaite values are available, it was then tried to find a reliable correlation between monthly Thornthwaite and Penman values with corresponding probabilities of occurence. The results were much more successful and adequate linear relationships could be derived for different probabilities. (See Table AG 2-2 below) Correlations between Blaney-Criddle and Penman monthly values for various frequencies were all found to be smaller.

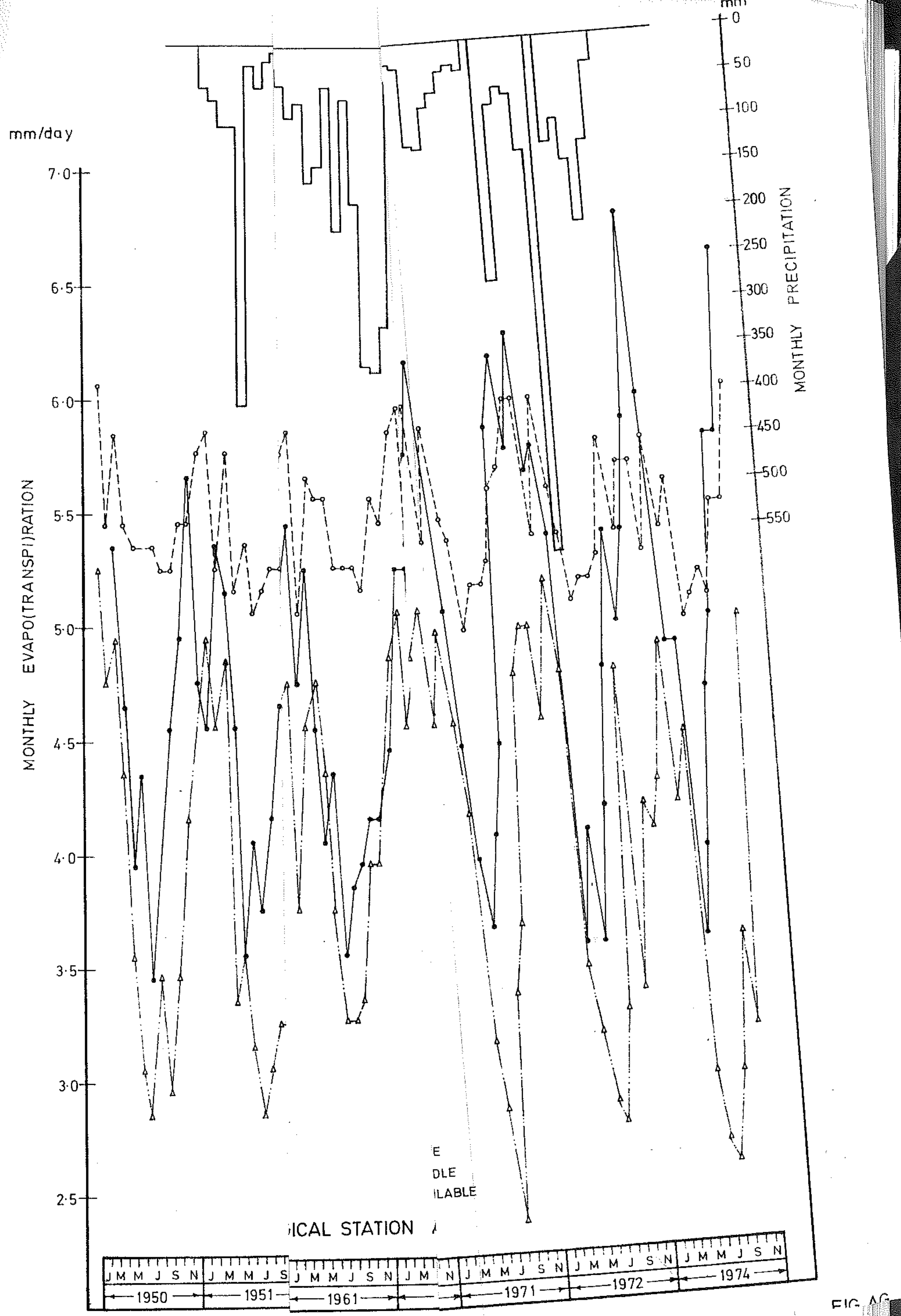
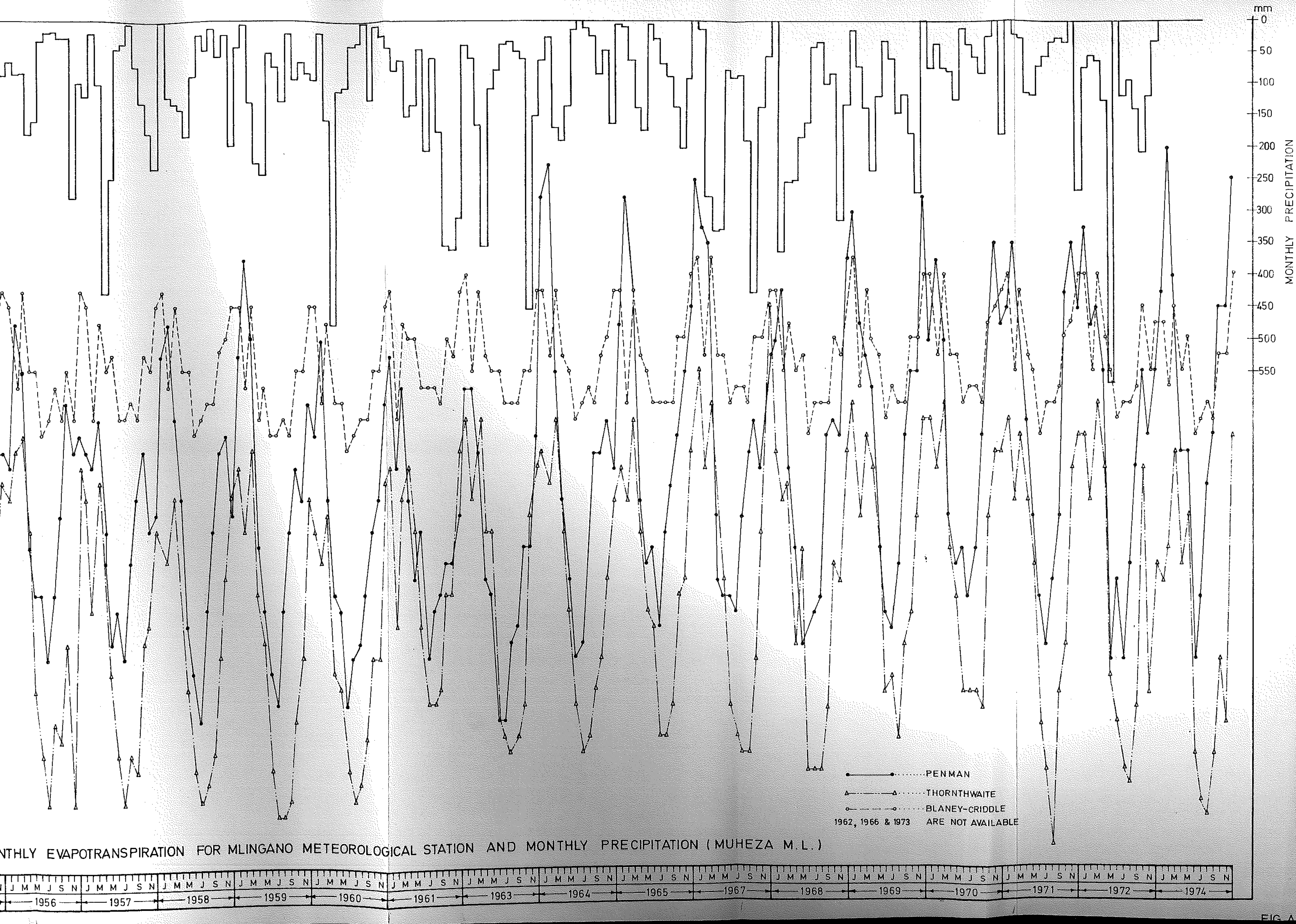
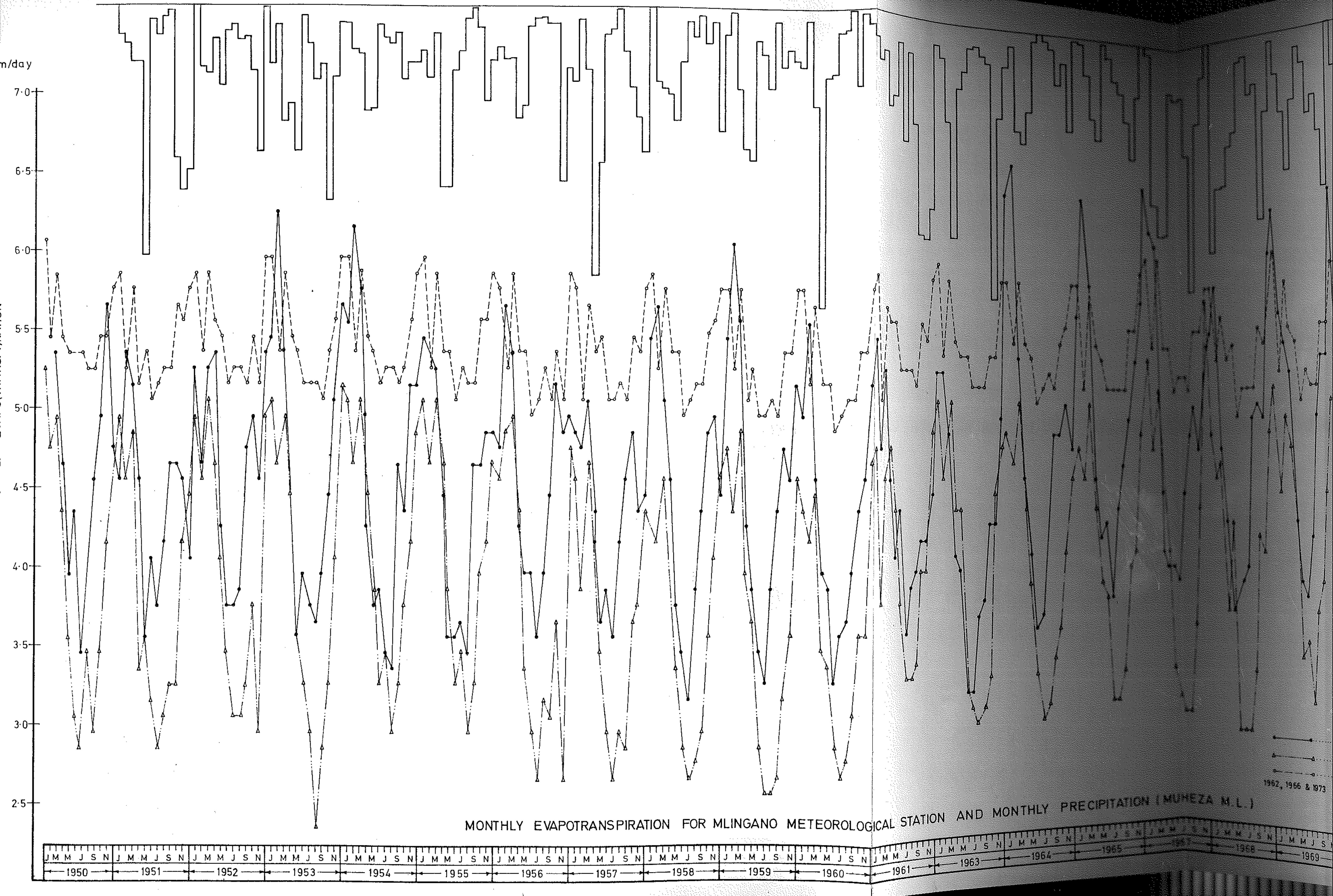


FIG. AG



NTHLY EVAPOTRANSPIRATION FOR MLINGANO METEOROLOGICAL STATION AND MONTHLY PRECIPITATION (MUHEZA M.L.)

FIG AG 2-1



MONTHLY EVAPOTRANSPIRATION FOR MLINGANO METEOROLOGICAL STATION AND MONTHLY PRECIPITATION (MUHEZA M.L.)

Table AG 2-2: RELATION BETWEEN MONTHLY THORNTHWAITE (x) AND PENMAN (y) VALUES FOR MLINGANO STATION

Probability of non-exceedence	$r_{x.y}$	Standard deviation		Linear Regression coefficients		Standard error of y about regression line
		S_x mm/day	S_y mm/day	a	b	$S_{y.x}$ (mm/day)
0.25	0.85	0.75	0.64	0.73	1.72	0.41
0.50	0.84	0.74	0.69	0.76	1.73	0.41
0.75	0.84	0.76	0.78	0.87	1.43	0.36
0.80	0.85	0.73	0.83	0.96	1.10	0.38
Arithmic mean	0.90	0.73	0.70	0.87	1.35	0.43

Frequency analyses were applied to computed Thornthwaite's E_p values of all other stations (Tanga, Mombo, Amani, Kalimawe and Same) and then converted into E_o values with corresponding frequencies, assuming that the above-mentioned regression coefficients are valid for all meteorological stations. The so obtained evaporation values from an open water surface (or evaporative demand) are graphically presented in Fig. AG 2-2 A and B and are an useful and reproduction indicator for potential water requirements of crops.

More detailed information on evapotranspiration reference values and calculation methods can be found in Technical Report No. 8 (Section I).

2.1.3 Agroclimatic Considerations

Since temperatures show little or no seasonal variations (5-6^{o}C), the emphasis as on rainfall, seasonal distributions and evapotranspiration deficit, the being a prodominant agro-climatological factor in the region.

Mean annual rainfall can however be affected by altitude and exposure to such an extent that it cannot be taken as the only differentiating criterion between agro-climatic regions. It is therefore the seasonal rainfall distribution which will be the most important consideration when agricultural development is concerned. Although seasonal distributions may vary with geographical locations, most parts of the regions show statistically significant dry and wet months (see Volume II).

Seasonal variations in relation to agricultural drought will be discussed in detail in Chapter 2.5.

A comparison of rainfall and potential evapotranspiration on the other hand will define more precisely than rainfall the availability of water for plant production as the evaporative demand of the atmosphere varies with location and seasons. Potential evapotranspiration (E_{po}) is defined as the evapotranspiration of a crop, tree, or grass cover when soil mositure is not limited and entirely avaiable for the plant. E_{po} is related to the evaporation from an open water surface (E_o) by crop factors, which are almost independent of the geographical location within the same climatic regime. Actual evapotranspiration (E_a) can be much less than E_{po} and depends mainly on the soil moisture stress (e.g. E_a/E_{po} ratios for grasses can be less then 0.1).

Previous studies (BRALUP Research Paper No. 24) show large water surpluses in south Tanzania during January till March, which are related to the southern position of the Intertropical convergence zone. As this zone moves northwards during April and May the surpluses shift to central latitudes of Tanzania and also include Tanga Region. From about June till October evapotranspiration deficits occur everywhere except at the windward side of the Usambara mountains. From October onwards evapotranspiration deficits are somewhat smaller and tend to increase in January.

In general only during April and May soil moisture recharge is significant in Tanga Region and subsequently determines the main crop growing season (March-June).
A second crop season may occur from October till November ("short rains") when evapotranspiration deficits are relatively low (Drought hazard however can be very high!). The average number of months with water surplus ($R > E_{po}$) is two in the Tanga Region, with exception of the Usambara Mountains. A more detailed analysis of climatic differences will be given in chapter 2.6 (Agro-Climatic Zones).

The annual evapotranspiration deficit in the Tanga Region has been analysed in more detail. Since variations in evapotranspiration are much lower than in rainfall, mean annual potential evapotranspiration was compared with 60% and 20% annual rainfall (probability of non-exceedence) and results were assumed to yield the water deficits for an approximate average and 20% dry year respectively (See Map Drawing AG 2-1 and AG 2-2).

MONTHLY VALUES OF EVAPORATION FROM AN OPEN WATER SURFACE (E_o)

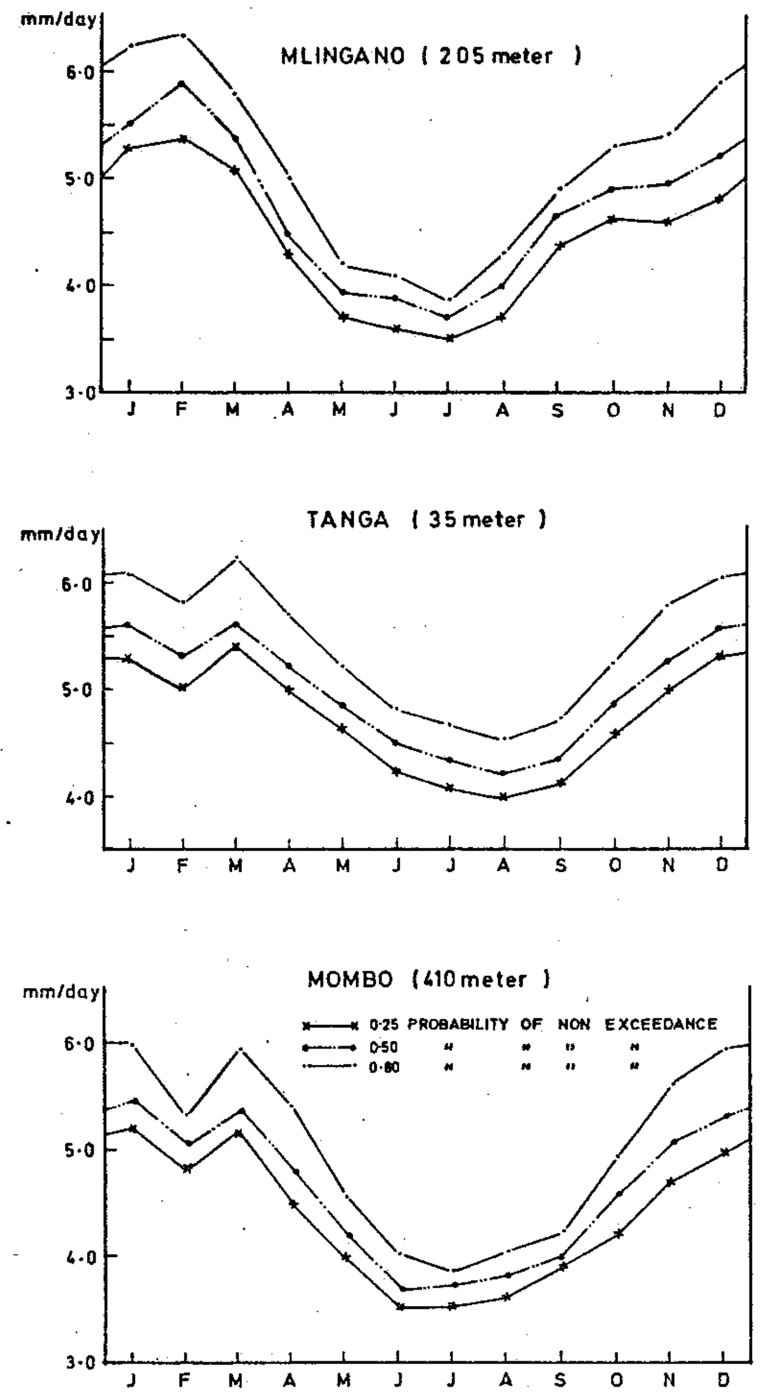


FIG. AG 2-2A

Mean annual potential evapotranspiration has been calculated by applying the E_o data from six stations to the following sub-catchment areas:

CATCHMENT AREA [1]		METEOROLOGICAL
L	NUMBER	STATION
C C ML	1,2,3,4,5,7,9 11, 13, 14, 16 7	TANGA
C SI MS PS PC PN	6,8,10,12,15 3,4 6,7 11, 12 8, 9 9	MLINGANO
SI CI UM PN	1, 2 2 2 4,6,7	AMANI
ML MS PS PC PN	1,2,3,4,5 2,3,4,5 7,8,9,10 4,5,6,7 3,8,5	MOMBO
MJ LU PS PC PN MS	1,2,3,4,5 1,2,3,4,5 1,2,3,4,5,6 2,3 2 1	SAME
US	1,3,4,5	KALIMAWE

The applied E_{po}/E_o ratios for different vegetation types can be found in Technical Report No. 8.

It must be emphasised that rainfall and evaporation data in the Handeni and Umba districts are not sufficient to give reliable results and evapotranspiration deficit classes therefore must be considered as rough extrapolation.

More detailed comparison of monthly E_{po} and rainfall with respect to irrigation requirements of crops can be found in chapter 3.6.

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1) For the definition of catchment and sub-catchment areas see Vol. VII.

MONTHLY VALUES OF EVAPORATION FROM AN OPEN WATER SURFACE (E_o)

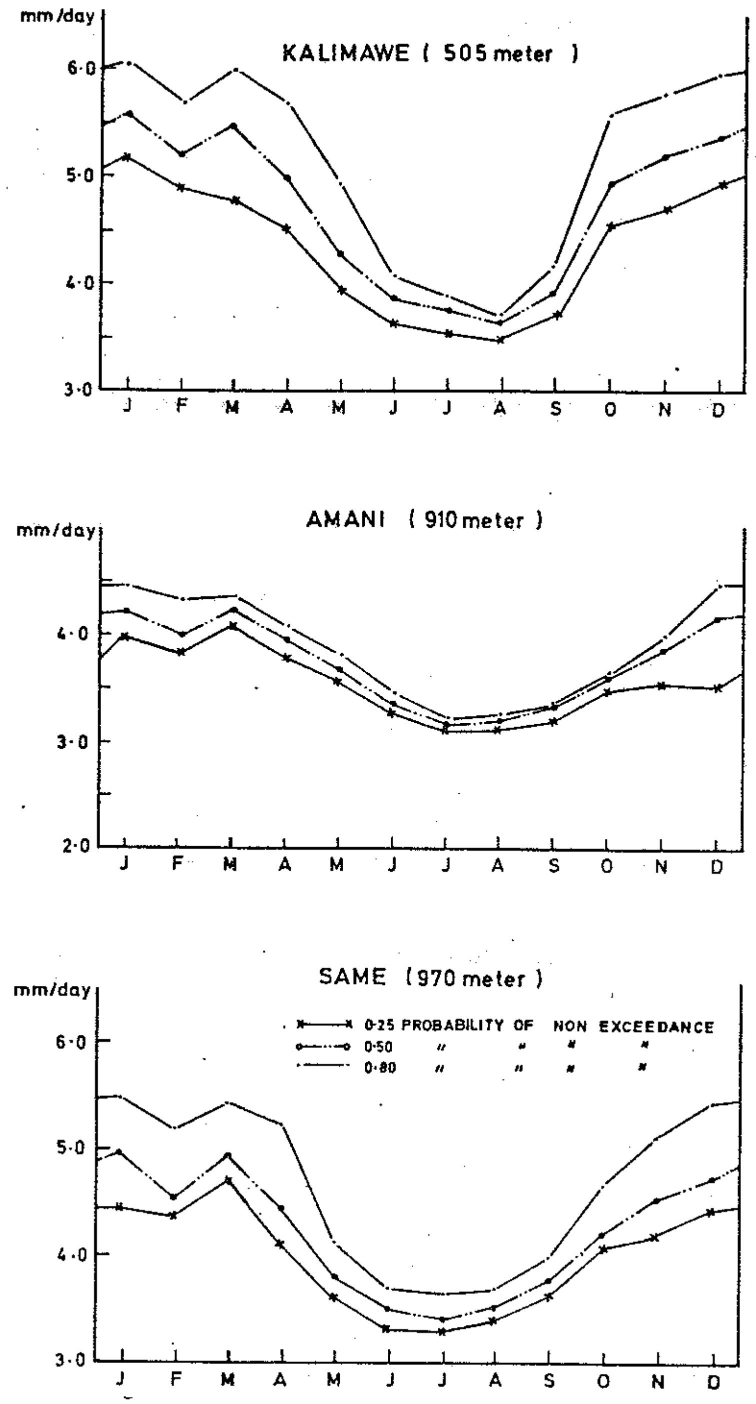


FIG.AG 2-2B

2.1.4 Rainfall Intensities

Rainfall intensity affects to a large extent the interaction of runoff and soil moisture recharge and is hence an important factor for the crop water budget.

Hourly rainfall records from Tanga Town and Mombo Aerodrome are available for approximately 2.5 years (1972-1975) Frequency analysis of 1, 3, 6, 12 and 24 hours rainfall duration are presented in Fig. AG 2-3 and AG 2-4. It should be noted that indicated frequencies of non-exceedance are real sample frequencies. Since 2.5 years of observations are not sufficient to estimate the sample probabilities (very wide confident limits), the indicated frequencies may not be converted into return periods.

Furthermore, frequency analysis of 1, 2 and 3 daily rainfall sequences have been carried out for 17 rain gauge stations, mainly with respect to the definition of drainage criteria for agricultural land. The results are presented in Table AG 2-3 overleaf.

Table AG 2-3

FREQUENCY ANALYSIS OF DAILY RAINFALL SEQUENCES (IN MM)

Raingauge Station	Number of Analysed Years	District	DURATION: 1 DAY – Return period in years				2 DAYS – Return period in years				3 DAYS – Return period in years			
			1x1	1x2	1x5	1x10	1x1	1x2	1x5	1x10	1x1	1x2	1x5	1x10
Mtotohovu	45	Muheza	84	97	123	146	104	130	160	178	115	148	185	213
Mwakijembe	4	Muheza	55	60	-	-	58	75	-	-	60	75	-	-
Sakura	42	Pangani	26	102	138	153	108	132	154	160	122	148	168	190
Handeni	43	Handeni	68	84	109	119	81	104	121	154	93	109	124	(194)
Pongwe	37	Muheza	91	104	137	162	112	143	167	197	133	161	187	217
Magila	20	Muheza	78	105	128	150	109	135	163	170	119	158	175	190
Korogwe	24	Korogwe	70	79	91	128	89	108	131	182	101	128	168	193
Kwamgwe	21	Handeni	76	84	109	130	100	128	154	165	123	144	169	185
Magoma	34	Korogwe	57	71	91	108	75	93	111	128	85	99	114	153
Mandera	36	Korogwe	59	69	85	94	77	91	110	119	92	108	124	136
Mnazi	8	Lushoto	75	85	127	-	85	90	127	-	89	118	132	-
Buiko	12	Korogwe	54	62	72	75	60	70	79	109	63	75	-	-
Mgera	6	Handeni	58	65	-	-	78	85	90		83	90	-	-
Same	19	Kilimanj.	67	80	91	106	88	104	121	128	108	124	141	171
Balangai	34	Lushoto	88	113	156	162	128	164	206	253	160	188	228	283
Amani	53	Muheza	91	124	157	174	125	159	211	234	145	188	229	259
Malindi	27	Lushoto	55	63	84	97	69	85	106	109	79	106	116	127

FIG.AG 2-3 PRECIPITATION INTENSITY-DURATION-FREQUENCY AT TANGA TOWN (1972 - 1975)

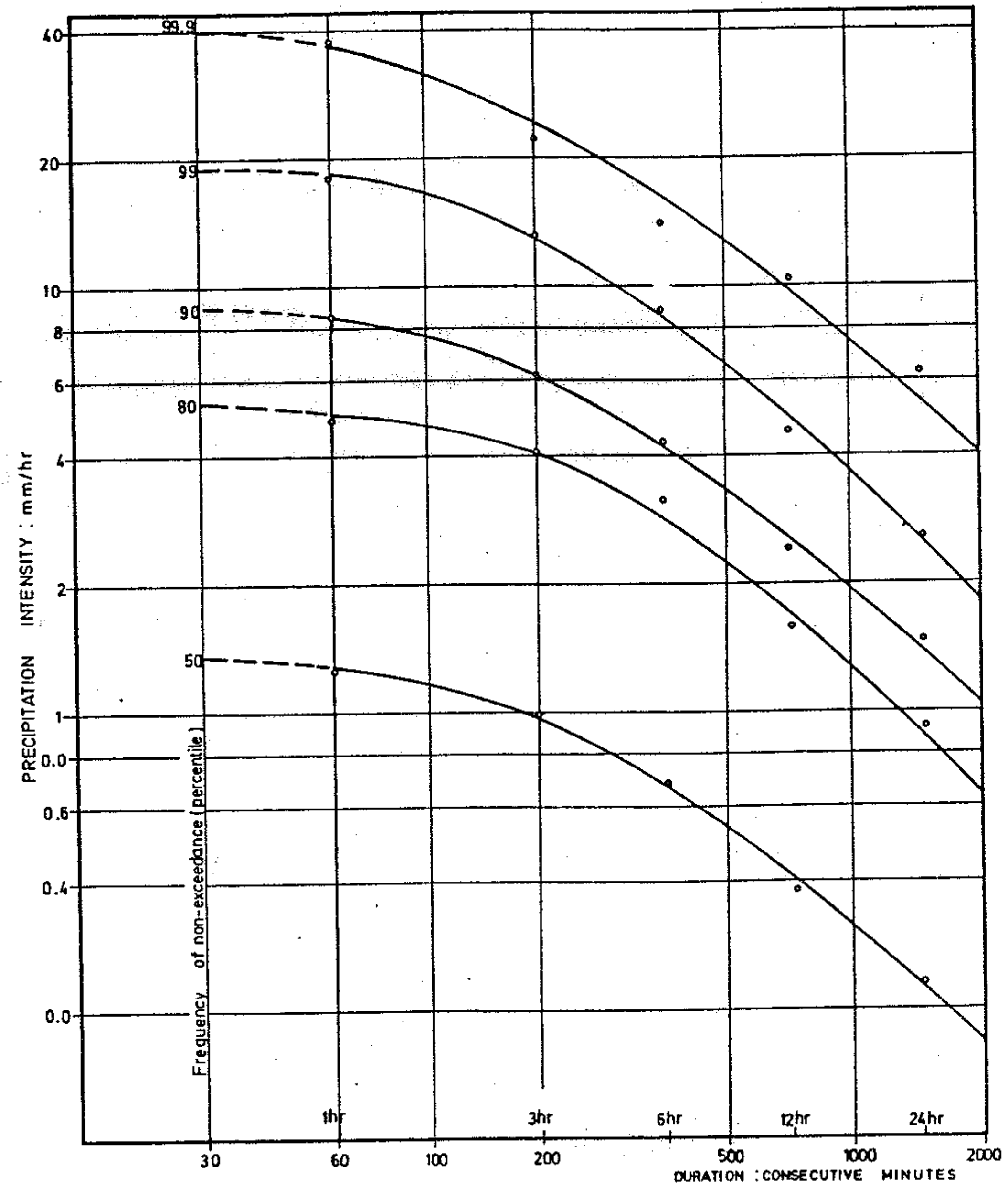
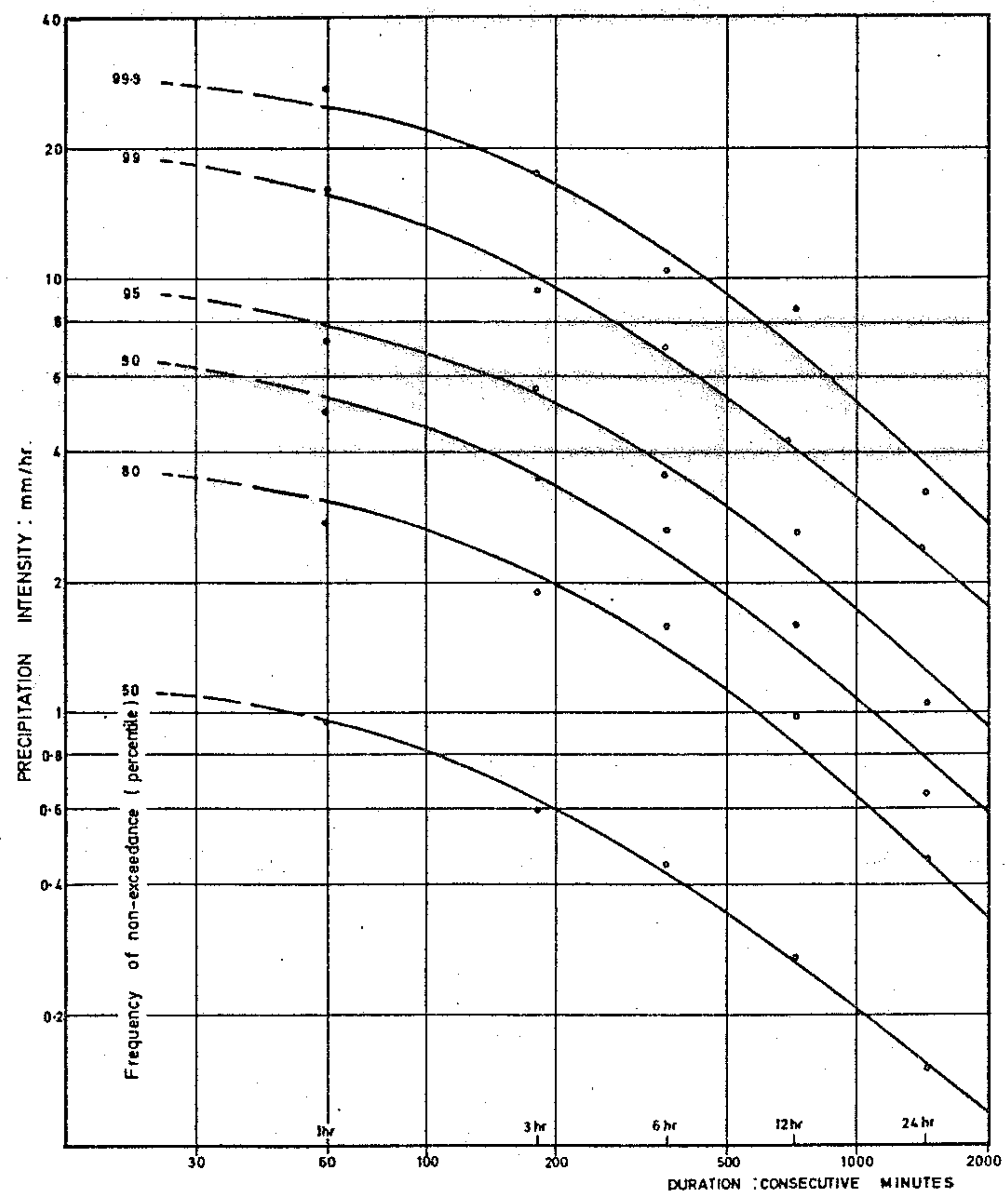


FIG.AG 2-4 PRECIPITATION INTENSITY—DURATION—FREQUENCY AT MOMBO (1972-1975)



2.2 AGRO-ECONOMIC ZONES

2.2.1 Introduction

In order to study the agricultural situation of Tanga Region, it is useful to subdivide the area into zones that are more or less uniform from an agricultural point of view. The original classification was made by BRALUP [1]. This was used with slight modifications by TIRDEP [2] and is also applied in this Report, again with minor modifications, as follows:

a) The zonal boundaries were shifted to coincide with administrative sub-boundaries too. Although this change tends to marginally reduce the homogeneity of some zones, it eliminates the problem of having some zones covering parts of two or more districts which should reduce potential project implementation problems and also allows the survey data [3] to be applied to the zones.

b) Two subzones were added, Handeni 3/4 - Central West and Lushoto 1/2 - North West.

Eighteen agro-economic zones were thus defined and are listed overleaf together with the administrative divisions and subdivisions they comprise.

1) Agro-Economic Zones of Tanzania, D. Conyers, Bureau of Resource Assessment and Land Use Planning, Research Paper No. 25

2) Tanga Regional Development Plan 1975-80, Volume 2, Tanga Integrated Rural Development Programme

3) Tanga Water Master Plan, Technical Reports No. 6 and No. 9.

District	AE Zone		Divisions & Subdivisions
Handeni:	H1	East	Kwamsisi, Mkumburu, Mzundu.
	2	Central	Chanika, Magamba, Mazingara.
	3	Nguru Mountains	Kimbe, Kwekivu.
	3/4	Central West	Mgera.
	4	Masai	Mswaki.
Korogwe:	K1	Highlands	Bungu, Vugiri.
	2	Wetter Plains	Korogwe, Makuyuni, Magoma Mnyuzi.
	3	Drier Plains	Mkomazi, Mombo.
Lushoto:	L1	Highlands	Bumbuli, Mgwashi, Gare, Mlola, Soni, Vuga, Bagabaga, Lushoto.
	1/2	North West	Mlalo, Mtae.
	2	Lowlands	Mbaramo.
Muheza:	M1	Highlands	Amani, Bwembwera, Songa Daluni, Maramba.
	2	South Coast	Kicheba, Mtindiro, Kigombe, Pongwe, Muheza, Mwakidila.
	3	North Coast	Moa, Mtimbwani, Gombero, Mabokweni.
	4	Dry Zone	Mkinga
Tanga:	T		Tanga.
Pangani:	P1	North	Madanga, Mwera.
	2	South	Mkwaja.

The zones are delineated on Map Drawing AG 2-3.

2.2.2 Areas and Populations

The areas and estimated 1975 populations and population densities of the zones are given below:

Table AG 2-4: AGRO-ECONOMIC ZONE AREAS AND POPULATION

	Area Sq.km.	Population	Population Density
H 1 East	2893	40,200	13.9
2 Central	4572	67,600	14.8
3 Nguru	2463	27,900	11.3
3/4 Central West	1254	21,000	16.7
4 Masai	2027	13,000	6.4
Handeni District	13209	169,700	12.8
K 1 Highlands	286	41,500	145.1
2 Wetter Plains	1885	86,400	45.8
3 Drier Plains	1585	37,900	23.9
Korogwe District	3756	165,800	44.1
L 1 Highlands	1317	169,670	128.8
1/2 North West	653	100,000	153.1
2 Lowlands	1527	13,500	8.8
Lushoto District	3497	283,170	81.0
M 1 Highlands	1550	80,800	52.1
2 South Coast	1209	98,300	81.3
3 North Coast	1188	38,600	32.5
4 Dry zone	974	14,800	15.2
Muheza District	4911	232,500	47.3
Tanga	10	89,000	-
P 1 North	976	30,800	31.6
2 South	448	4,200	9.4
Pangani District	1425	35,000	24.6
Total	26807	975,170	36.4

The population densities are thus very variable, from the very sparse populations of Handeni, L2, M4 and P2 zones, to the very dense populations in the Western Usambara zones (K1, L1, L1/2).

2.2.3 Rural Survey

A detailed rural survey was undertaken as part of the Tanga Water Master Plan[1]. The survey included questions on cropping patterns and livestock numbers, which have been analysed by subdivision, district and agro-economic zone. The detailed analyses are presented in Technical Report No 9.

The maps on the following four pages indicate the relative importance of the major crop and livestock enterprises in each zone.

1) See TWMP Technical Reports No 6 and No 9.

2.3 PRESENT LAND USE

2.3.1 Vegetation Map (1955)

The 1 : 50,000 topographic maps and aerial photographs were studied and the major vegetation boundaries delineated. The maps were reduced to 1: 250,000 and a mosaic made for the entire region. The aerial photography on which the maps are based was mainly undertaken in the mid 1950's. A number of significant changes have taken place since that time, in particular the clearing of bush for cultivation, the destruction of forests and the establishment of sisal estates but no adjustments were made.

Due to the reduction in scale it was necessary to combine a number of the original vegetation classes for the sake of clarity and the following eight classes have therefore been delineated. The included classes from the 1956/58 and 1967/74 series 1: 50,000 maps are also indicated.

Class		1956/58 Series	1967/74 Series
I	Mangrove	Mangrove	Mangrove Swamp
II	Swamp/Rice	Mbuga Swamp Swamp Vegetation Rice	Seasonal Swamp Tree Swamp Papyrus Swamp
III	Forest	Forest	Forest
IV	Woodland	Light Forest Scrub and Scattered Trees	Woodland Scattered Trees
V	Scrub	Scrub Thicket	Scrub Thicket
VI	Village Cultivation	No Class	No Class
VII	Palm	Palm, Mango	Palms
VIII	Estates	Cultivation and Plantation	Plantation

The vegetation map is presented as Drawing AG 2-4.

2.3.2 Present Land Use Map A - by Agro-Economic Zone

From the extrapolated Agro-Economic Zone data, the percentage of land under dry land, estate and tree crops could be identified. The area irrigated was derived from section 2.6 of this Report and the area of Forest Reserve from Forestry Department records. The balance of the area in each zone was given the classification grazing and unutilized.

Since dry land crops, tree crops and grazing areas can occur on the same field, and cropping country is often used for grazing at certain times of the year, the dividing line between the three classes is indistinct. Nonetheless the table on the following page gives an indication of the relative importance of each class in each Agro-Economic Zone.

The percentage of land in each class is shown in Present Land Use Map Drawing AG 2-5.

2.3.3 Present Land Use Map B - Class Boundaries

The Present Land Use Map B is presented as Drawing AG 2-6. It is mainly based on the vegetation map and on the district maps for forestry and game reserve areas.

The following classes are distinguished:

1. Agricultural - Predominantly Cropping
2. Agricultural - Predominantly Grazing
3. Irrigation Areas
4. Estates
5. Forest Reserves
6. Other public Lands under Forest or Woodland
7. Game Reserve
8. Game Controlled Areas

Table AG 2-5 PRESENT LAND USE (Square Kilometres)

AE Zone	Total Area	Arable Crop Area 1)	Tree Crop Area	Estates Area	Irrig. Area	Dry land Crop Area	Forest Reserve Area	Grazing And Unused	L.U.
Handeni									
H1	2893	282.5	27.5	72.0	-	210.5	8.9	2574.1	16883
H2	4572	274.0	10.1	-	-	274.0	194.2	4093.7	45491
H3	2463	88.1	2.9	-	-	88.1	138.0	2234.0	11043
H3/4	1254	82.9	3.2	-	-	82.9	97.1	1070.8	34512
H4	2027	50.3	0.9	-	-	50.3	15.5	1960.3	23776
Korogwe									
K1	286	139.9	60.0	16.9	-	123.0	3.3	82.8	10747
K2	1885	789.2	94.0	389.4	3.9	395.9	80.7	921.1	52421
K3	1585	312.5	4.2	208.8	11.7	92.0	92.0	1176.3	33411
Lushoto									
L1	1317	821.9	108.0	-	50.0	771.9	155.5	231.6	110585
L1/2	653	378.6	40.9	-	15.0	363.6	154.6	78.9	41148
L2	1527	71.2	3.9	12.5	11.7	47.0	8.0	1443.9 2)	16793
Muheza									
M1	1550	702.3	113.6	192.4	-	509.9	150.3	583.8	11643
M2 3)	1219	867.1	164.7	436.6	-	430.5	-	137.2	33394
M3	1188	419.6	227.0	264.5	-	155.1	-	541.4	8602
M4	974	84.5	56.1	-	-	84.5	-	833.4 2)	5257
Pangani									
P1	976	281.4	85.9	188.5	0.4	92.5	44.0	564.7	7690
P2	448	13.8	34.2	-	-	13.8	-	400.0	13384
Total	26807	5659.8	1037.5	1781.6	92.7	3785.5	1142.1	18968.0	476780

1) including estates and irrigation
2) includes Mkomazi Game Reserve - c. 950 km^2 in L2 and 270 km^2 in M4.
3) includes Tanga Town

2.3.4 Crop Production

2.3.4.1 Introduction

The major crop production systems that can be identified in Tanga Region are as follows:

Smallholder Production
Ujamaa Village Collective Farming
Block Cultivation
Estate Farming.

Further subdivisions can be made into:

Irrigated, Rainfed or Dry Farming
Permanent or Shifting Cultivation
Monoculture or Intercropping.

Smallholder Production continues to account for a large proportion of the agricultural output of Tanga Region. Cropping patterns are largely dictated by subsistence requirements with limited volumes of specific cash crop and surplus staple crop production being marketed[1]. Detailed analysis of cropping pattern by agro-economic zone is presented in Technical Report TR 7.

Traditionally the villagers of Tanga Region practised shifting cultivation, with an extended bush regeneration phase following each relatively short cropping cycle. As population pressures have increased however the emphasis has changed towards more permanent cultivation.

Smallholder irrigation is undertaken in the Usambaras, producing staple food crops and vegetables and in several valley flood plains, mainly producing rice. The irrigation schemes of the region are described in section 2.6 of this Report.

Ujamaa Village Collective Farming has expanded in recent years but remains a relatively minor contributor to agricultural output. Problems have been experienced in achieving adequate labour inputs and productivity and it is considered likely that progress will have to be made with mechanisation or oxenisation before significant gains can be made. In the long term however, ujamaa village production should become more important in the region.

1) Exceptions occur in the Usambara Mountains where extensive smallholder production of tea, coffee and vegetables is undertaken and with cashew and coconut production in the coastal areas.

Block Cultivation refers to the communal cultivation of village lands, often by tractor, but with the remaining operations undertaken by the families on their individual farms. It would appear that greater productivity can be achieved under this system than under collectivised farming at present and it is considered to represent a logical intermediate step between smallholder and eventual fully collective operation.

Estate Farming is very significant to the cash and export economy of Tanga Region. It is also a major employer of labour, and at least has the potential to become a vehicle for technological development throughout much of the agricultural sector. The main estate crops are:

- Sisal, grown in the coastal areas and in the plains and foothills surrounding the Usambaras.
- Tea, grown in the Usambaras,
- Bananas and coconuts small estates occur along the Pangani River.

2.3.4.2 Cropped Areas

The areas of the most important arable and tree crops by district are given in the following tables:

Table AG 2-6 ARABLE CROP AREAS (1000 HA)[1)]

District	Handeni	Korogwe	Lushoto	Muheza[2)]	Pangani	Region
Beans	10.2	6.1	30.0	1.4	-	47.7
Maize	42.0	35.9	39.1	32.7	4.7	154.4
Rice	1.1	5.4	0.8	4.0	0.7	12.1
Vegetables	0.4	0.8	4.4	0.3	-	5.8
Sisal	1.2	0.2	0.2	2.8	-	4.5
Sisal, Estate[3)]	2.5	48.4	0.6	50.5[4)]	8.7	110.7
Cardomom	0.1	2.0	1.2	2.0	-	5.2
Cotton	3.2	2.1	0.4	-	0.1	5.8
Groundnuts	-	0.1	0.5	0.2	-	0.9
Sweet Potatoes	1.3	0.6	9.5	0.5	0.4	12.3
Irish Potatoes	0.1	-	11.8	-	-	11.9
Sorghum	2.0	-	-	7.2	0.5	9.7
Bananas[5)]	2.6	3.1	14.7	38.4	0.3	59.2
Cassava	6.1	5.3	12.9	28.2	3.7	56.3
Total	72.8	110.4	126.2	168.3	19.2	496.8
Smallholder	70.3	61.8	125.6	117.8	10.5	386.1
Estate	2.5	48.4	0.6	50.5	8.7	110.7

1) Includes Estate and Urban Centre crops and therefore differs from the district summaries of Technical Report TR 7, Agricultural Statistics of Tanga Region

2) Includes Tanga Town

3) Area under sisal, as opposed to area of estate used in TR 7.

4) Includes 1821 ha in M2 AEZ and 647 ha in M3 AEZ, owned by ujamaa villages

5) Excludes banana plantations along the Pangani river

Source: TWMP rural survey extrapolated

Table AG 2-7 TREE CROP AREAS (1000 HA EQUIV.)[1]

	Handeni	Korogwe	Lushoto	Muheza[2]	Pangani	Region
Coconut	0.3	5.4	0.2	14.3	4.2	24.4
Coconut, Estate	-	-	-	-	0.6	0.6
Citrus	0.3	0.2	0.1	2.1	0.1	2.8
Citrus, Estate	-	-	-	0.2	-	0.2
Cashew	2.9	2.2	0.3	35.0	6.8	47.2
Pome	-	0.4	3.5	-	-	4.0
Mango	0.9	2.0	1.8	0.8	0.3	5.8
Coffee	-	3.8	6.2	-	-	10.1
Tea	-	1.8	2.5	0.1	-	4.4
Tea, Estate	-	-	0.5	2.4	-	2.9
Cocoa, Estate	-	-	-	0.9	-	0.9
Oil Palm, Estate	-	-	-	0.3	-	0.3
Total	4.5	15.8	15.3	56.1	12.0	103.7
Smallholder	4.5	15.8	14.8	52.3	11.4	98.8
Estate	-	-	0.5	3.8	0.6	4.9

1) Includes urban centre and estate data and therefore differs from the district summaries of TR 7

Conversion Factors (trees per hectare equivalent)

Coconuts	125	Pome	250	Coffee	2000
Citrus	250	Mango	75	tea	9000
Cashew	60				

2) Includes Tanga town

Source TWMP rural survey extrapolated.

A brief description of the major arable and tree crops grown in Tanga Region is given in Technical Report No. 20.

2.3.5 Livestock Production

2.3.5.1 Introduction

Livestock form an important part of the agricultural economy of Tanga Region, as shown by the following table.

Table AG 2-8 TOTAL LIVESTOCK NUMBERS - BY DISTRICT 1975 (1000 HEAD)[1]

	Handeni	Korogwe	Lushoto	Muheza[2]	Pangani	Region
Cattle Smallholder[3]	60.8	76.5	116.1	21.3	1.4	276.1
Ranch	13.0	1.0	-	10.0	18.0	42.0
Masai	35.0	-	8.0	-	-	43.0
Sheep[1]	27.8	24.5	94.9	45.6	1.3	194.1
Goats[1]	88.4	69.9	139.7	96.6	5.2	399.8
Pigs	-	0.4	3.2	0.1	-	3.7
Hens[1]	308.6	270.4	404.2	359.3	52.7	1394.1
Ducks	13.1	16.7	20.9	10.6	1.0	62.3
Donkeys	0.4	0.3	-	0.3	-	1.1
Total L.U.[4]	131.8	96.5	168.5	59.0	21.0	476.8

1) Since the Table includes Urban Centre, Ranch and Masai livestock, the figures differ from the district summaries of TR 7 which refer to smallholder livestock only.

2) Includes Tanga Town, Tanga District and Muheza District.

3) Includes urban centres.

4) L.U. = Livestock Unit. One L.U. is the stock equivalent to a mature cow of 300 kg liveweight.
1 L.U = 1 beef animal
6 sheep or goats
1.2 donkeys
100 head of poultry

A more detailed analysis is given in Technical Report No. 20.

The percentage of the total livestock population of the Region (expressed in Livestock Units) represented by each type of stock is as follows:

	L.U.x 10^3	%
Cattle	361	75.8
Sheep	32	6.7
Goats	67	14.1
Pigs	1	0.2
Poultry	15	3.0
Donkeys	1	0.2
	477	100.0

2.3.5.2 Stocking Intensities

From the extrapolated survey data, L.U. per agro-economic zone were calculated. Since poultry are insignificant contributors to grazing or watering pressure, they have been excluded.
Two stocking intensities are calculated,

a) L.U./Total AE Zone Area
b) L.U./Grazing and Unused Land as calculated in section 2.3.

Table AG 2-9 STOCKING INTENSITIES BY AGRO ECONOMIC ZONE

AE Zone		Area Total sq.km	Area Grazing sq.km	L.U.	a LU/sq.km Total Area	b LU/sq.km Grazing Area
Handeni	1	2893	2574	15900	5.5	6.2
	2	4572	4094	44500	9.7	10.9
	3	2463	2234	10500	4.3	4.7
	3/4	1254	1071	34100	27.2	31.8
	4	2027	1960	23600	11.6	12.0
Korogwe	1	286	83	9900	34.6	119.3 1)
	2	1884	921	51300	27.2	55.7
	3	1585	1176	33100	20.9	28.1
Lushoto	1	1317	232	108000	82.0	465.5 1)
	1/2	653	79	39800	60.9	503.8 1)
	2	1527	1444	16500	10.8	11.4
Muheza	1	1550	584	10600	6.8	18.2
	2 2)	1219	185	29900	24.5	161.6 1)
	3	1188	541	8200	6.9	15.2
	4	974	833	5100	5.2	6.1
Pangani	1	976	565	7200	7.4	12.7
	2	448	400	13300	29.7	33.3
Region		26807	18976	461500	17.2	24.3

1) The livestock in these zones are largely supported on the cropped areas and probably in the forest reserves.
2) Including Tanga Town

Some of the stocking intensities calculated above would appear to be virtually physically infeasible, in particular in the Western Usambaras, although the stocking rates in this area are certainly very high. A possible explanation is inaccuracy in the data provided by the survey respondents, but the survey data is nonetheless included without adaption.

In the following table the stocking intensities are placed in sequence (total area basis).

Table AG 2-10 STOCKING INTENSITY CLASSES

Intensity	AE Zone	Hectares/L.U.	L.U./Sq.km
Low	H3	23.2	4.3
	M4	19.2	5.2
	H1	18.2	5.5
	M1	14.7	6.8
	M3	14.5	6.9
	P1	13.5	7.4
Moderate	H2	10.3	9.7
	L2	9.3	10.8
	H4	8.6	11.6
	Mean	5.8	17.2
High	K3	4.7	20.9
	M2	4.0	24.5
	K2	3.7	27.2
	H3/4	3.7	27.2
	P2	3.4	29.7
Very High	K1	2.9	34.6
	L1/2	1.6	60.9
	L1	1.2	82.0

The extensive livestock areas are thus generally in the west, north and south of the region, with intensive stocking concentrated in and around the Usambaras. The main anomalies are P2 (Pangani South) and K3 (Korogwe Drier Plains), which are relatively heavily stocked, the former due to the presence of Mkwaja ranch. M1 (Muheza Highlands) on the other hand, is very lightly stocked in relation to the remaining highland areas, due largely to the extensive areas of forest and undeveloped country and the relatively low population density.

The major livestock enterprises of Tanga Region are briefly described in Technical Report No. 20.

2.3.6 Forestry

2.3.6.1 Classification

There are three main classifications of forest land in Tanga Region

- Forest Reserves
- Public Land Forests
- Plantations

Forest Reserves

The forest reserves mainly comprise hardwood species, many of which are suitable for the production of construction or veneer material. BRALUP[1] gives the following classification of Productive and Protected Reserves for Tanga Region.

Table AG 2-11 FOREST RESERVES, TANGA REGION

	Handeni	Lushoto Korogwe	Pangani	Muheza Tanga	Total
Productive Reserves					
Closed Forest	439	9393	608	3055	13495
Woodland	18107	3852	1813	2487	26259
Grassland	-	-	-	1085	1085
Mangrove	-	-	600	10004	10604
Protective Reserves					
Closed Forest	20430	35044	-	14673	70147
Woodland	10954	1501	-	-	16860
Grassland	36	701	-	364	1101
TOTAL	49966	50491	3021	36073	139551
Source: BRALUP Research Note 5d (December 1968 data)					

In addition there is a total of 1,585 hectares in local authority reserves in the Lushoto/Korogwe area.

Forest Reserve areas compiled from Forestry Department records and maps were given by Agro-Economic zone in Table AG 2-5.

1) Bureau of Resource Assessment and Landuse Planning University of Dar es Salaam, Research Note 5d, 1969

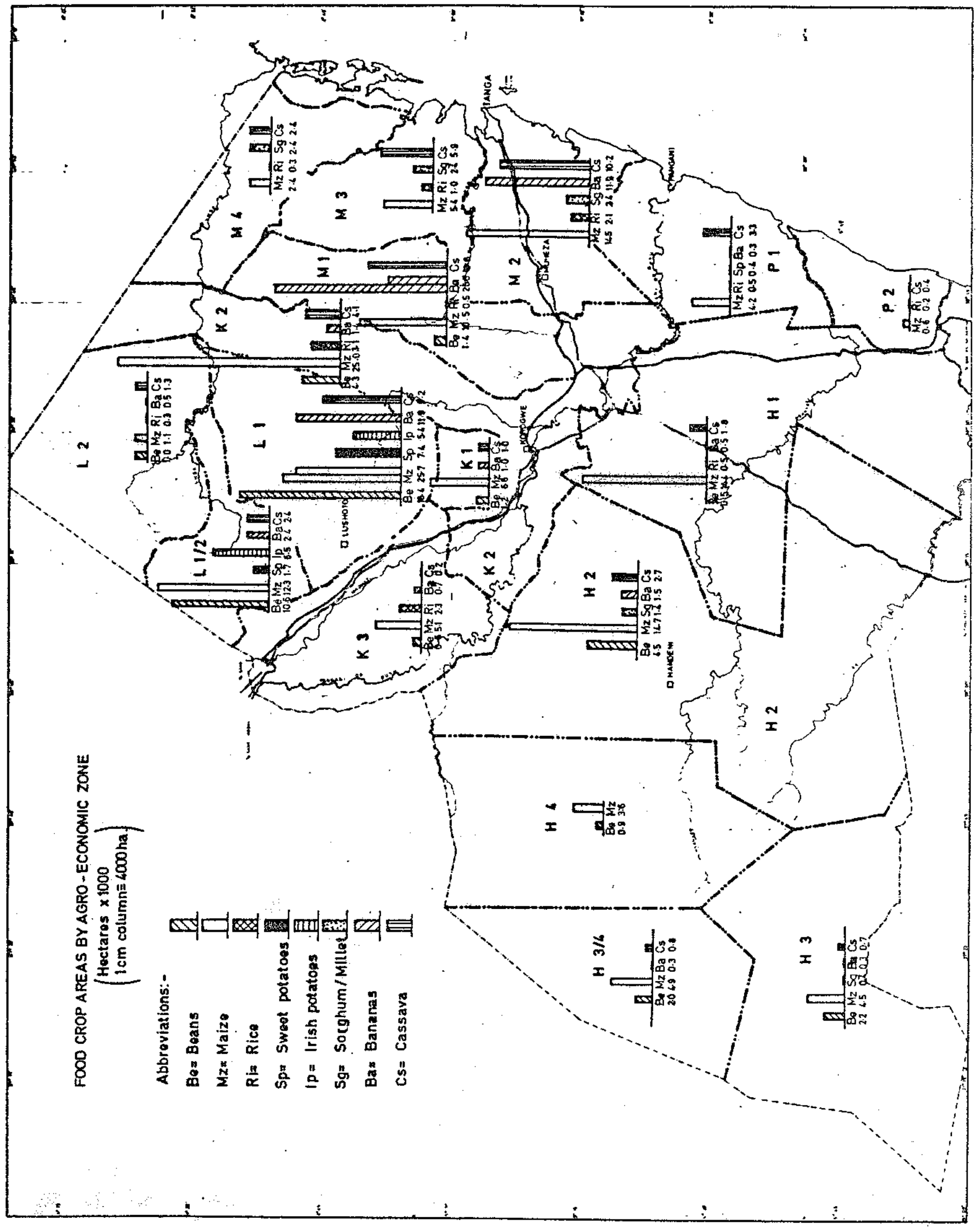


FIG. AG 2-5

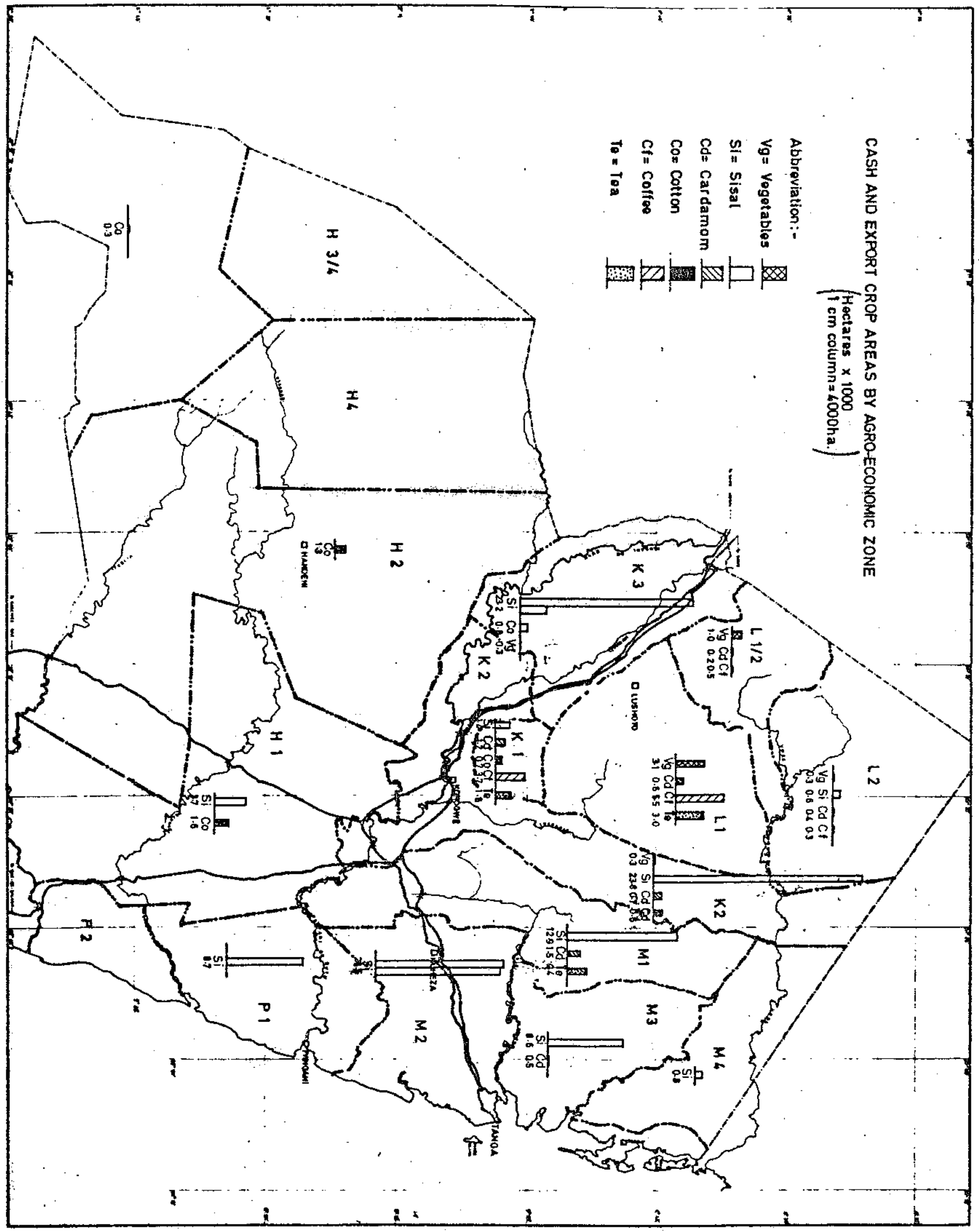


FIG. AG. 2- 6

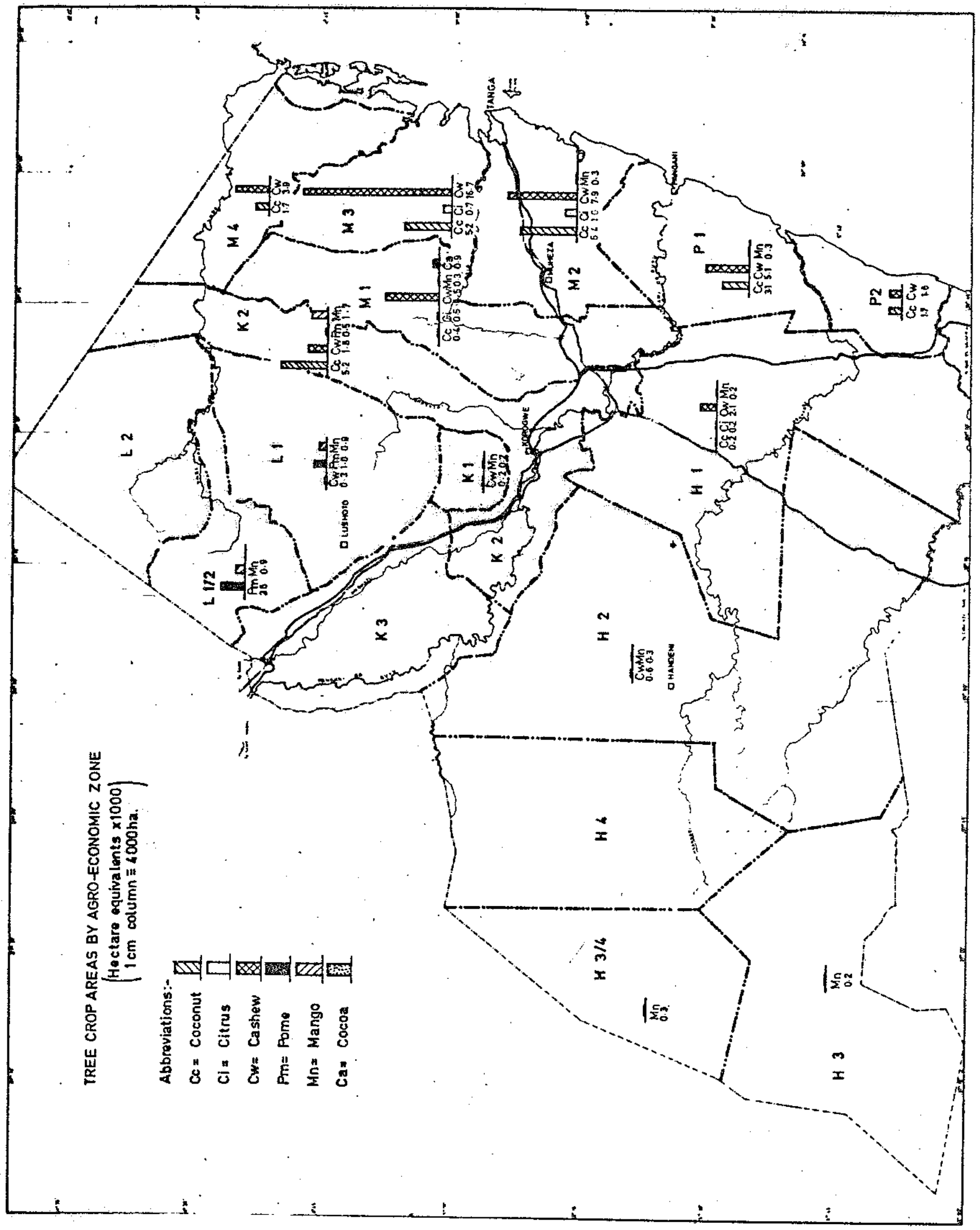


FIG. AG 2-7

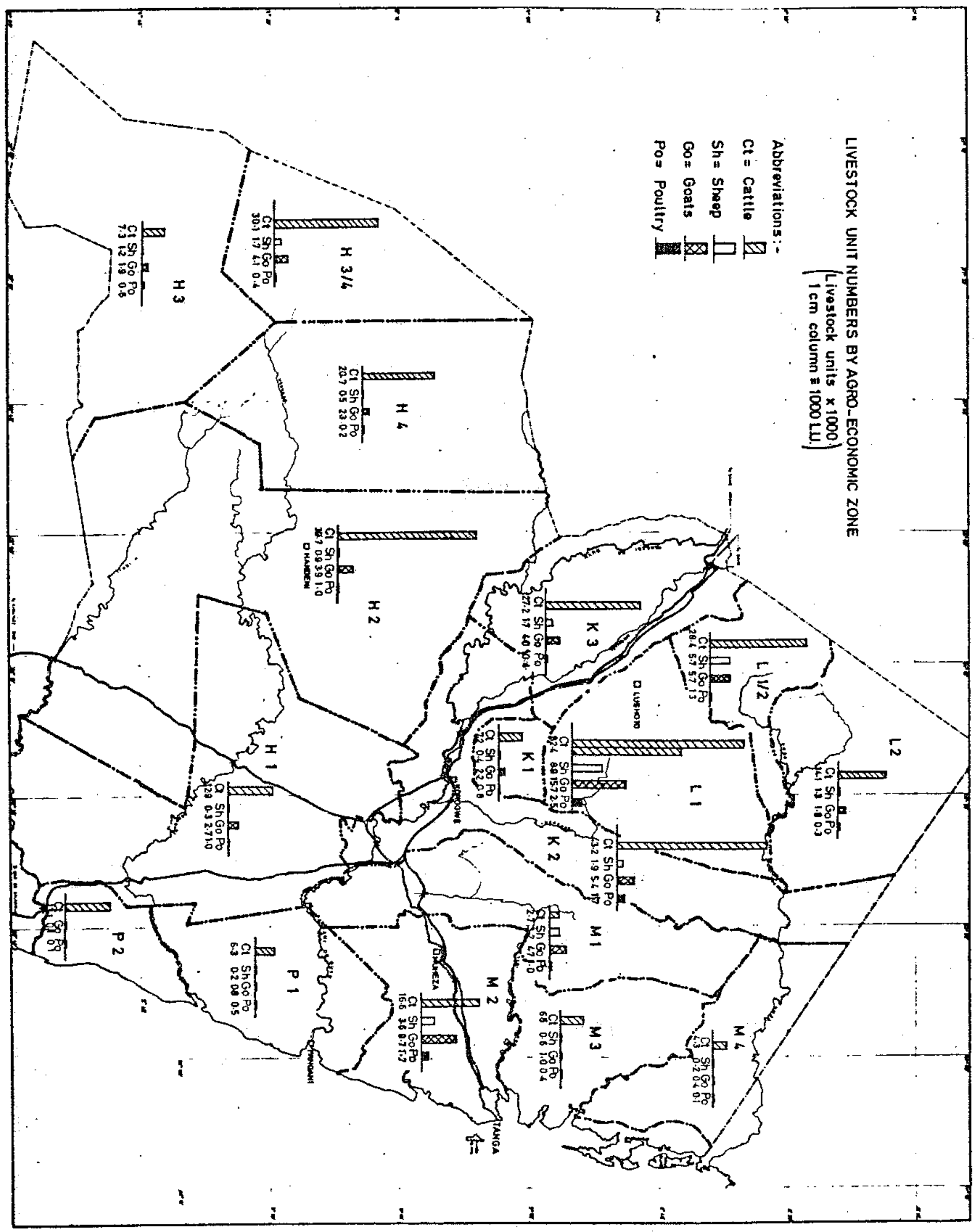


FIG. AG 2-8

Public Land Forests

These forest areas are largely used for the production of firewood and charcoal on a local basis. Some logging is undertaken under permit. Marked reduction in the area of Public Land Forests has occurred over recent years particularly in Lushoto District.

Plantations

There are three major plantation forests in Tanga Region

	Main Species
Shume	Cypress/Pine
Lungara	Teak
Kwamkoro	Hardwood/Teak

Timber Mills

The main units within the region are located at Tanga, Mkumbara, Lushoto, Mombo and Muheza.

2.3.6.2 Forestry Projects

Major projects being undertaken by local or national departments are as follows:

- supply of seedlings to 100 Ujamaa Villages
- afforestation of catchment areas
- plantation extension
- natural regeneration of Magamba forest, Lushoto District

2.3.6.3 Future Developments

There would appear to be considerable scope to increase the value of timber produced in Tanga Region, particularly the veneer types, which could form a valuable export product.

Overall the forests, particularly the public land forest areas, have degenerated significantly over recent years, with consequent effects on climate, erosion in catchment areas and the loss of a potentially valuable product. It is considered that great emphasis should be placed on maintaining and improving the remaining forest areas, and on promoting extensive regeneration or replanting in areas not essential for, or suited to, continuous food crop production.

2.3.7 Game Reserves and Controlled Areas

There are four game reserves or controlled areas lying partly within Tanga Region, which are listed below together with their area within the region.

	Area within Tanga Region sq. km.
Mkomazi Game Reserve	1220
Handeni Controlled Area	3950
Kalimawe Controlled Area	165
Umba River Controlled Area	450
	5785

The game reserves and controlled areas are shown on Present Land Use Map B, Drawing AG 2-6.

2.4 IRRIGATION SCHEMES

Irrigation at present in Tanga Region is of very little importance if compared with rainfed agriculture, the total irrigated area being estimated at some 9,000 ha. In the past only little attention has been given to irrigation development, due to the following (probable) reasons:

1) A large part of the region receives sufficient rainfall for rainfed agriculture, predominantly sisal, tea and coffee. Supplementary irrigation of these estate crops has always been considered infeasible.

2) The major water source of the Region is the Pangani river, but in making use of its water priority has been given to hydropower development instead of irrigation.

3) Most of the potential irrigation areas are almost only suitable for rice cultivation. However, rice is not a local staple food but a rather unimportant cash crop. The incentive to grow rice on a large scale has therefore been absent in the past, but will now be promoted by the Government with improved marketing systems.

Most of the small irrigation schemes which exist at present time or which are proposed in the near future are situated in the Mkomazi valley, the Lwengera valley and along the Umba river and its tributaries. The valley of the lower Pangani river, which has apparent irrigation potentials, is little or not developed. On the slopes of the Usambara Mountains traditional smallholder irrigation has been in practice for a long time.

Irrigation practice in general is rather poor and consists mainly of flooding and furrowing by gravity. Some unsuccessful trials with overhead irrigation were carried out on private tea and coffee estates in the Usambara Mountains. Occasionally sprinkler installations are used on sisal nursery beds, and for vegetable crops in the valley bottoms of the Usambara Mountains.

All the schemes, with exception of the Usambara schemes, are poorly managed and maintained and control structures are in a poor state of operation. A proper water distribution on the fields is almost everywhere missing, partly due to the shortage of field extension officers, partly to lack of funds.

Irrigation in the Usambara Mountains shows better field distribution techniques, but if practised on the steep slopes it causes, however, a tremendous erosion problem.

Drainage and flood protection of irrigated land are in most cases absent or neglected. Reclamation of salt-affected or swampy areas is seldom seen. Successful drainage is practiced in coconut plantations along the tidally influenced Lower Pangani river (reclamation of mangrove areas).

Before the end of the financial year 1974, all irrigation activities were coordinated and supervised by the Water Development and Irrigation Department (W.D. & I.D.) in the Ministry of Water Development and Power, but after that date the Irrigation Department was shifted to the Ministry of Agriculture (Kilimo). Since Kilimo is not quite adapted to the new situation, the Ministry of Water Development and Power (Maji) may still give technical assistance to carry out irrigation works which are now planned and supervised by Kilimo. Files, drawings and historical background of existing projects in Tanga Region can still be found in the office of the Regional Water Engineer in Tanga.

At present, however, the Irrigation Division of Kilimo is strongly understaffed and comprises:

1 Officer in charge of Irrigation for Tanga and Muheza district (he is also a co-ordinator on a regional level)

1 Executive Engineer (Indian Technical Aid) stationed in Tanga

1 Officer in charge of Irrigation for Korogwe district (left in May 1976)

1 Officer in charge of Irrigation for Lushoto district

These officers are responsible for all irrigation projects in the respective districts and are responsible to the Regional Agricultural Development Officer. Moreover a new National Directorate of Irrigation has recently been set up in Dar es Salaam which is to provide the ability and staff to work out project proposals and coordinate all irrigation activities in Tanzania. They also intend to delegate most of the work to the Regions and to appoint a Regional Irrigation Engineer in each of the Regions.

At present no Irrigation Enactment exists in Tanzania and gazetting of irrigation areas cannot be controlled by the law. The legislation of the utilization of public water resources and waterrights is laid down in the Water Utilization Act of 1974 (see also Vol. VII, Sect. 9)!

Once an irrigation scheme has been constructed (mostly with self-help of the local farmers), it is handed over to the users which then bear full responsibility for maintenance of the scheme. For major repairs they can apply for assistance of Kilimo or Maji (situation not yet very clear). New

irrigation schemes are planned and implemented on request of the landowners or users (mostly collective farmers or Ujamaa Villages), whereas the water rights have to be applied for by the District Development Director. These water rights are then allocated by the Ministry of Water Development and Power. During the last years no applications for water rights have been made for individual farmers or pirvate estates.

A brief summary of the most important irrigation schemes and the estimated present water consumption is given in Table AG 2-12. A more detailed description of all existing projects can be found in Technical Report No 20, whereas the location of the existing irrigation schemes is displayed on Drawing AG 2-7.

Estimated present irrigation water consumption by Agro-Economic Zone and by sub-catchment areas is presented in Tables AG 2-13 and AG 2-14 respectively.

Table AG 2-12

REVIEW OF EXISTING IRRIGATION SCHEMES (1974 - 1975)

Name or Site	Location	Agro - Economic Zone	Sub Catch-ment Area	Estimated area under irrigation at present (ha)	Initial proposed area to be irrigated (ha)	Water Source	Major irrigated crops	Estimated annual Water Con-sumption 10^6 m^3
Mkomazi Valley Bendera-Mikocheni	Upper Mkomazi Valley	K_3	PN 2	400	800	Mkomazi River	rice, maize	7.0
Lake Manka Swamp-Majengo	Upper edges of Lake	K_3	PN 2	150	-	Mkomazi River	rice	2.4
Mazinde	Mkomazi Valley	K_3	PN 3	120	-	Mkomazi River	rice	2.0
Mombo Irrigation Scheme	Mkomazi Valley	K_3	PN 3	240	240	Soni river	rice, maize	3.3
Kwesasu - Kidundai	Mkomazi Valley	K_3	PN 3	200	200	Soni river	rice, maize bananas	4.0
Checkelei Irrigation Scheme	Mkomazi Valley	K_3	PC 6	110	110	Vuruni river	rice	2.2
Kwamngumi	At Pangani river near Korogwe	K_2	PC 6	60	160	Pangani river	rice fishponds	4.3
Mahenge	Lwengera Valley	K_2	PN 8	160	280	Nkole river	rice bananas	3.9
Kizara	Bombo-Majimoto (Footslopes Eastern Usambaras)	K_2	VM 4	80	80	Bombo tribu-tary	rice	1.1
Kwemazandu	Lwengera Valley	K_2	PN 8	70	70	Lwengera river	rice	1.7

Table AG 2-12 (contd.)

Name or Site	Location	Agro - Economic Zone	Sub Catch-ment Area	Estimated area under irrigation at present (ha)	Initial proposed area to be irrigated (ha)	Water Source	Major Irrigated Crops	Estimated annual Water Con-sumption 10^6 m^3
Kerenge Mfunte	Lwengera Valley	K_2	PN 8	80	80	Lwengera	rice bananas	1.6
Pangadeco	Lower Pangani Valley	P_1	PC 9	25	50	Pangani river	rice bananas	0.2
T.C.U.[1)]	Lower Pangani Valley	P_1	PC 9	10	20	Pangani river	rice	0.1
Mnazi Irrigation Scheme	Bordering Mkomazi Game Reserve	L_2	UM 1	200	250	Mbaluma river	rice	3.8
Mnazi Village	Bordering Mkomazi Game Reserve	L_2	UM 1	150	200	Shengui	rice	2.8
Kivingo-Antakae	Bordering Mkomazi Game Reserve	L_2	UM 1	200	200	Mbaluma	rice	3.8
Kitivo Irrigation	Upper Umba Flood plain	$L_2,L_{1/2}$	UM 2	320	480	Umba river	rice maize	10.4
Lunguza	Upper Umba Flood plain	L_2	UM 2	300	300	Umba river	rice maize	5.4
Usambara Irrigation complex	Mainly western Usambaras	$L_1,L_{1/2}$	2)	6,500	-	various rivers	vegetables potatoes bananas	43.0
Mwakijembe Irrigation Scheme	Mwakijembe village	M_4	UM 6	-	45	Umba river	maize	-
Misoswe Irrigation Scheme	Footslopes of Eastern Usambaras	M_2	SI 3	-	150	Mruka	mixed cropping	-
Amboni	Lower Sigi	M_3	SI 4	-	80	Sigi river	rice	-
			Totals	9,375				103.0

1) Tanga Co-operative Union

2) UM 1, UM 2, PN 4, PN 6, PN 7.

Table AG 2 - 13 ESTIMATED PRESENT IRRIGATION WATER CONSUMPTION PER AGRO-ECONOMIC ZONE (AS PER 1975)

Agro-Economic Zone	Water Consumption In $m^3 \times 10^6$ per year	Area under irrigation In Ha
K2	12.6	450
K3	20.9	1,220
P1	0.3	35
L1	36.0	5,400
L1/2	12.2	1,260
L2	21.0	1,010

Table AG 2 - 14 ESTIMATED PRESENT IRRIGATION WATER CONSUMPTION PER SUB-CATCHMENT AREA (AS PER 1975)

Sub-Catchment Area	Water Consumption In 10^6 m^3 per year	Area under irrigation In Ha
PN 2	9.4	550
PN 3	9.3	560
PN 4	18.0	2,700
PN 5	2.2	110
PN 6	10.8	1,650
PN 7	4.0	600
PN 8	7.2	310
PC 6	4.3	60
PC 9	0.3	35
UM 1	10.6	600
UM 2	25.8	2,120
UM 4	1.1	80

2.5 DROUGHT ANALYSIS

2.5.1 General

Although annual rainfall can be fairly high, agricultural activities in Tanga Region are very much hampered by severe moisture deficiencies during the growing season of a particular crop. Rainfall must be considered as the most important input to the agricultural system. However, not the mean rainfall, but the distribution of rainfall over the growing season determines to a large extent the sucessfulness of a particular rainfed crop growth.

Impact of drought and rainfall distribution and its consequences for agricultural activities have therefore been studied by analysing the daily rainfall pattern and the frequency of dry spells, details of which are presented in Technical Report No. 19 entitled "Analysis of Drought".

Within the scope of the Tanga Water Master Plan, this drought analysis aimed in the first place at providing useful information for better land use planning. In addition, the drought study may be considered as a first attempt to indicate some human adjustments to drought and the possibilities of drought evasion (see also chapter 3.3).

Finally the so obtained information could be used in defining some major agro-climatic zones in the Region (see chapter 2.6).

For the purpose of this Study, a distinction has been made between meteorological and agricultural drought.

The first one refers exclusively to the length and frequency of dry spells, without any regard to water requirements of plant and animal. Agricultural drought refers to direct soil moisture stress in the rooting zone of a particular crop and is usually expressed in terms of crop failure or yield reduction. The latter is considered as a reliable drought indicator of the agricultural system.

2.5.2 Meteorological Drought

Frequency analysis of dry spells during the average potential growing season (defined as total year less significant driest months) were carried out for 18 rainfall stations in Tanga Region and one in Kilimanjaro Region (Same).

Table AG 2-15 ANNUAL RAINFALL VARIABILITY

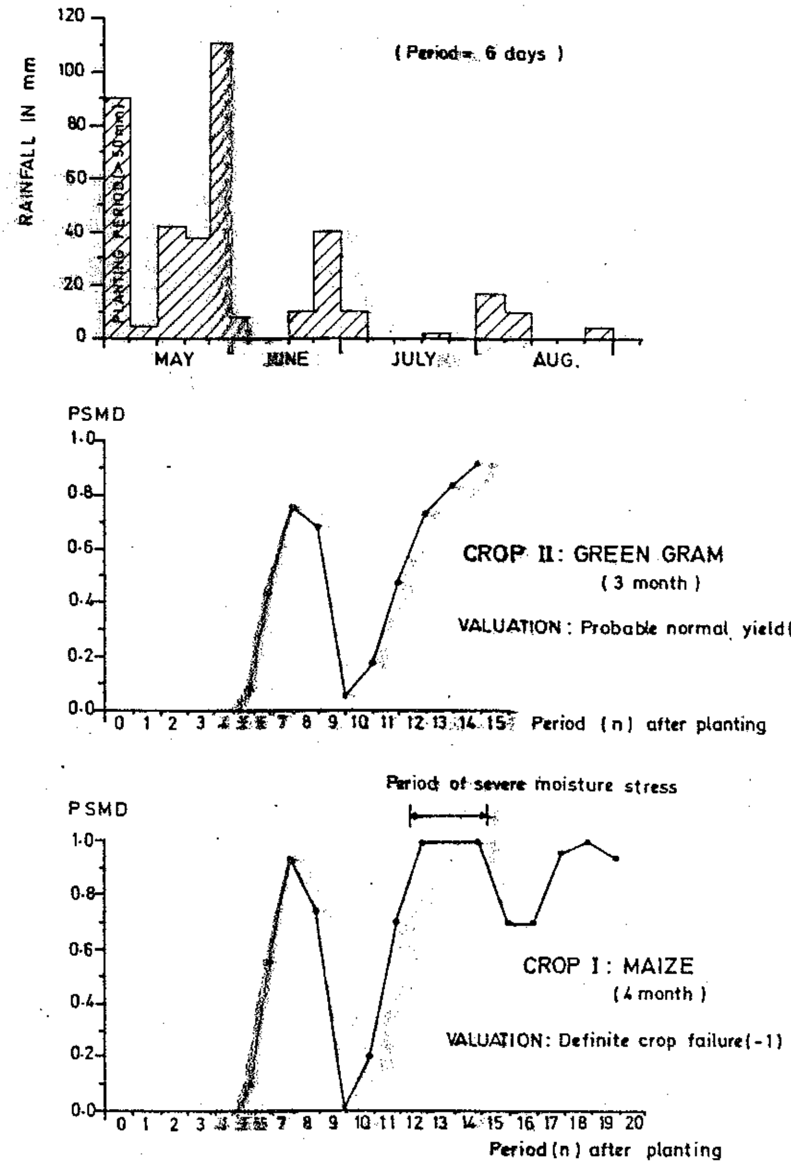
Station	Ref.	Years	P_{75} mm	P_{50} mm	P_{25} mm	Variability* %	A.E. Zone
Amani	9538 003	66	2200	1900	1600	15.8	M1
Ambangulu	9538 004	45	2460	2000	1620	20.6	K1
Amboni	9539 010	25	1400	1085	865	23.6	M3
Balangai	9438 002	53	2070	1580	1250	24.7	L1
Gonja	9438 011	35	1065	808	732	18.5	Kilimanjaro
Hale	9538 010	39	1400	1185	975	17.9	K2
Handeni	9538 007	47	1040	835	646	23.4	H2
Hekulu	9438 028	23	1620	1270	1020	22.7	L1
Karimi	9538 013	40	1600	1300	1100	18.5	K2
Kigombe	9539 009	36	1500	1250	965	21.7	M2
Kikwajuni	9438 021	29	890	655	570	21.9	K2
Kiwanda	9538 025	31	1440	1245	1065	14.9	P1
Korogwe	9538 008	40	1380	1080	815	25.7	K2
Kwamdulu	9538 020	37	1220	980	780	22.0	K2
Kwamgwe	9538 032	21	1500	1200	960	22.0	H1
Kwamkoro	9538 014	40	2500	2200	1900	13.6	M1
Kwashemshi	9538 012	30	1320	1050	850	21.7	K1
Lushoto	9438 003	53	1280	1070	970	13.8	L1
Lwandai	9438 001	26	1480	1170	880	25.4	L1/2
Lwengera	9538 030	20	1470	1015	860	26.2	K2
Mabogo	9438 020	25	736	606	524	16.8	K3
Magamba	9438 013	38	1170	1040	900	13.0	L1
Magoma	9438 016	25	915	680	604	20.4	K2
Magunga	9538 015	43	1600	1300	1045	21.0	M1
Makinyumbi	9538 019	37	1490	1240	1010	18.5	H1
Mandera	9538 017	33	1140	865	690	24.6	K2
Malindi	9438 024	27	770	620	530	18.5	L1/2
Mazinde S.E.	9438 018	24	1080	900	660	24.1	K2
Mazinde Fac.	9438 019	41	940	750	570	24.5	K2
Mazumbai	9438 023	40	1600	1315	1070	19.8	L1
Mswaha	9538 033	22	1105	870	648	26.1	K2
Mtotohovu	9439 006	45	1180	1085	820	18.0	M3
Muheza S.E.	9538 028	22	1400	1140	890	22.2	M2
Muheza M.L.	9538 029	22	1415	1120	1010	16.7	M2
Mwambani	9539 019	22	1410	1140	870	23.7	M2
Mwele	9438 025	22	1515	1240	1045	18.4	M1
Mwera	9538 022	37	1425	1141	948	20.1	P1
Ngaraya	9538 002	40	1970	1770	1260	21.9	K1
Ngombezi	9538 018	35	1295	1020	800	23.6	K2
Ngomeni	9538 011	39	1340	1180	940	17.5	M2
Pangani	9538 006	58	1460	1190	1020	17.7	P1
Pongwe S.E.	9538 021	37	1350	1165	920	18.9	M2
Sakura	9538 009	48	1285	1160	940	15.5	P1
Shume	9438 012	45	860	745	660	13.2	L1/2
Tanga	9539 000	68	1570	1330	1070	18.1	T
Tanga Airport	9539 015	21	1550	1175	940	24.5	T

* Variability = $\frac{P_{75} - P_{25}}{P_{75} + P_{25}} \times 100$

FIG. AG 2-3 SIMULATION OF SOIL MOISTURE DEPLETION
(EXAMPLE FOR PONGWE RAINFALL STATION)

YEAR: 1938
PLANT DATE: FIRST PERIOD OF MAY (MAY 1)
MOISTURE HOLDING CAPACITY OF SOIL: 50 mm/100 cm DEPTH (SOIL I)

PSMD = $\frac{\text{SOIL MOISTURE DEPLETION}}{\text{MAXIMUM POSSIBLE MOISTURE DEPLETION}}$



The analysed stations were classified according to their relative drought hazard and 3 classes were distinguisted:

Class 1 : Relatively low hazard of meteorological drought with low to moderate annual rainfall variability. Moderate to good possibilities for rainfed arable crops.

Class 2 : Relatively moderate hazard of meteorological drought, with moderate to high annual rainfall variability. Poor to moderate possibilities for rainfed arable crops, especially on light textured soils.

Class 3 : Relatively high hazard of meteorological drought, with high annual rainfall variability. Poor possibilities for rainfed arable crops, with regular total crop failures.

Class boundaries were then compiled by inter- and extra polation and are displayed on Drawing AG 2-8.

For this purpose, use was also made of information on annual rainfall variability, as presented in Table AG 2-15 for stations which have more than 20 years of records. It must be noted that clan boundaries in the Handeni area are the least reliable ones, due to lack of adequate information.

2.5.3 Agricultural Drought

The impact of agricultural drought has been analysed by simulating soil moisture depletion in the rooting zone for a particular crop.

Daily rainfall records of 16 stations were used as stochastic input to the simulation model, which has the following variables.

- Crops (growing cycle and root depth)
- Soil characteristics (moisture holding capacity)
- Crop water requirements (consumptive use)

It was assumed that, more or less according to local practice, a crop will generally be planted or sown after a 3-days rainfall exceeding a threshold of 50 mm (further called potential plant event). Simulation of agriculture drought (expressed in soil moisture deficiency) was then carried out for all recorded potential plant events (See Technical Report No. 19).

An example of such a similation process is presented in Fig. 2-9, based on data from Pongwe rainfall station.

In order to quantify the impact of drought on crop production, the soil moisture deficiencies (or stress) obtained by simulation were translated into terms of expected crop yields. For the sake of simplicity only 3 possible valuations were distinguished:

1) definite crop failure (-1)
2) probable yield reduction (0)
3) probable normal yield (+1)

To each case of soil moisture stress simulation one of the 3 possible valuations was allocated and results were grouped together by equal planting periods. For this purpose the year was divided into 60 periods of 6 days each.

In Map Drawing AG 2-9, entitled "Impact of Agricultural Drought", the evaluated results are summarised and presented in a graphical form per Agro-climatic zone (Agro-climatic zones are defined and described in the next chapter).

Distinction has been made between the major and second potential plant season. A potential plant season has arbitrarily been defined as a sequence of periods (of 6 days) with significantly more potential plant events than the rest of the year. The major plant season very often coincides with the main rainy season.

In Drawing AG 2-9 the average number of potential plant events for both potential plant seasons is represented by the height of the columns. The average number of definite crop failures (-1) are indicated as a percentage of the total column height (hatched). The absolute length of the remaining white (non-hatched) part of the column is a relative measure for the impact of drought on the agricultural activities.

A few general conclusions can be drawn from the foregoing study:

- beans or green grams have always a lower risk of crop failures than maize, if grown on the same type of soil

- risk of crop failure on soils with low water holding capacity is always higher than on soils with higher water holding capacity, if the same crop is grown

- optimum planting period for maize falls earlier than for beans or grams

- beans and grams can often still be grown at the end of the rainy season

- possibilities of growing maize in the second short rainy season are often very poor, whereas possibilities for beans and grams are fairly good in both seasons.

- rainfall in most of the Tanga Region is too erratic for regular and proper cultivation of maize. More drought tolerant crops (like sorghum and millet) should replace the less drought tolerant maize in some low rainfall areas.

- planting outside the potential plant season has a remarkably low risk of crop failures. However potential plant events outside the seasons only occur unexpectedly and irregularly so that the farmer cannot rely on them.

2.6 AGRO-CLIMATIC ZONES

Significant differences in climatological characteristics can be found all over the Tanga Region. Subsequently it was felt useful to distinguish some major climatic zones.

In defining the different zones emphasis has been given to agricultural aspects of the climate such as moisture deficit, water requirements of crops and rainfall distribution (drought).

The agro-climatic zones therefore were defined on the basis of (in order of importance) the following criteria.

1. Evapotranspiration deficit
2. Annual rainfall
3. Rainfall variability and drought hazard
4. Temperature
5. Physiography
6. Vegetation and field checks

The zones distinguished are briefly described below: (Figures between brackets indicate the mean annual rainfall range and temperatures indicated represent mean monthly values).

1. <u>Coastal Belt</u> (1200 - 1300 mm)

A small strip along the coast with significantly higher rainfall and slightly higher evapotranspiration than the adjacent foothills.

Maximum temperature : $28^{o}C$ (March)
Minimum temperature : $24^{o}C$ (July-August)

Köppen-Geiger[1] : A_w Climate

Rainfall surpluses occur during the main wet season (April-May), but supplementary irrigation is still required if cropping in the drier seasons is contemplated.

Main crops at present : Coconut and Sisal
Altitude range : 0 - 50 m

Impact of rainfall distribution and drought on rainfed agricultural activities:

- meteorological drought hazard is moderate

- <u>moderately</u> suited for maize and very <u>well</u> suited for pulse crops[2] (like grams, peas) if planted from end of March - beginning of May

- <u>lowly</u> to <u>moderately</u> suited for pulse crops in second rainy season (planting from end-October to end-November) but <u>no possibilities</u> for second maize crop (probability of crop failure almost 100%)

- light textured sandy soils <u>well</u> suited for pulse crops in main season (end of March - beginning of May) of low risk of crop failure, but <u>little</u> suited for maize in main season.

2. <u>Coastal Upland</u> (900 - 1200 mm)

Comprises partly the footslopes of the eastern Usambaras and part of coastal plain, which extends in the south parallel to the coast line. Seasonal variations of rainfall and temperature are lower than in the Coastal Belt, whilst relative humidity is higher.

Maximum temperature : $27.5^{o}C$ (March)
Minimum temperature : $23.2^{o}C$ (July-August)

Rainfall surpluses in the rainy season (April-May) are insufficient to cover the evapotranspiration deficit in the drier periods (highest deficit in January).

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1) Climatological classification according to Köppen and Geiger.

2) Pulses may be considered as representative for a group of early maturing drought resistant crops.

Main crops at present : Sisal, Coconuts and Maize
Altitude range : 20 - 300 m

Impact of rainfall distribution and drought on agricultural activities:

- meteorological drought hazard is moderate to low
- moderately suited for maize and well suited for pulse crops if planted from beginning of April to mid-May
- little suited for pulse crops in second rainy season, but no possibility for second maize crop (100% risk of crop failure)
- light textured sandy soils moderately suited for pulse crops in main season (planting end of Arpil to mid-May) because moderate risk of crop failure, but little suited for maize in main season (because of moderate to high risk of crop failure).

3. Eastern Usambara (1200 - 2000 mm)

This zone comprises the highland and the footslopes of the eastern Usambara Mountains, receiving very high rainfall on the eastern windward slopes. Low annual rainfall variability.

Maximum temperature : 22.6°C (February)
Minimum temperature : 18.1°C (July-August)

Very high relative humidity (86% in May).
High rainfall surpluses occur in both wet seasons, and only January and February have small evapotranspiration deficits, which can easily be covered by the preceding surplus.

Köppen-Geiger : A_f Climate (tropical rain forest)

Main crops at present : Sisal, Cashew, Tea
Altitude range : 300 - 1300

Impact of rainfall distribution and drought on agricultural activities:

- very low to low hazard of meteorological drought
- very well suited for both maize and pulse crops if planted from April to end of May.
- moderately well suited for maize and well suited for pulse crops if planted in first half of November

- well suited for maize and very well suited for pulse crops on light textured sandy soils, if planted from April to end - May.
- light textured sandy soils in the second season (November) only moderately well suited for pulse crops
- rainfall distribution in the highlands (near Amani) is so optimal that it is very well suited for all relevant types of annual and perennial crops (tree crops)

4. Central Usambara (1200 - 2000 mm)

This zone comprises the highlands and part of the foot-slopes of the central Usambara mountains.

The zone has similar characteristics as the previous one, but seasonal rainfall variations are much higher (mean monthly rainfall in May is 360 mm).

Köppen-Geiger : A_f Climate (tropical rain forest)

Main crops at present : Maize, Coffee, Tea
Altitude range : 400 - 1800 m

Impact of rainfall distribution and drought on agricultural activities:

- moderate hazard of meteorological drought
- well suited for maize and very well suited for beans and vegetables if planted in April - May.
- moderately well suited for maize and beans in second rainy season (October - November)
- moderately to well suited for maize and beans on light textured sandy soils in main season (planting April to end of May)
- low suitability for maize and beans on light textured soils in second season
- rainfall distribution is less favourable for perennial crops than in the Eastern Usambara Zone.

5. Western Usambara (800 - 1200 mm)

This zone covers the greatest part of the Usambara mountains. Due to its mountainous character, this zone has great local differences in rainfall. The average rainfall is however much lower then in the previous zone and it has a well pronounced dry season from June to November with a high evapotranspiration deficit. Irrigation is indispensible, if crops are grown in this season.

Köppen-Geiger : A_w Climate

Main crops at present : Maize, Potatoes, Vegetables
Altitude range : 500 - 2500 m

Impact of rainfall distribution and drought on rainfed agricultural activities:

- moderate to high hazard of meteorological drought
- very low suitability for maize, beans or vegetables if planted in main rainy season (April), because of very high risk of crop failures (based on Malindi rainfall station only)
- little suited for beans and vegetables if planted in second season (December)
- possibilities of cropping on light textured sandy soils are nil.
- moderately well suited for sorghum and millet if planted in December

N.B. Rainfall in the vicinity of Mlalo (Lwandai) is significantly higher, with subsequent slightly lower risks of crop failures

6. Usambara Footplains (800 - 1100 mm)

This zone south of the Usambaras (including the Lwengera and part of the Mkomazi Valley) is somewhat drier than the Western Usambaras and the coastal Upland. It is typical sisal area, although the evapotranspiration deficit can be fairly high. Annual rainfall variability is moderate and humidity is relatively low. Double cropping only possible with irrigation.

Maximum temperature : 27.3°C (March)
Minimum temperature : 22.3°C (July)

Köppen-Geiger : A_w Climate

Main crops : Sisal, Maize
Altitude range : 300 - 700 m

The zonal boundary in North-West Handeni could not be properly defined, because of insufficient data.

Impact of rainfall distribution and drought on rainfed agricultural activities:

- moderate to high hazard of meteorological drought
- well suited for maize and very well suited for pulse crops, if planted from April - end May.
- little suited for beans and very little suited for maize in second rainy season (end October - end November)
- light textured sandy soils little suited for maize well suited for pulse crops and moderately well suited for sorghum and millet in main season (mid April - end May)
- very little possibilities for crops on light textured soils in second rainy season

7. Mkomazi (300 - 700 mm)

This zone in the rain shadow of the central Usambaras receives the least rainfall of the Tanga Region. The high evaporative demand of the air causes extremely high evapotranspiration deficits throughout the whole year (over 1000 mm annually) and a semi-desert vegetation can be seen in this zone. Crop production is only possible if practised on suitable soils under irrigation.

Maximum temperature : 27.5°C (February)
Minimum temperature : 22.3°C (July)

Köppen-Geiger : BW - BS Climate (desert-steppe climate)

Main crops at present : Maize (Rice on valley bottoms)
Altitude range : 500 - 600 m

The zonal boundary in the south could not be properly defined.

Impact of rainfall distribution and drought on rainfed agricultural activities:

- very high hazard of meteorological drought
- no possibilities for pulse crops and maize
- very little suited for sorghum and millet

8. Umba Steppe (500 - 700 mm)

Located north of the Usambaras, this zone also consists to a large extent of rainsadow areas of the Usambaras. Rainfall is somewhat higher than in the Mkomazi zone, but annual variability is very high as well. It has a real steppe vegetation, where grass only grows after the rains. There is an evapotranspiration deficit throughout the whole year, and irrigation requirements therefore can be very high. Crop production without irrigation is almost impossible.

Maximum temperature : 27.5°C (March)
Minimum temperature : 23.2°C (July-August)

Köppen-Geiger : BS Climate (steppe)

Altitude range : 150 - 500 m

Impact of rainfall distribution and drought on rainfed agricultural activities:

- high hazard of meteorological drought
- no possibilities for maize and very little suited for pulse crops (planting end of November or May)
- little to moderately suited for sorghum and millet in May on the northern footslopes of the Usambaras (where rainfall is slightly higher)

9. Central Handeni (700 - 1000 mm)

An extensive high plateau with important differences in micro-relief. Rainfall during the main wet season is sometimes sufficient for rainfed farming, but double cropping definitely requires irrigation. The zone has a distinct boundary in the east, viz. parallel to the escarpment towards the coastal zone. The north and north-west boundary is not well defined due to lack of data.

It has a woodland and savannah vegetation; temperatures are somewhat lower than in the coastal zone.

Maximum temperature : 26.4°C (February-March)
Minimum temperature : 21.4°C (July)

Köppen-Geiger : A_w Climate

Main crops at present : Maize, Grams
Altitude range : 300 - 1000 m

Impact of rainfall distribution and drought on rainfed agricultural activities:

- moderate to high hazard of meteorological drought
- very little suited for maize and little suited for pulse crops if planted from mid-March to end-May
- little suited for pulse crops in second rainy season (November), but no possibilities for maize
- moderately well suited for sorghum and millet if planted in March
- little to moderately suited for pulse crops on light textured sandy soils if planted from March - April.

10. Nguru Highlands (700 - 1200 mm)

This zone comprises the eastern part of the Nguru mountain complex where rainfall is higher and evapotranspiration somewhat lower that in Central Handeni, resulting in lower deficits. In contrast to other zones in the Tanga Region, the rainy season starts in December and lasts about until May, the months January and February receiving fairly good rainfall as well (due to the "Kaskazi" winds blowing from a north-east direction and causing cloud formation at the eastern slopes of the highlands). Local differences in rainfall occur because of its mountainous character.

Maximum temperature : 24.1°C (February)
Minimum temperature : 19.3°C (July)

Köppen-Geiger : A_w Climate

Main crops : Maize, Beans
Altitude range : 1000 - 1500 m

Impact of rainfall distribution and drought on agricultural activities:

- moderate hazard of meteorological drought
- very little suited for maize and moderately well suited for beans and vegetables if planted in February
- little suited for maize and beans if planted in second half of November
- moderately suited for sorghum and millet if planted in February - March
- light textured sandy soils only moderately well suited for beans and vegetables if planted in February - March
- rainfall distribution in the highest part of the mountains (in the surroundings of Lulago) is favourable for perennial and tree crops

11. Western Handeni (600 - 800 mm)

This zone in the very remote western part of Handeni is not very accurately defined, since all data here are extrapolated from adjacent zones. Annual rainfall however is lower than in the Nguru highlands, and an evapotranspiration deficit occurs throughout the whole year.

Maximum temperature : 25.6°C (February)
Minimum temperature : 20.4°C (July)

Köppen-Geiger : BS A_W Climate

Main crops at present : Maize, Beans
Altitude range : 300 - 1000 m

Impact of rainfall distribution and drought[1] on agricultural activities:

- little suited for maize and beans if planted in November-December
- very little possibilities for maize and beans in second season (planting end of March to end of April)
- moderately suited for sorghum and millet if planted in November

1) Drought analyses of Same (Kilimanjaro Region) have been considered as the most representative for this zone.

The agro-climatic zones are presented on Drawing AG 2-10. Mean monthly rainfall, potential evapotranspiration, temperature and relative humidity are displayed for each zone as well on the same map. The values were compiled from the following rainfall and meteorological stations:

No.	Zone	Rainfall Stations	Meteorological Stations
1	Coastal Belt	Tanga, Sakura	Tanga
2	Coastal Foothills	Mtotohovu, Muheza, Hale	Mlingano
3	Eastern Usambaras	Amani, Mwele	Amani
4	Central Usambaras	Mzundai, Balangai Ambangulu	Amani
5	Western Usambaras	Lwandai, Shume, Lushoto	Amani
6	Usambara Footplains	Mazinde, Mandera Lwengera	Mombo
7	Mkomazi	Buiko, Maboga	Kalimawe Mombo
8	Umba Steppe	Mnazi, Magoma, Mwakijembe	Kalimawe
9	Central Handeni	Mzundu, Handeni, Mgera	Same, Mombo
10	Nguru Highlands	Mgera	Same, Amani
11	Western Handeni	(Kwekivu), Mgera	Same