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
TR	11	Wells Finished Until March 31st, 1976
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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LIST OF DRAWINGS (in back pocket)

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.

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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 $S_{y.x}$ (mm/day)
			s_x (mm/day)	s_y (mm/day)	a	b	
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.

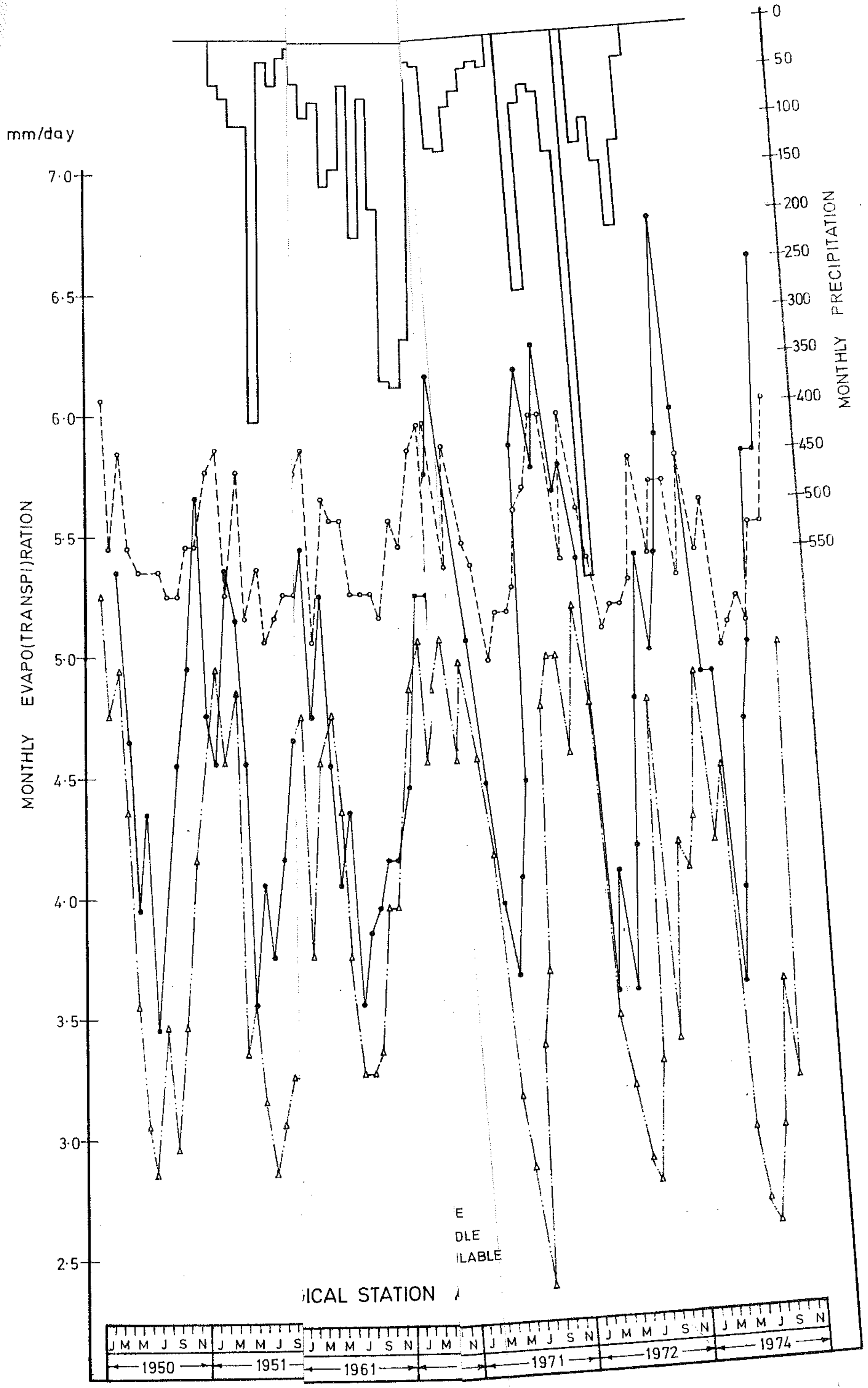
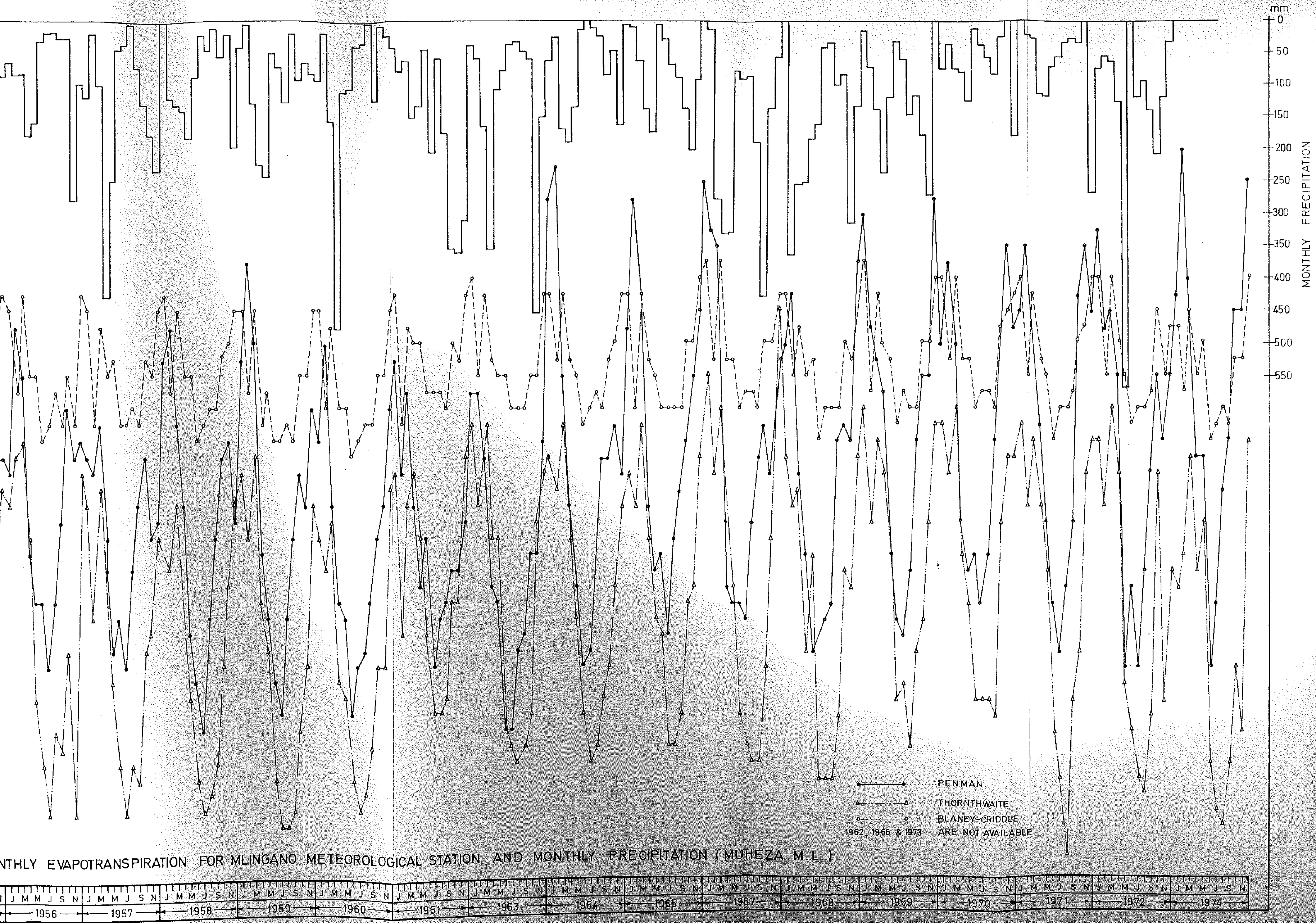
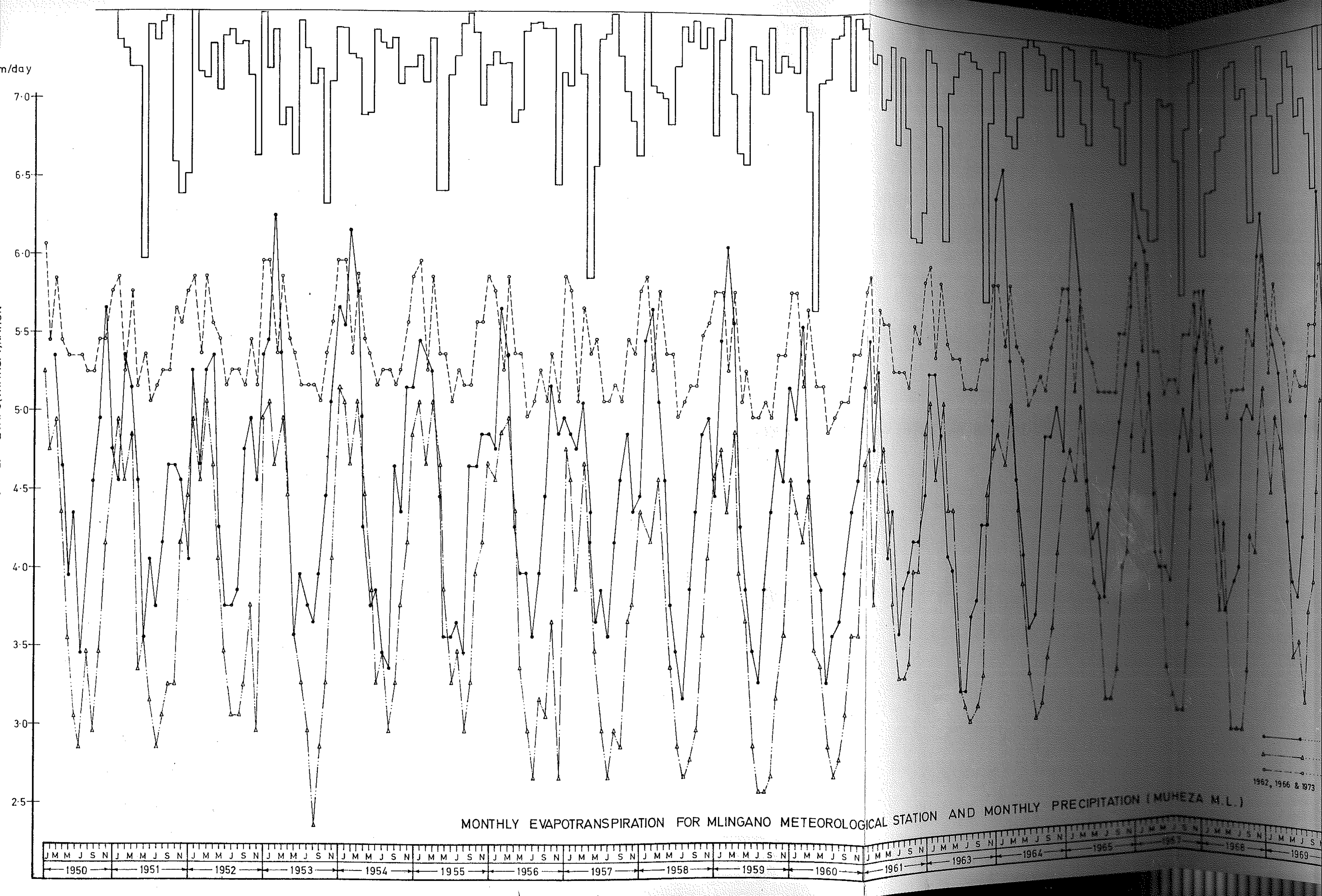


FIG. AG



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°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)

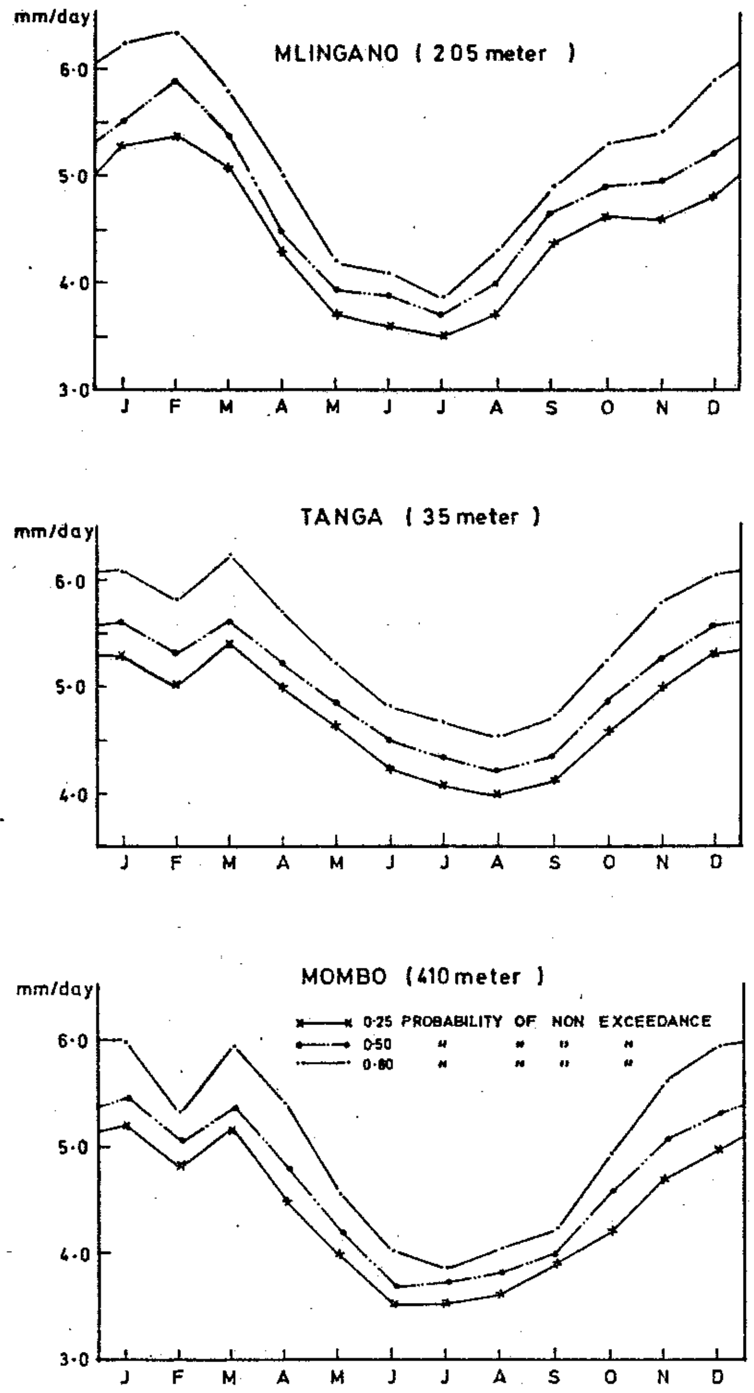


FIG.AG 2-2A

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)

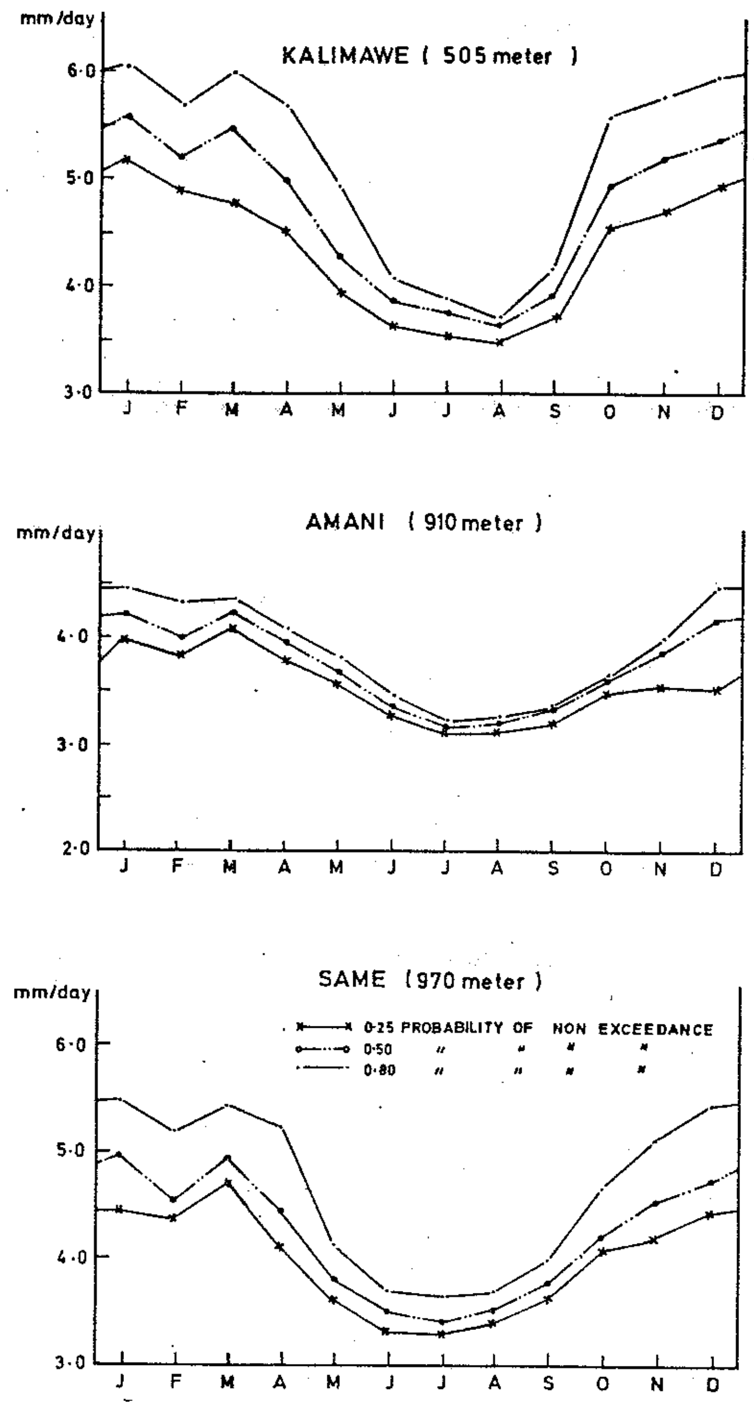


FIG.AG 2-2B

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				2 DAYS				3 DAYS			
			Return period in years				Return period in years				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)

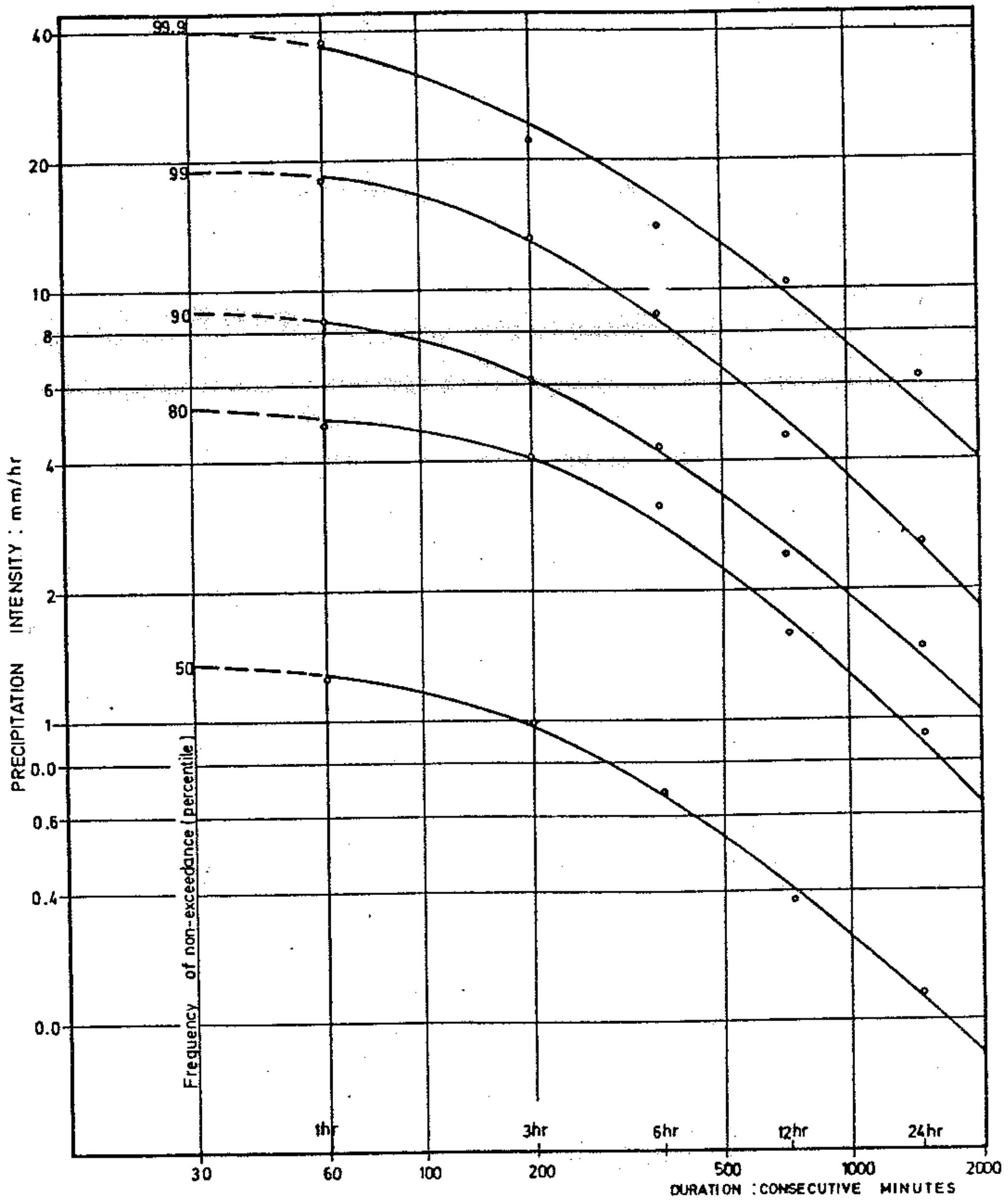
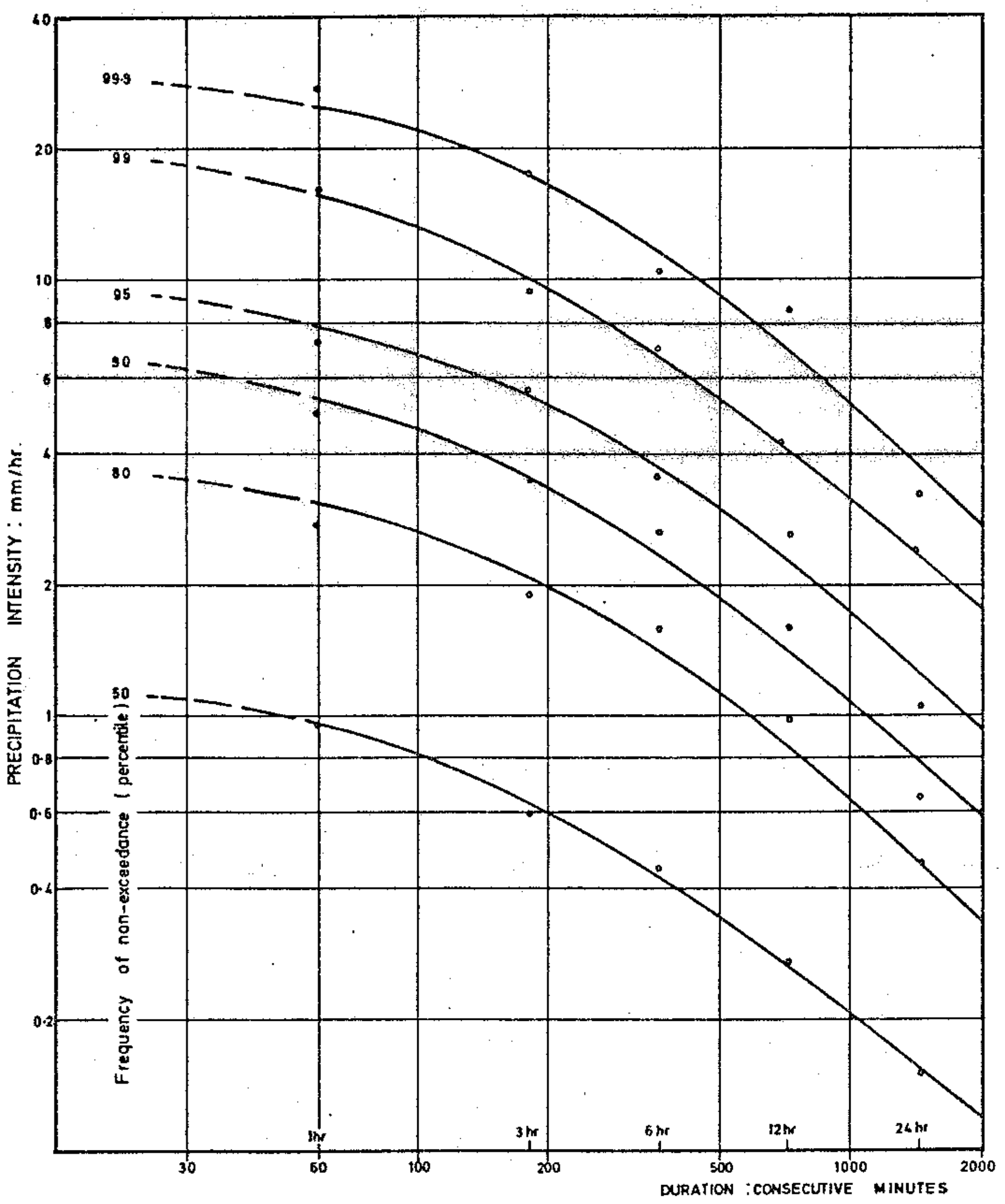


FIG.AG 2-4 PRECIPITATION INTENSITY—DURATION—FREQUENCY AT MOMBO (1972-1975)



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[1] Crop Area	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.

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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.

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

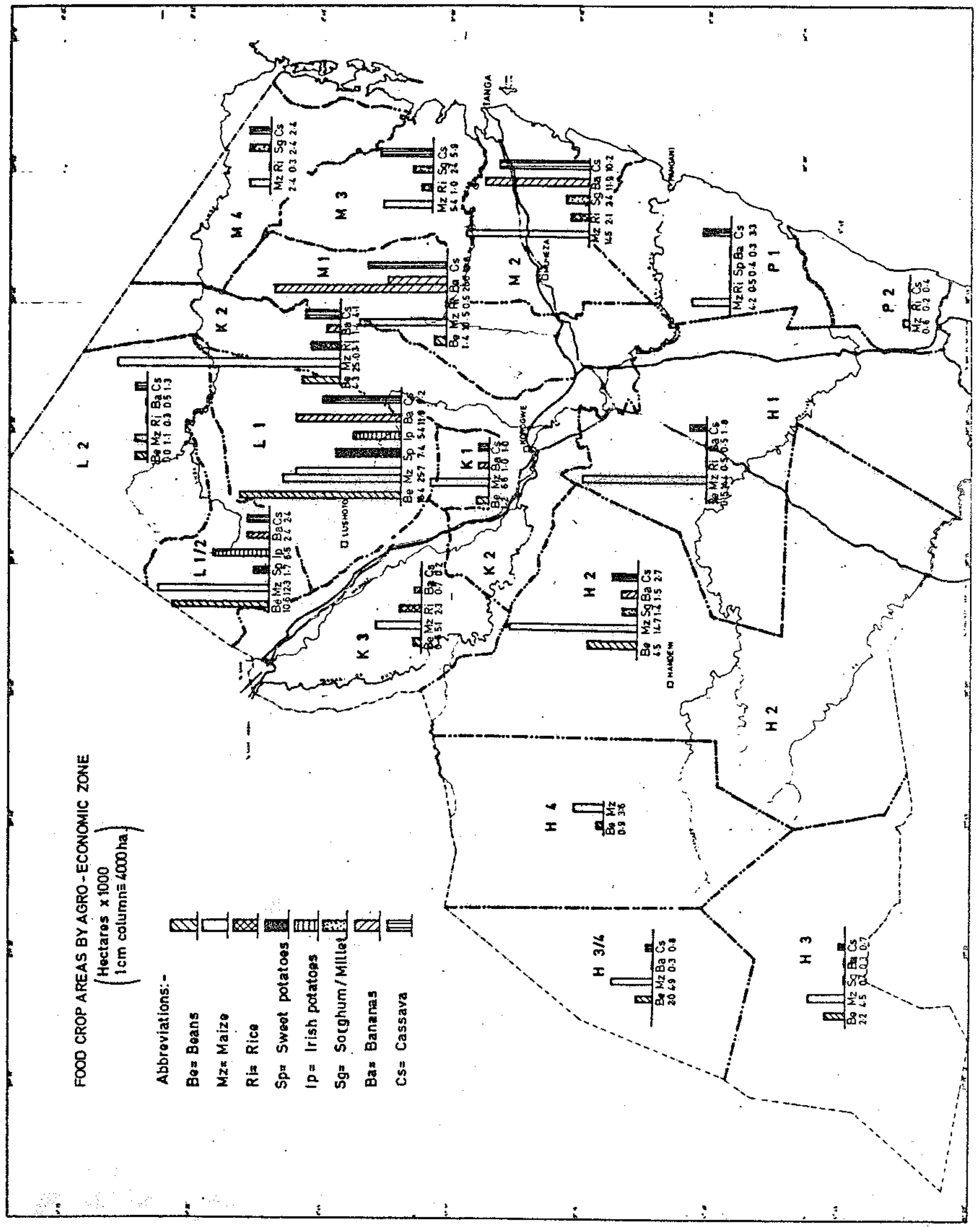


FIG. AG 2-5

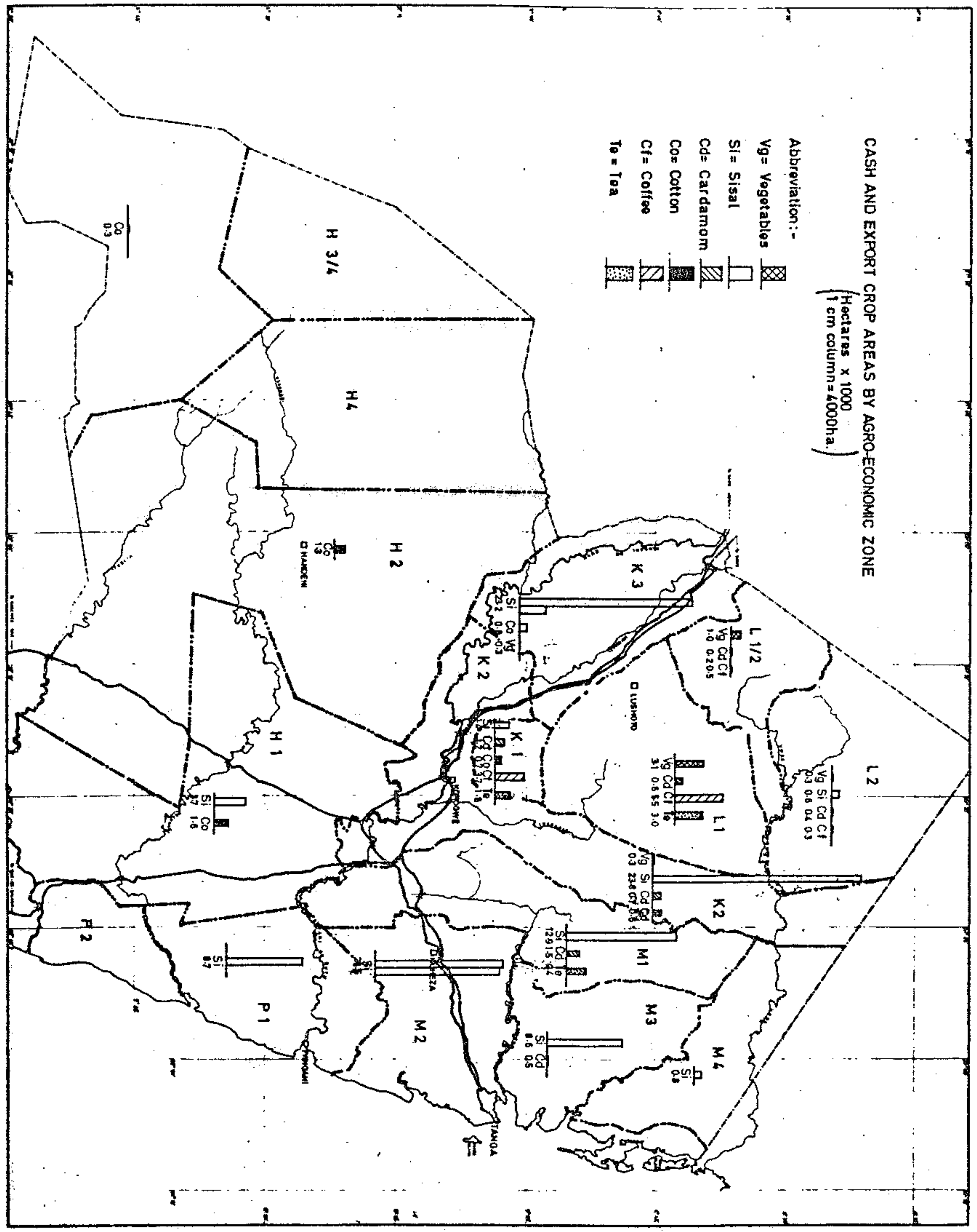

CASH AND EXPORT CROP AREAS BY AGRO-ECONOMIC ZONE
(Hectares x 1000
1 cm column = 4000ha.)

FIG. AG. 2- 6

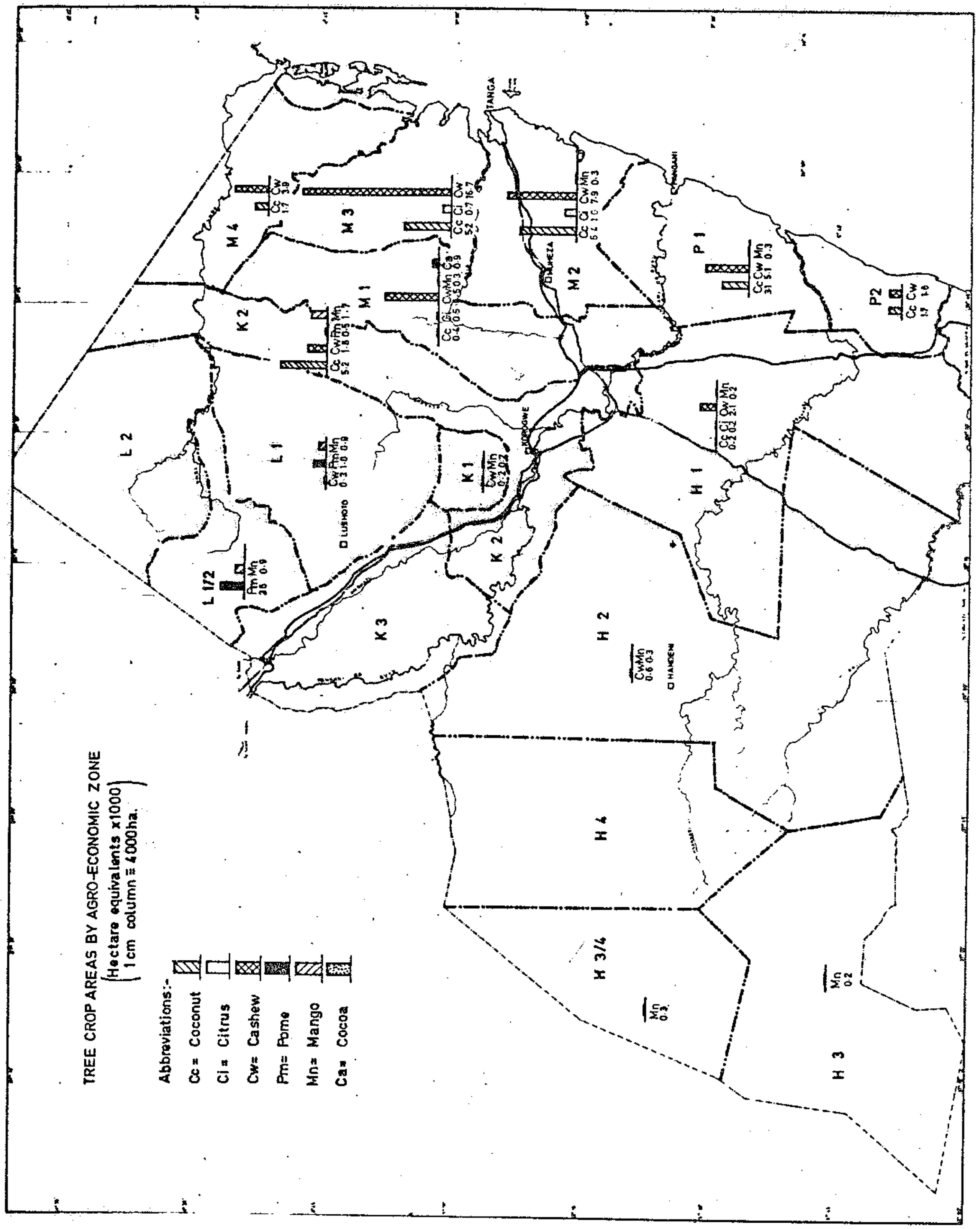

TREE CROP AREAS BY AGRO-ECONOMIC ZONE
(Hectare equivalents x1000
1cm column = 4000ha.)

FIG. AG 2-7

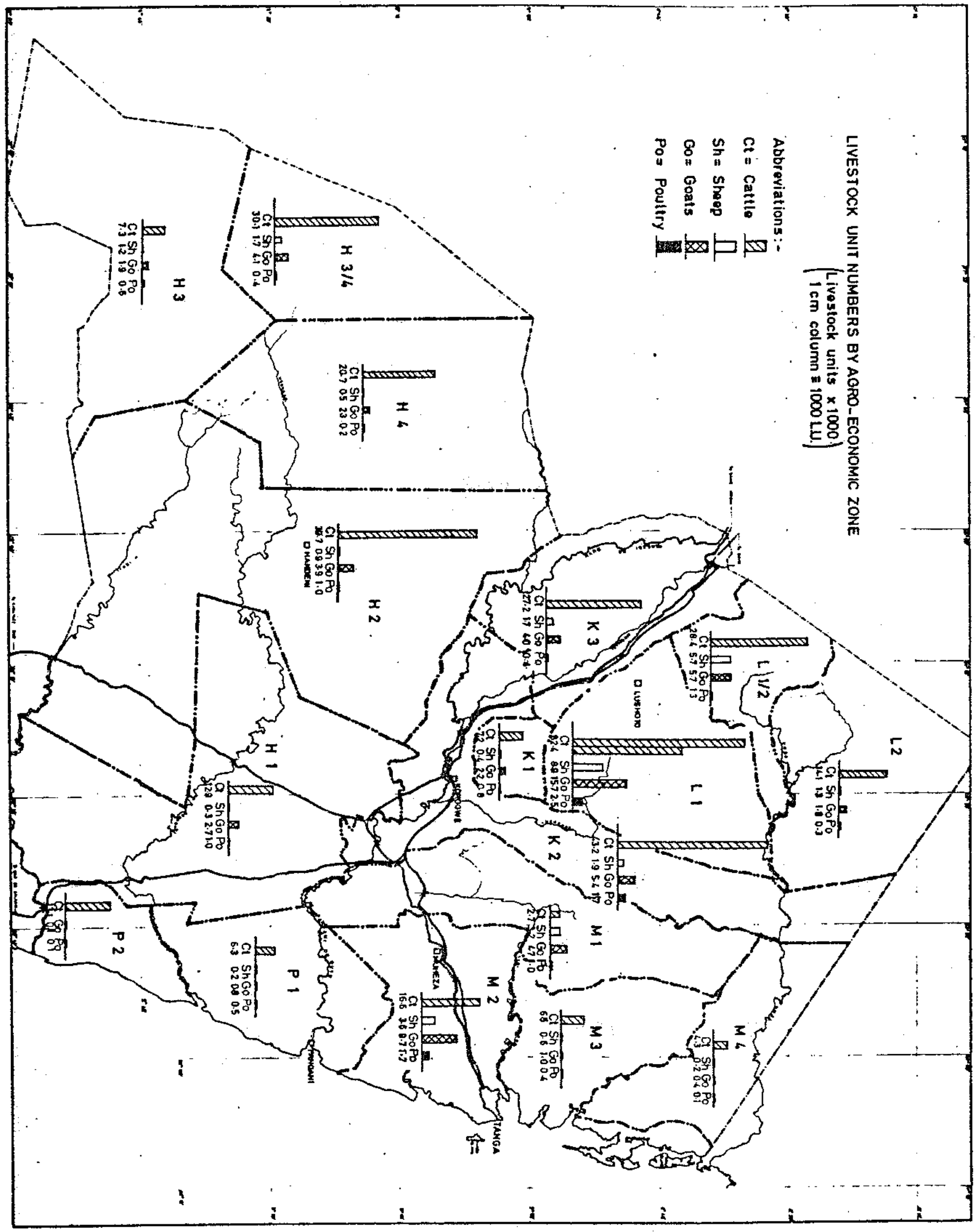


FIG. AG 2-8

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 tributary	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

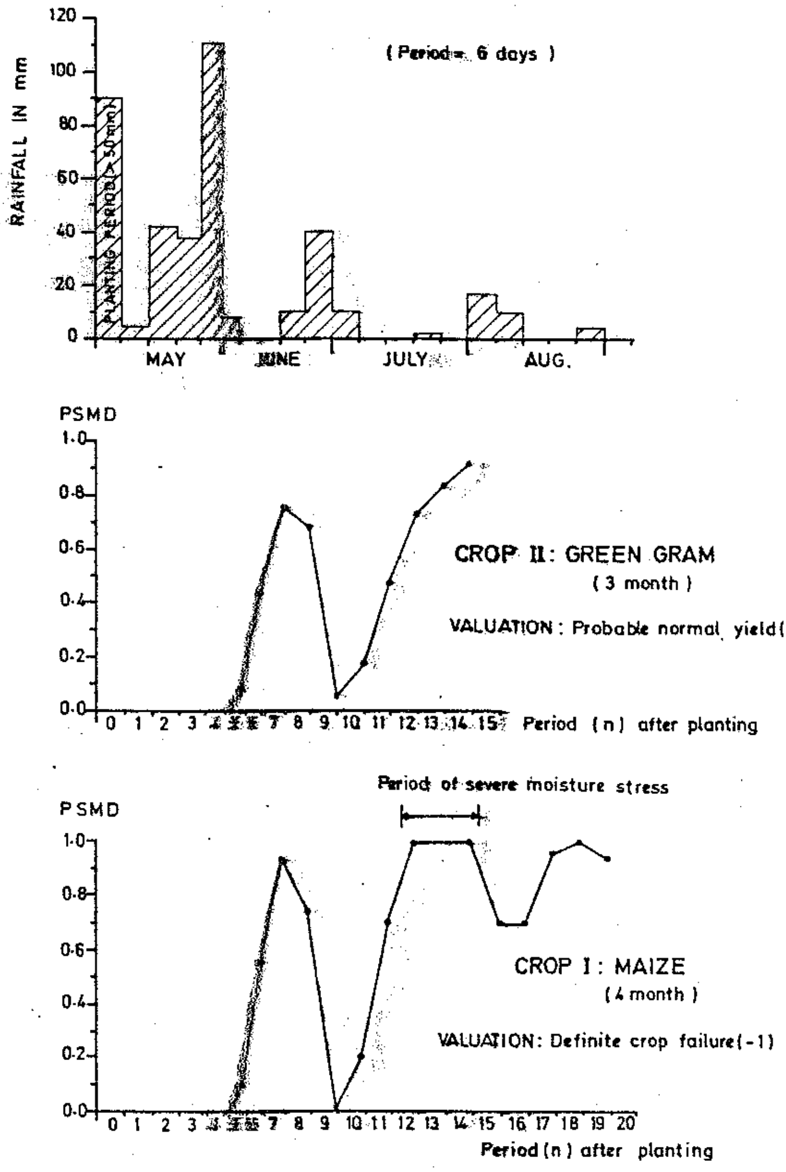
Station	Ref.	Years	P_{75} mm	P_{50} mm	P_{25} mm	Variability* %	A.E. Zone
Amani	9538 003	66	2200	1900	1600	15.8	M1
Ambangulu	9538 004	45	2460	2000	1620	20.6	K1
Amboni	9539 010	25	1400	1085	865	23.6	M3
Balangai	9438 002	53	2070	1580	1250	24.7	L1
Gonja	9438 011	35	1065	808	732	18.5	Kilimanjaro
Hale	9538 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 23 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°C (March)
Minimum temperature : 24°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°C (March)
Minimum temperature : 23.2°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 footslopes 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

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[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

3. POTENTIAL AGRICULTURAL DEVELOPMENT

3.1 LAND CAPABILITY

Soil suitability and/or land capability is considered as one of the major constraints to agricultural development, both in respect to rainfed and irrigated agriculture. For several purposes of the Water Master Plan (hydrological units, erosion hazard, groundwater recharge, irrigation potentials, etc.) a reconnaissance soil survey was carried out for the whole Region.

From the soil map (Drawing PE 5-1) a land capability map (Drawing PE 8-1) was derived, according to the U.S.D.A. Land Capability Classification for upland crops (See Volume IV, section 7) Nevertheless, this land capability map gives also a first indication of the soils which are suited for and/or restricted to irrigated crops.

In addition, the land capability map will serve in conjunction with the analyses of climate and drought (Chapter 2.4. and 2.5.) as the basis for a potential land use map (Chapter 3.9.).

3.2 CROPPING PATTERNS AND CROP NOTES FOR IRRIGATED AND RAINFED AGRICULTURE

3.2.1 Introduction

In this volume a distinction is made between three farming systems in the region, viz.: dry farming, rain-fed farming and irrigated farming. Dry farming is in fact a marginal type of rain-fed farming, and arbitrarily an average annual rainfall of 900 mm has been taken as the upper limit for dry farming and the lower limit for rain-fed farming.

In the dry farming system the choice of crops is limited to drought tolerant and/or very early maturing varieties and a few species of tree crops. In the rain-fed farming system the choice of crops is much wider and includes many tree crops. An early maturing crop can often be grown when total crop failure is the rule in dry farming areas.

In relation to the objectives of the Tanga Water Master Plan, attention will be paid in this chapter primarily to cropping patterns in irrigated agriculture.

In addition, some specific aspects of rain-fed farming in the region, such as cash crops which can be grown on sisal estates, will be discussed.

Some general outlines of dry farming will be presented, in the next chapter. (3.3)

3.2.2 Constraints on Crop Production

3.2.2.1. Rainfall and Climate

Rainfall is the major determinant of which crops can be grown and with what degree of success in the various parts of the region. In comparison with much of Tanzania, Tanga Region receives a reasonable amount of rainfall of good distribution for rain-fed crop production. Climate was described in outline in Section 2.1 of this volume and is further discussed in Volume II. Agricultural drought is analysed in section 2.5 of this volume.

3.2.2.2. Marketing

The marketing of the agricultural production of the region that is surplus to subsistance, drought reserve or local requirements is assessed as a major bottleneck at present. Sisal, which represents about 70% of the total value of marketed production in the region, has its own well defined and relatively efficient marketing channels. The marketing of the remaining crops however, whether sold through co-operatives or parastatals, is generally highly inefficient (Refer TIRDEP, Tanga Regional Development Plan 1975-80, Volume 2 and TWMP, vol. V, Section 7, p. 102-112). This factor partially explains the high proportion of total production which is marketed through unofficial (and thus illegal) channels.

3.2.2.3. Irrigation

Although irrigation in theory should result in a dramatic increase in productivity, the schemes operating at present are in general only marginally more productive than the surrounding rainfed agriculture[1]. There is considerable scope both to improve productivity on the existing schemes and to develop new areas for irrigation.

3.2.2.4. Seeds and Planting Material

Kilimo distributes improved seeds and planting material when it has sufficient funds, and promotes their use when funds are not available. There is still considerable room for improvement however, and further development in this direction should show a very high return.

3.2.2.5. Fertilizer

Despite the presence in Tanga of Tanzania's only fertilizer factory, fertilizer use and distribution comprises a major bottleneck in agricultural production in the region. Smallholders frequently experience difficulty in obtaining small quantities of fertilizer and usage is consequently very low. Prices have also been very high in recent years. The recently announed subsidy and change in distribution methods should improve the situation.

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[1] The irrigation of vegetables in the Usambaras is an exception.

3.2.2.6. Cultural Practice

Almost all land is still cultivated by hoe and most attempts at oxenisation and mechanisation have not been markedly successful. The area of land cultivated by each family or Ujamaa village is therefore very restricted. It is considered that intensive efforts will be required to promote efficient mechanisation in the region in the long term if major increases in productivity are to be achieved.

3.2.3. Irrigated Agriculture

3.2.3.1. Mkomazi Valley[1]

The limited availability of water for irrigation in the Mkomazi valley imposes certain limitations on the choice of crops. Irrigated rice, with its high water requirement, should, for instance, not be grown on well-drained soils. The high water requirement of this crop, aggravated by seepage and percolation losses, will result in high costs per tonne of grain produced. With half that amount of water about two times as much maize can be produced (hybrids or composite maize varieties grown under irrigation).

The use of irrigated rice should therefore be restricted to the heavy to soils which at present are waterlogged for several months during the rainy season or which are flooded for such a period of time by the river. Proper soil management and drainage as also the use of selected varieties, can increase yields substantially.

The upland crops most suitable for irrigated agriculture under present conditions of the Mkomazi Valley will be the following:

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[1] For further details and for possibilities under intensive irrigation see also: AHT: Reconnaissance Study of the Lower Mkomazi Valley, Essen 1976

Hybrid maize: Either hybrids or composites from Ilonga (cooperation with the outreach programme of CIMMYT, Mexico) suitable for the lowland (high temperature) conditions of the Mkomazi valley would be feasible. Hybrid or composites which give highest yields without fertilizer applications should be preferred to those with a higher yield potential, but which can express this potential only under high soil fertility conditions. Furrow irrigation and border irrigation will be the most suitable types of irrigation for this crop. The water requirement of maize increases from 5 weeks after sowing onwards and reaches a peak at silking. It decreases sharply 3 - 4 weeks later.

Cotton: This crop can be grown on dry land farms in the lower part of the valley, but requires irrigation in the low rainfall areas in the northwest. Furrow irrigation can be applied. The peak water requirement of the crop is from the beginning of flowering until 1 1/2 - 2 months later. Best varieties for the area will be the UKA varieties from Ukiriguru (Tanzania). Particularly when large areas are planted with cotton, insect pests, always a problem in cotton growing, may become a serious threat to the crop.

Beans and pulses: Temperatures in the Mkomazi valley are in fact too high for an optimal production of beans. Beans are preferred over pulses in the local diet, however. Therefore it is likely that beans will be grown to an appreciable extent on irrigated fields. Furrow irrigation will be the most suitable type of irrigation. Beans need regular water supply throughout their growing period, but their total life period is short: 2 1/2 - 3 months. Pulses, particularly green and black grams, with their short life cycles and relatively high drought tolerance, can be grown shortly after the harvesting of the main crop when still some irrigation water is avaialble for 1 - 1 1/2 month, or can be intersown 2 - 3 weeks before the harvesting of the main crop.

Vegetables: Types of vegetables which can be grown under irrigation in the valley are for example tomatoes, onions peppers, egg plants, okra and cucumbers. Vegetables need moist soils throughout their growing period. Furrow irrigation will generally be the most suitable type of irrigation.

Bananas: This crop can be planted along the irrigation cannals or, when planted in pure stands, on ridges with irrigation furrows in between. The spacing between rows will have to be about 4.5 m and in the rows 3.5 - 4.0 m for tall varieties. For optimum yields a constant supply of moisture is required. However, waterlogging has to be avoided at any time.

Sweet potatoes: This crop can be planted on irrigated fields when insufficient water is available to grow maize or cotton in the dry season. Sweet potato cuttings can be planted on ridges in a period when still sufficient moisutre can be supplied for a rapid early growth of the vines. The crop will have to be treated as an annual crop. Harvesting can take place 5-7 months after planting. Smallholders will usually harvest the tubers piecemeal. Cutting from high yielding early maturing clones from Ukiriguru would be the most suitable plant material.

3.2.3.2. Lower Pangani River Valley [1]

(1) Vegetables

On the banks of the Pangani river, soil characteristics are more favourable than in the clayey plains further inland. PANGADECO demonstrated on one of these banks that a successful cultivation of vegetables, bananas and pawpaw is possible.

The banks are confined to strips of about 20 - 30 m wide along the river. The digging of ditches in these banks is sufficient to ensure adequate drainage.

Vegetables, bananas and pawpaw can be grown under either rain-fed or irrigated conditions on these banks. High yields will be possible only under irrigated conditons [1] since the average annual rainfall does not exceed 1.200 mm. The present small vegetable plots of PANGADECO can well be extended along the banks on both sides of the river.

(2) Rice

The relatively flat water-logged clay plains of the valley were initially primarily considered suitable for irrigated rice cultivation. Rice can be grown on these soils, but a few factors will have to be taken into consideration.

a) The type of organic matter in the top soil. This type is likely to yield toxic products such as butyric acid in anaerobic decomposition (flooded rice soils). Such products cause stunted growth of rice roots and an increased susceptibility of the plant to fungus diseases.

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[1] For further details and for possibilities under intensive irrigation see also: AHT: Reconnaissance Study of the Lower Pangani Valley, Essen 1976.

b) The weed problem. When rice is grown on a large scale in this area, the fields are likely to be infested to an increasing extend by e.g. Cyprus spp. An example of this is the rice area in the coastal beld of Kenya. Such weeds will be difficult to control without a very high input of hand labour and/or an intensive use of herbicides.

c) Technical complications. The irrigation system for the irrigated rice cultivation will have to be operated by pumps. The maintenance of the pumps, and particularly repairs in case of a breakdown, will present major problems for the rice farmers and the irrigation authority.

(3) Sugar Cane

The clay soils along the Pangani river, when properly drained, are suitable for sugar cane cultivation, provided the crop can be irrigated whenever this is required.

Sugar cane needs a steady supply of soil moisture through out the year if it is to give maximum yields. The mean annual rainfall in this area (about 1.200 mm) cannot meet this requirement. Sugar cane only yields well under conditions of free drainage. On the heavy soils along the Pangani river it will therefore be necessary to construct an extensive drainage system.

The requirements for sugar cane growing on the Pangani soils can be summarized as follows:

a) A reclamation stage of about 2 years to leach the salt from the soil and to permit a ripening of the soil to a depth of about 1 m,

b) The construction of an extensive drainage system, after the reclamation stage, preferably with drain-pipes

c) The construction of a surface irrigation system. The irrigation water will have to be pumped from the river.

On the soils along the Pangani river it will probably be profitable to harvest up to three ratoon crops after the plant crop.

Apart from soils and ecological conditions, high average yields of sugar cane can be obtained only when a high level of technical management can be applied for both, the sugar cane plantation and the sugar mill. In the lower Pangani river valley this would also include the management and maintenance of the irrigation (and possibly drainage) pumps and the canals.

On the very heavy sticky Pangani soils cane cutting will have to be largely, if not entirely, confined to the dry seasons. At least part of the harvesting work will have to be mechanized to be able to speed up the operation.

The high initial costs for land reclamation, the construction of irrigation and drainage systems, service roads and a sugar mill, will have to be compensated by high average yields of sugar cane. Conditions in the lower Pangani valley will permit such yields.

(a) Yield expectations

On well managed sugar estates average yields of 10-20 t/ha of sugar are common in East Africa under irrigation.

In the Pangani river valley the heavy fertile soils, the availability of sufficient irrigation water, the coastal climate and the relatively high incidence of sunshine, provide favourable conditions for high yielding Barbados varieties. Potential yields under such conditions could reach 25 t/ha of sugar. Based on a full production level of 80% of the cropped area, and actual production of 20 t/ha on 2000 - 3500 ha would imply a total annual production of the order of 30 - 50,000 tons of sugar. It would require the construction of a medium to large sugar mill to process this amount of sugar.

(b) Proposed Pilot Project

A detailed proposal for the reclamation of the clay plains along the lower Pangani river for mechanized or semi-mechanized sugar cane growing, will have to be proceeded by a pilot project of about 100 ha.

The irrigation and part of the drainage system of this pilot project will have to be operated by pumps.

The programme of the pilot project would have to include the following items:

a) trials with different types of soil reclamation,

b) irrigation and drainage trials,

c) trials with different sugar cane varieties and

d) crop management and fertilizer trials.

The design of each of these trials will have to be a simple one (comparison of a few factors only) and should be based on previous experience in East Africa.

In the pilot project experimental data will have to be collected over a period of at least 3 years before definite proposals can be made regarding the establishment of a sugar cane plantation and a sugar mill in the lower Pangani river valley.

3.2.3.3. The Upper Umba River Flood Plain

The upper Umba river flood plain is situated to the northwest of the foothills of the Usambara mountains.

The total gross area of the flood plain potentially suitable for irrigation is estimated at about 2,000 ha. Swamps and marsh reed areas are found in several parts along the river.

The soils of the alluvial plain are fairly heavy dark brown to dark grey clays. The structure of the soil when dry is largely granular. The soils in the slight depressions in the plain (marshy areas) have a heavier texture. Some remain waterlogged during the dry seasons.

The existing irrigation systems, from the tertiary canals onwards, make a rather haphazard impression. The badly levelled fields at the highest elevations of the plain have been used for irrigated rice. Rice growing should have been confined to the lowest-lying fields with the heaviest soils. As a result of poor drainage in the rainy season, these cannot be used for other crops. Maize, cotton, beans and vegetables would do better on the well-drained soils at somewhat higher elevations. The water available in the dry season is at present not used for irrigation.

Much can be improved in respect of irrigation, soil management and crop management.

A pilot and demonstration farm, possibly as part of an aid project, could be established in this area with, for a period of about 5 years, qualified management and personnel will be required for the demonstration and training tasks of this centre.

The following characteristics could apply to the farm:

- it would cover an area of 50 - 60 ha of irrigated land (e.g. 15 ha rice, 15 ha maize, 10 ha cotton, 5 ha vegetables, 5 ha bananas).
- it would have a mechanization unit with equipment for land levelling, ditch construction, etc. and for soil management practices (ploughing, harrowing, sowing, etc.)
- it would have multiplication plots (5-10 ha) to grow seed or propagate plant material of improved varieties for sale to local farmers.

On this farm, the effect of proper land preparation, irrigation techniques, crop management (including double cropping) and the use of improved varieties can be demonstrated during the first 3 years (necessary to gain sufficient experience). After that, it would be possible to train small groups of farmers at the centre and to bring their fields and irrigation systems up to the standard of the farm. After this has been completed for the whole area, the farm may be maintained by either KILIMO or the villages as a farm mechanization unit (see also section 8) and as a centre for the multiplication of seeds and improved plant material for the area.

It would not be difficult to demonstrate on the pilot farm that proper irrigation and crop management techniques, double cropping, as also the use of improved varieties can very substantially increase yields/ha/year, even when no fertilizers are used. This implies that the area can support many more people per unit surface area than at present.

3.2.3.4. The Lwengera Valley

The Lwengera valley is situated between the central and eastern Usambara mountains and covers, downstreams of Magoma village, about 17,000 ha. A large part of the valley is hilly with sisal estates and rain-fed farming. Along the streambeds of the Lwengera river and one of its tributaries (the Nkole river) strips can be found of alluvial soils (heavy dark brown clay soils). Part of these are seasonally or permanently flooded (reed marshes). The major difficulties in this area to develop irrigated agriculture are the heavy soils of the flood plains which require special preparation (narrow beds and deep ditches) to grow crops other than rice and possibly chick peas, the salinity of the soils, and their poor drainage (the soils are highly impermeable).

Provided a substantial increase in the irrigable area in the Lwengera valley is possible (e.g. by constructing a reservoir dam in the Lwengera river in the foothills of the central Usambaras) a pilot project could be proposed in the valley, operating along the same lines and based on the same considerations as mentioned earlier in section 3.2.3.3.

In the Lwengera valley such a pilot project (demonstration farm) would have to include a section on rain-fed agriculture. Soil management (including water conservation techniques), crop management and the use of improved varieties of maize, cotton, beans and pulses, but particularly of virus-free plant material (cuttings) of cassava and sweet potatoes, could increase yields of rain-fed crops very substantially in this area.

In case irrigated agriculture could not be extended appreciably in the valley, the pilot project would have to be oriented primarily towards rain-fed agriculture. Such a demonstration/training centre could provide a nucleus for the intensification of agriculture in the valley and hence for a much higher population density in the area.

3.2.3.5. Lower Msangasi Flood Plain

If the irrigation proposals[1] for the lower Msangasi Flood plain put forward in 1963 (east of the railway Korogwe-Dar es Salaam near Mkaruma railway station) are realistic, the cropping pattern considerations of the Mkomazi valley will be roughly applicable to this flood-plain as well. However slight differences in yields and soil management can be expected due to different soil conditions.

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[1] See section 3.8 , para. E 1 of this Volume and Technical Report No. 20, Section III.

3.2.3.6. Usambara Mountains

Potential suitable land for irrigated agriculture is restricted by land pressure, topography and soil/water conservation priorities. Irrigation should therefore be confined to high yielding and intensive crops, such as vegetables, potatoes, beans and probably some tree crops. Irrigation of row crops (like maize) on the steep slopes should be avoided as much as possible.

3.2.4 Alternative Crops for Sisal

About 60% of Tanzania's sisal is produced in Tanga region. Almost all of it is grown on estates.

The hard sisal fibre can be used to make twine, ropes, sacks or matting. About 80% of the exported sisal is used for agricultural twine. Competitive fibres are synthetics and other hard plant fibres. The outlook for agricultural twines is very gloomy. Although sisal can compete with both types from a price viewpoint, the total market for agricultural twine may well contract.

For this reason, an effort has to be made to find crops which can replace sisal on some or most of the estates. The following considerations seem relevant.

3.2.4.1 Ecology and Soils

Most of Tanga's sisal estates are situated at an altitude below 900 m. The average annual rainfall varies, depending on the area, from about 800 to over 1200 mm. The soils of the estates are generally well-drained and reasonably fertile, though many of the estates do have very poor soils which are most efficiently used by sisal. Fertilizers and manure (sisal waste) have been applied to the soil on several estates.

Very dry years may be observed once in two to four years. The rainfall pattern is fairly erratic in most years.

The number of crops which may replace sisal successfully on the estates is limited by:

- ecological conditions
- soils
- shortage of pesticides and fertilizers
- prospects for agricultural commodities on the world market
- required capital expenditure
- the necessity to write off most of the investment in sisal processing buildings and plant.

There seem to be reasonable prospects for the following crops 1):

3.2.4.2 Sunflower

Sunflowers usually vary in height, according to variety, from about 1.0 to 4.5 m. The plants have strong tap roots and dense surface mats of feeding roots. Sunflowers are very drought-resistant and yield well in climates with an average annual rainfall of about 750 mm. This implies that in higher rainfall areas (1100 - 1200 mm) the crop will even yield well in dry years. The peak sensitivity of the crop to drought is during the 3 - 4 weeks flowering period. Depending on the variety, plants flower after 2 1/2 - 4 months and take a total of 3 1/2 - 6 months to mature.

The crop can be sown with a maize planter at spacings of 0.3 - 0.4 x 0.75 m. East African varieties are tall and ripen unevenly. The oil content of the seeds is 25 - 28%. Some of the new Russian varieties are much shorter, ripen evenly and can be harvested with a combine harvester. The oil content of the seeds is as high as 50%. There is no experience yet of mechanical harvesting in East Africa.

When sunflowers are grown on a large scale on sisal estates, mechanization of crop management will be necessary, particularly in respect of the harvesting operation which should last as short as possible to avoid shattering of seeds and bird damage. Average yields can be expected to be 1. 7 t seed/ha. With improved varieties and good crop husbandry it will probably be possible to increase this figure to 2.5 - 2.8 t/ha.

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1) See also TWMP, Technical Report TR 13

Sunflower can be grown in rotation with maize, pulses, cotton and cassava. Various combinations are possible, such as:

sunflower - maize - sunflower -
sunflower - maize - pulses - sunflower -
sunflower - maize - cotton - sunflower -
sunflower - sunflower - cassava (2 years) - sunflower -
sunflower - cotton - pulses - sunflower - etc.

The most profitable rotation will depend on market outlets and prices. After several years of crop cultivation, cow peas or tropical kudzu can be grown as a green manure.

It will be possible to grow sunflowers profitably on the sisal estates only if there is a vertical integration of the whole production process. This implies that the crop is not only grown on the estate, but also that seeds are stored, and the oil is extracted, graded and transported to the harbour by the estate. This will minimize storage costs (and losses) and transport costs.

The press cakes of sunflower seeds are a valuable livestock feed and can also be exported.

The long term prospects for sunflower oil on the world market are reasonably good. This semi-drying edible oil is now, together with maize oil, the most important raw material for the production of modern "non-cholesterol" types of margarine and cooking oils in Europe and the USA.

3.2.4.3 Cassava

Advantages of cassava are:

(1) its ability to yield well on poor soils,

(2) its ability to remain in the soil for long periods without a reduction in tuber quality,

(3) its drought resistance and,

(4) its resistance to pests.

These favourable characteristics apply much more to moderately late (16 months) and late (24 months) maturing bitter varieties than to sweet varieties (most of which can be harvested in less than a year).

Rainy seasons have to be long enough to allow for satisfactory tuber expansion. High yields can be expected in climates with an average annual rainfall of at least 1000 - 1250 mm. Well-drained deep soils are best suited for cassava.

Cassava is vegetatively propagated by means of stem cuttings. Planting in rows (spacing 0.8 x 1.6 m) along contour lines may enhance water conservation, particularly when the rows are planted on low ridges. The use of virus-free plant material of clones with a high degree of resistance to mosaic virus and bacterial leaf blight is an essential preliminary for high yields. Early growth is slow and weeding is important at that stage. A very low nutrient requirement is characteristic for cassava.

Late maturing bitter varieties can be harvested two years after planting, but may last for several years in the soil without becoming too fibrous. This implies that when twice as much cassava is planted as will be harvested in a particular year, the reserve plantation can be harvested in an extremely dry year. Thus a constant production can be maintained irrespective of the erratic occurrence of very dry years. This is an important advantage of cassava over other crops when a constant supply of the harvested product to a factory is required.

Mechanical harvesting is not practised anywhere in the world yet, but the implements which would be required for this can be constructed in a fairly simple way (Cassava Division, CIAT, Cali, Colombia).

Cassava as an alternative crop to sisal could be grown for two purposes. The first one would be to grow sweet varieties and produce dried chips for export to Europe as a livestock feed (Tanzania already exports this commodity). The second one would be to grow bitter varieties (with all their advantages) and to extract starch from the tubers in a factory on the estate. The starch would have to be shipped to Europe.

The latter possibility will allow for much less storage and transportation costs, less maintenance costs and security of harvests in very dry years. Yet the initial investment (construction of a factory) will be high.

Cassava can be grown in rotation with sunflowers, maize, cotton or pulses. These crops will generally react favourably to soils cropped for two or more years in succession with late maturing cassava varieties. The most profitable rotation will depend on the marketing situation for the commodities concerned.

3.2.4.4 Cotton

Cotton is probably the most dubious of the crops suggested as alternatives for sisal because: (1) there is no experience in East Africa yet with cotton grown on large farms or estates, (2) the varieties grown successfully in East Africa tend to ripen unevenly (and are therefore not very suitable for mechanical harvesting), and (3) it can be expected that when the crops is grown on a large scale in pure stands, insect pests will become a serious problem. An intensive pest control programme would then be necessary. In addition, intensive weed control is required.

Favourable aspects of cotton are its high drought tolerance, its easy adaptation to a wide variety of soils and, probably most important, the favourable outlook on the world market for cotton (lint), cotton seed oil (an edible oil used in the manufacturing of margarine, cooking oil, soap, etc.) and the residual seed cake (which, due to its high protein content, is a valuable livestock feed).

Soil preparation and sowing can be mechanized without difficulty. Sowing in rows at spacings of e.g. 0.9 x 0.3 m is common practice. The early growth of the plants is slow and intensive weeding is necessary. The main water requirement of the crop is in the 3rd, 4th and 5th month after sowing with a peak in the 4th month. Only American upland varieties have been successful in East Africa. Improved varieties have been bred at Ukiriguru in Tanzania (UKA lines).

On most soils in the Tanga Region, cotton will require nitrogen and phosphate application to give high yields. With good husbandry and efficient pest control yields of seed cotton may reach an average of 2 - 2.5 t/ha.

When cotton is grown on a large scale on sisal estates, it will be necessary to find varieties suitable for mechanical harvesting. In addition, a vertical integration of cotton production would be necessary at the estate level (ginning, grading, baling, oil extraction, etc.) to obtain optimal economic returns. Only estates further inland, with a fairly dry climate, would be suitable for cotton. The climate along the coast is too wet during boll ripening.

3.2.4.5 Maize and Legumes in the Rotation

Soils suitable for sunflowers are also suitable for maize and grams. Depending on the market situation, maize can be grown in rotation with sunflower for both, oil and flour production[1]. The advantage of maize is that for mechanized crop husbandry the same equipment can be used as for sunflowers. Only the harvesters will have to be adapted.

The extraction of maize oil and the grinding of maize flour will have to take place at the estates to economize on production costs. The market for maize oil is the same as the one for sunflower oil. For maize flour there is a potential domestic market since Tanzania has to import maize every year. Most of the maize hybrids and composites suitable for the coastal climate mature in 4 - 6 months.

For short (2 1/2 - 3 months) rotations, e.g. during the short rainy season, green and black grams are probably most suitable because of the high drought tolerance of these crops and because of the relatively high prices paid for these pulses on the domestic market. At least for green grams there is also a limited market in Europe.

Drought resistant legumes which can be grown as green manures include cowpeas and tropical kudzu.

3.2.4.6 Proposed Pilot Projects

To investigate crop husbandry techniques for sunflower and cassava, as also for the crops which can be grown in rotation with these two crops, it will be necessary to establish two pilot projects on sisal estates.

The first one will have to concerntrate on the sunflower - maize rotation, perhaps with, in one plot, grams included in the rotation. This will have to be carried one on a 40 - 60 ha scale. If the pilot area is situated in a relatively, an additional trial could be carried out with a cotton - sunflower - maize rotation (25 ha scale).

The second pilot project, preferably in the coastal region, would have to concentrate on the cassava - maize rotation (80 - 100 ha scale).

Data from the pilot projects will have to be available for at least 3 years before definite recommendations can be made.

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[1] and possibly for the production of high fructose maize syrups

3.3 DRY FARMING

3.3.1 Introduction

The term dry farming is used in this Report for farming conditions in areas with a too low and/or a too erratic annual rainfall pattern for the more reliable rainfed farming systems. An average annual rainfall of 900 mm is taken here as the arbitrary upper limit for dry farming conditions. Dry farming in East Africa is found from sea level up to an altitude of about 2000 m. At still higher altitutudes the rainfall is usually too high.

The ecosystems of dry areas and the factors involved in dry farming, are still very incompletely understood. Research is urgently needed to find methods to increase production under dry farming conditions. Some outlines of the present knowledge on this subject will be presented in the subsequent sections.

3.3.2 Climate

A bimodal annual rainfall distribution with a "long" and a "short" rainy season is common in most dry farming areas of East Africa. During any of these seasons rainfall distribution is often very erratic, may be concentrated in a few heavy showers with long periods of drought in between, or may come too early, too late or not at all.

Any planning of agricultural activities is very difficult under such conditions and much depends on the flexibility, adaptation, of the individual farmer to the rainfall conditions in a particular season.

In the lowlands the shortage of water in the dry farming areas is aggravated by the prevailing high average night temperatures which may increase the transpiration and respiration rates of crop plants. Remarkably low respiration rates under high temperatures have been found in some of the tropical grass species, however.

3.3.3 Water

3.3.3.1 Total Amount Available

Registered rainfall figures over 15 to 20 years may provide a reasonable average of the total amount of water which can be expected to be available in a particular rainy season in a particular area. On the basis of surface run-off, infiltration rates in the soil, water retention capacity of the soil and evapotranspiration, it can either be calculated or established empirically for which crops sufficiend water would be available to complete their life cycle. This is principally the same approach as the one followed in rainfeld agriculture, but the margins of the total amount of available water which will permit successful crop growth, are much more critical in dry farming than in rainfeld farming.

3.3.3.2. Erratic Distribution

The principal hazard of dry farming ist hat the total amount of water which becomes available in a particular season, is only rarely evenly distributed over that period. In addition, the "season" is often a fairly variable period in the year with a markedly fluctuating total rainfall. Effects of shortages of rainfall, as also of prolonged periods of drought between rains, may result in total crop failures. (See Chapt. 2.5. of this Volume).

If the rainfall pattern has been registeres during periods or more, it is possible to calculate the percentage chance, of a crop to complete its life cycle when it is sown after a certain amount of rain has fallen in a certain period. 1) This is as far as prediction on the most suitable sowing dates can go at present. Further improvement awaits accurate waether forecasting techniques over periods of about three months.

3.3.3.3. Moisture Conservation

The retention of rain water in the soil depends on the physical properties of the soil and on soil management. Light soils generally have a poor moisture retention capacity and offer very little potential for dry farming. Soil management techniques can be applied for the following purposes:

- conservation of the moisture present in the soil,
- prevention of surface run-off of rain water,
- promotion of rain water infiltration in the soil,
- utilization of residual moisture in the soil after the cropping season.

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1) See Technical Report No. 19

The moisture which is present in the soil can be conserved by a thorough tillage of the upper layer of the soil. This layer then dries up and prevents further evaporation of moisture from the deeper soil layers (disruption of soil capillaries). A method based on the same principle is the cultivation of the land during a fallow period, whereby all weeds are ploughed into the soil and a fairly shallow tilled layer of 10-15 cm is formed. The elimination of weeds can be quite important, since these tend to dry out the soil completely before the onset of the following rainy season. This naturally makes the moisture supply during the subsequent cropping season more critical.

Surface run-off may be quite serious, even on only slightly undulating land, when the soil has a low structural stability of the upper horizons and silts up or forms surface crusts when wetted to zero tension. The surface run-off can cause soil erosion. Methods to prevent it are:

(1) certain types of soil management (contour ploughing, contour ridges, terraces),

(2) the use of vegetation (strips of vigorously rooting grasses planted along the contours or on terrace walls, grass or legume cover crops),

(3) mulches of plant material, mainly cut grass (rarely available in sufficient quantities)

(4) stone and/or gravel mulches.

The latter have been used successfully in tree or shrub crop plantations in some countries (e.g. Iran). These mulches can also suppress weed growth satisfactorily.

The infiltration of rain water in the soil is promoted by the same methods as the ones used to prevent run-off. Other methods are: shallow tillage (breaking the surface crust) or adding organic manures (which are hardly ever available) to the top soil layer.

The utilization of residual water in the soil after the cropping season, is usually confined to soil moisture conservation for the following cropping season. Only on heavy soils in fairly flat areas and with a moderate rainfall (700-900 mm/year) it may be possible to raise a crop in the dry season on the residual moisture in the soil. For this purpose broad and deep ditches have to be constructed along the contour lines at about 2 m distances. Furrows are dug on the ridges to secure sufficient penetration of rain water in the soil. During the rainy season, crops are grown on these ridges. Water tends to accumulate in the ditches. At the end of the rainy season, the ditches begin to dry up. Crops are then planted in these ditches and the soil between the plants is superficially tilled to prevent further water losses through evaporation. This second crop, grown in the dry season, is usually planted one to three weeks before the harvest of the first crop. The second crop may consist of early maturing varieties of maize, beans, pulses, cowpeas and sweet potatoes.

The yield of this second crop is usually much lower than that of the first crop, but it is important with regard to a better distributed food supply throughout the year. It diminishes the need for food storage.

3.3.4 Crops

3.3.4.1 Crop Characteristics

Crops suitable for dry farming conditions can either be tolerant to drought or can "escape" drought (by very short maturation periods). Other useful plant characteristics are, in combination with drought tolerance, a flexible harvesting period (e.g. cassava) and a perennial growth habit (e.g. of tree crops).

In most crop plants sensitivity to drought reaches a peak at the flowering and early fruit development stages. The degree of sensitivity varies greatly among different crop species, however. Maize, for instance, is much more sensitive to drought during that stage than millet or sorghum.

Farmers in dry areas normally try to avoid the risk of unexpected periods of drought during the sensitive stage of a particular crop plant by intercropping two, three or even four different species. For example, maize and pumpkin; cotton, maize and grounnuts; cassava, maize, pidgeon peas and beans (or groundnuts, cowpeas). In such combinations each of the species, reaches its peak sensitivity to drought in a different period. Drought during a particular period may then result in the failure of one crop, but would leave the farmer with the yields from the other crops grown in his field.

The intercropping system, in addition, spreads the risk of pests and disease damage.

The combination of different plant species in mixed stands often yields more than the sum of the same number of plants would do when grown in pure stands. The reasons for this probably include differences between plant species in rooting depth, moisture and nutrient extraction capacity, nitrogen fixation (legumes), shading, etc. Such intercropping systems

are generally the best possible production method available to the small farmer under the prevailing conditions (low and unreliable rainfall, few possibilities to control pests and diseases, no fertilizers and low labour productivity).

An important advantage of the intercropping system is that crops are grown together will mature at different periods. The subsequent harvests provide the farmer with a diverse supply of products over longer periods, thereby reducing the need for food storage and maintaining a diversified diet. This in particular because several crops have an "extended" harvesting period. Piece-meal harvesting of young fruits (maize, groundnuts, beans) or tubers (sweet potato) for daily consumption may start a few weeks before the actual harvesting of the mature product. Both factors, the regular supply of products and the diversity of products are usually highly valued by the farmer.

3.3.4.2 Drought Tolerance

The following major crops grown in East Africa are drought tolerant (the lowest average annual rainfall in mm under which these crops can still be grown successfully in certain parts of East Africa, is presented in brackets behind the name of each crop).

- cereal crops : bulrush millet (500 - 600 mm), sorghum (650 mm),
- pulses : green and black grams (650 mm); pigeon peas (650 mm), cowpeas (700 mm),
- oil crops : sesamum (750 mm), sunflower (750 mm), perennial castor (500 - 625 mm)
- fruits : mangoes (650 mm), cashew (700 mm), pumpkin (750 mm), pineapple (850 mm),
- fibre crops : sisal (650 mm), cotton (650 mm).

A flexible harvesting period is particularly pronounced in late maturing bitter cassava varieties which are not ready for harvesting until two years after planting and may last as long as six years in the ground without becoming too fibrous. The crop can thus serve as an important source of "stored" food in the ground during very dry years when other crops fail to produce yields. However, cassava is restricted to lower altitudes (up to about 1500 m) and yields poorly in dry areas. The bitter cassava varieties have, on the other hand, the advantage of being almost completely free of pests (pigs, porcupines, baboons, insects).

A flexible harvesting period is also found, but to a much lesser extent, in sweet potatoes. The smallholder usually harvests the tubers of this crop piecemeal.

Perennial crops, particularly trees, have the advantage that they can extract moisture from much deeper soil layers than annual crops, and that their extensive root systems can even absorb the moisture supplied by a few small showers which may occur in very dry years.

The perennial growth habit of cassava, pidgeon peas, castor and sisal are important in this respect, but an even greater potential is probably offered by the tree crops (cashew, mango) but this remains to be investigated properly. To these tree crops, some species indigenous in semi-arid zones, such as the shea butter tree, can probably be added. But this, again, remains to be investigated.

3.3.4.3 Drought Evasion

Very early maturing (70 - 100 days) crop plants can evade drought by completing their life cycle at the end of very short rainy seasons. Very early maturing varieties are e.g. available of grams, beans and groundnuts (70 - 90 days), bulrush millet, sorghum and maize (85 - 100 days) and sunflowers (100 - 110 days). Some varieties have been bred primarily for dry farming conditions such as some early maturing maize varieties (the Katumani composites) for the Machakos and Kitui Districts in Kenya.

To take as much advantage of the first rains as possible, seeds can be sown in dry soil before the onset of the rains. This is, for instance, practised in the Machakos District with maize. Early sowing is apparently also favourable for maize because of an optimal air: water ratio for root development in the soil after the early rains. In cassava cultivation the maximum use of early rains can be made by planting the cuttings in furrows which accumulate rain water. At later stages, the furrows are levelled and finally ridged to promore tuber formation.

3.3.5 Storage

Storage of harvested products and sowing seed is more important in dry farming than in ordinary rainfed farming systems because of the much greater risks of crop failures in dry as compared to wet climates.

3.3.5.1 Storage of Seeds and Food Grains

When the onset of the early rains is followed by a long dry spell, early crop growth may fail completely. The fields will then have to be resown. This may even happen several times in succession. The stored amount of sowing seed would have to be sufficient to meet such conditions but it rarely does. The farmers are then in the position that they have to use either their own food grain stocks for sowing seed or that they have to try to obtain seeds from outside the region. Perennial crops in this respect have the advantage over annual crops that they have to be sown once in so many years only.

Storage facilities are, contrary to their needs, often poorly developed in dry farming areas. Lack of capital and incentives are usually the main reasons for this. Products such as cassava tubers, which can be harvested whenever needed, are therefore of particular importance. Yet these are usually insufficient to bridge prolonged periods of food shortage in very dry years. Stored food, cereals in particular, would have to be the main basis to overcome such shortages.

3.3.5.2 Food Production and Storage

One of the main difficulties at present is that farmers even if a sufficient storage capacity would be available, would not be able to produce sufficiently to obtain a substantial surplus of agricultural products for storage. The principal constraints to farm productivity are the low average yields per hectare and the limited surface of land a farmer and his family can cultivate. To improve this situation labour productivity (and/or labour input) and crop yield would have to be increased (by using, e.g. improved varieties, improved soil management and water conservation techniques, fertilizers, better pest and disease control, etc).

Of these factors, increases in labour productivity by oxenization or mechanization, and of yields by (chemical) fertilizer applications or by (chemical) control of pests and diseases, would require the highest capital inputs. Improved soil management techniques generally require a high labour input. First priority should therefore be given to the use of improved varieties (bred for drought tolerance, drought evasion, and/or pest and disease resistance).

3.4. AGRICULTURAL ENTERPRISE BUDGETS

3.4.1 Introduction

In order to define the economics of irrigation development in the Region and to give a general indication of the profitability of dryland crop production, the following enterprises are analysed. 1)

Irrigated	Dryland
Beans	Beans
Maize	Maize
Rice	Cotton
Bananas	Sorghum
	Cassava

3.4.2 Value of Production

In order to simplify calculations,product prices are always expressed in cash terms, based on the current parastatal or co-op buying prices. Thus subsistence requirements are valued at sales price while major crop losses after harvest are not taken into account.

The following product prices are applied:

Grade	A Sh/Mt	B Sh/MT	C Sh/MT	Average Sh/MT
Maize	750	500	350	700
Beans (navy)	1750	1350	-	1630
Rive (paddy)	1000	-	-	1000
Cassava (dried)	400	380	-	390
Sorghum	750	-	-	750
Millet	850	-	-	850
Cotton	2000	1000	-	1700
Groundnuts	2000	-	-	2000
Sunflower seeds	1000	-	-	200
Bananas	200	-	-	200

1) More detailed analysis is contained in:
TIRPED: Tanga Integrated Rural Development Plan 1975-80, Volume 3; AHT: Reconnaissance Study of the Lower Mkomazi
Valley: AHT Reconnaissance Study of the Lower Pangani Valley

2) Average free market price at farm gate.

3.4.3 Crop Yields

As outlined in section 2.3, yields throughout the region are very variable, depending on:

- average rainfall, amount and distribution
- rainfall within one cropping season
- drought incidence
- pest and disease incidence
- the managerial ability of the farmer
- soil type
- the availability of irrigation water
- farm and family size
- availability of improved seeds
- quality of the extension service.

Since reliable data on yields in the various areas over a period of years are unavailable, it is necessary to make estimates in each case.

Rainfed/Dryland Crop Yields

a) Low or unreliable rainfall areas

	Yield Potential MT/ha	Present Yield MT/ha	Likely Future Yield1) MT/ha
Beans	1.0	0.4	0.6
Maize	2.0	0.7	1.3
Cotton	1.0	0.3	0.5
Sorghum	1.8	0.6	1.2
Cassava2)	2.0	0.8	1.5

b) Areas of adequate rainfall

Beans	1.5	0.6	0.9
Maize	3.5	1.0	2.0
Cotton	1.5	0.5	0.7
Sorghum	3.0	0.9	1.7
Cassava	3.0	1.1	2.0

---

1) 20 year horizon
2) Per annum

c) Irrigated Crop Yields

Without Fertilizer

	Yield Potential MT/ha	Smallholder Present MT/ha	Smallholder Future MT/ha	Irrigation Scheme Future MT/ha
Beans	2.0	0.7	1.1	1.3
Maize	4.5	1.2	2.5	3.5
Rice1)	4.0	1.8	2.5	3.0
Bananas	25.0	10.0	15.0	20.0

With Fertilizer

Beans	2.5	-	1.3	1.6
Maize	5.5	-	3.5	4.5
Rice	5.0	-	3.5	4.0
Bananas	35.0	-	20.0	30.0

3.4.4 Crop Costs and Gross Margins

The major costs of production are seeds, (which of course often are retained, but still represent a cost), fertilizer, machinery use or hire when applicable and labour. It is debatable whether smallholder labour inputs should be allocated a positive price, but since subsistence output is valued, and also in order to take account of labour constraints, labour is costed here at its approximate shadow price of Sh 3 per day 2). Irrigation water is not costed.3)

Crop costs are summarised in the following Table AG 3-1, together with budgeted output and enterprise gross margins (output minus directly attributable costs).

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1) Single cropped

2) This price corresponds closely with free market rural labour price.

3) Irrigation water is not charged for at present, while in analysing any future scheme, cost estimates must be made for the specific case.

Table AG 3-1: Crop Costs, output and gross margin

		Output	Costs	Gross Margin	
				Single Cropped	Double Cropped
		Sh/ha	Sh/ha	Sh/ha	Sh/ha
Irrigated beans	1	1140	470	670	-
	2	1790	600	1190	-
	3	2120	700	1420	2480
	4	2120	660	1460	-
	5	2600	760	1840	3220
Maize	1	840	420	420	-
	2	1750	620	1130	-
	3	2450	960	1490	2610
	4	2450	920	1530	-
	5	3150	1440	1710	3000
Rice	1	1800	590	1210	-
	2	2500	760	1740	-
	3	3000	1060	1940	3400
	4	3500	1100	2400	-
	5	4000	1420	2580	4520
Bananas	1	2000	250	1750	-
	2	3000	420	2580	-
	3	4000	480	3520	-
	4	4000	610	3390	-
	5	5000	860	4140	-

1 Smallholder present, without fertilizer
2 Smallholder 1995, without fertilizer
3 Irrigation scheme, 1995
4 Smallholder 1995, with fertilizer
5 Irrigation scheme, 1995 with fertilizer

The double cropping results refer to 100% double cropping for maize and beans and 75% double cropping for rice (the balance of the land being single cropped).

Table AG 3-1 (contd.)

		Output Sh/ha	Costs*) Sh/ha	Gross Margin Sh/ha
Dryland Low Rainfall				
Beans	1	650	380	270
	2	980	480	500
Maize	1	490	300	190
	2	910	370	540
Cotton	1	510	460	50
	2	850	650	200
Sorghum	1	450	300	150
	2	900	370	530
Cassava	1	310	200	110
	2	590	420	170
Dryland Good Rainfall				
Beans	1	980	450	530
	2	1470	570	900
Maize	1	700	350	350
	2	1400	430	970
Cotton	1	850	540	310
	2	1190	770	420
Sorghum	1	680	350	330
	2	1280	430	850
Cassava	1	430	230	200
	2	780	490	290

1) Smallholder, present

2) Smallholder 1995, partially mechanised

*) Costs for Low Rainfall reduced by 15% to account for years in which full cultivation and planting is not possible.

3.4.5 Discussion

The results of the analysis indicate that:

a) The low rainfall dryland crop enterprises generally show rather low returns, but in general are able to cover their direct costs (which are mainly labour). Cotton and cassava show poor returns, due to low yields and low product prices. Cotton continues to be grown in Tanga Region largely because it has a relatively well organised infrastructure, and is a 100% cash crop, while cassava, despite its low cash value, is a valuable staple and drought reserve food stuff.

b) Under good rainfall conditions, gross margins increase by an average of 50 % compared to low rainfall margins, since costs are directly comparable and output is substantially higher.

c) The irrigated crops analysed all show substantially higher returns than the dryland crops, but it must be remembered that water costs must be deducted before direct comparison is possible.

3.5 LIVESTOCK

3.5.1 Constraints

The major constraints affecting livestock development are outlined below. A number of the factors are examined in more detail in sections 3.5.2 to 3.5.5. below

a) Water

During the wet seasons, water is virtually non-limiting, but after the end of the rains, water becomes progressively scarcer throughout much of the lowland part of the region. This creates severe management problems and in, fact prevents full use being made of many of the regions grazing areas. The development of ground water resources or construction of surface storages is possible in most areas, but it must be remembered that the provision of a limited water supply network can create severe problems of overgrazing in the vicinity of the water points.

b) Pasture Types

Relatively few of the pasture species in the region are very productive, since the periods when they are reasonably nutritious are very limited. Potential liveweight gains per hectare are thus low. Little work has been undertaken in the field of pasture improvement, and much development work will be required before it becomes economic on a large scale.

c) Livestock Performance

The strains of most types of livestock produced in the region are generally unproductive, with poor breeding and weight gain potential. The accelerated introduction of improved stock (or semen) should be given high priority if livestock output is to be improved.

d) Social and Management Problems

The main constraints on smallholder livestock production in Tanga Region are listed below:

- the major objectives of cattle ownership are security, social status and wealth. These objectives are to a large extent imcompatible with economic production. Herd size is maximised at the expense of productivity.
- ownership is often complex.
- grazing areas are communal.
- stocking is uncontrolled.
- there is little or no attempt at systematic disease control.
- water points are widely separated during dry seasons.
- tick and tsetse fly are major problems
- the grazing areas and watering points available to the Masai are being reduced due to the establishment of ranches and ujamaa villages. The cost of well sinking has also risen sharply.
- reproductive performance is poor, calf mortality high and growth rates low.
- the practice of keeping stock in night bomas, which greatly reduces potential rates of weight gain.

e) Ranch Production

Ranches experience many of the same problems especially with disease (Red Water, East Coast Fever, Trypanasomiasis, Foot and Mouth), and are at present unable to achieve economic production. They also incur high labour costs which cannot be offset by intensification. Further research on improved pasture establishment and herd upgrading may allow economic ranch beef production in future.

f) Overstocking

Several areas in Tanga Region show signs of severe overstocking, in particular:

The Mkomazi Valley between the Usambara and Pare Mountains. Grass cover has virtually been eliminated and severe sheet and gully erosion is widespread. This overgrazing appears to be mainly caused by the use of the valley as a stock movement route by nomadic herdsmen.

The Umba Plain - at least along the Mnazi to Tanga road overgrazing is evident.

Chanika Division - Central Chanika, in the Mzeri Hill Ranch area, has historically been overgrazed but is now regenerating due to controlled grazing. The area to the north and west of the ranch however is under severe stress due to the reduction of the grazing area left to the Masai after the establishment of the ranch.

Densely Settled Areas - Many areas of overgrazing are to be found in the vicinity of watering points in densely settled areas. The Western Usambaras in particular appear to be carrying an extremely high number of livestock.

g) Ticks and Tsetse

Ticks are a severe problem for cattle and to a lesser extent goats in most of Tanga Region. They cause direct losses through

- causing East Coast Fever and Red Water with resulting loss of condition or death
- affecting stock health through their physical numbers
- necessitating frequent dipping, weekly or more frequently in the case of the red tick, with loss of productivity and considerable cost of labour and acaricide (anti-tick insecticides).

Many acaricides moreover are losing their efficacy due to the evolution of resistant strains of tick.

It remains possible however to contain tick numbers and prevent major stock losses, but it will be difficult and expensive to attempt a regional control programme.

Tsetse fly cause economic loss due to

- causing physical unrest among the stock
- the transmission of trypanasomiasis which results in lowered growth rates, loss of condition and death in severe cases
- precluding human habitation and/or livestock production in some areas
- the cost of curative and preventative chemicals and associated labour costs.

Tsetse fly are prevalent throughout much of the bush and woodland of Tanga Region. Long term control may be feasible if areas of its habitat can be isolated by clearing and sowing crops or pasture, followed by insecticide application and sterile male release. This approach is being applied by the Tsetse Fly Research Centre in Tanga.

3.5.2 Pasture Improvement

Rangelands

Up to the present, very little pasture improvement has been undertaken, and reliance is largely placed on the native species such as green panic (Panicum maximum), Themeda, Hyparrhenia and Digitaria species. Most native species tend to produce good quality fodder when young but often mature rapidly and have low protein and energy contents during most of the year. In order to support higher stocking intensities than the normally achieved levels of one LU per 2 to 3 hectares, suitable improved species will have to be found and introduced.

Since the technology of bush control and pasture establishment, fertilisation and management is virtually untried in Tanga Region at present it is unlikely that pasture improvement will have any significant impact on the rangelands of the west, north and south of the region within 20 years. It is important however to lay the foundation now for the long term future, and to this end individual ranches and enterprises could be given assistance with field scale varietal evaluation and pasture improvement technology.

Ujamaa and Smallholder Areas

Very few villages have thus far been involved with pasture improvement. Exceptions include guinea grass, green panic and guatemala grass which have been planted in some areas as forage crops and as erosion controlling strips in parts of the Usambaras.

There would seem to be great scope to increase the area sown to improved grass and legume species in most areas of Tanga Region. In the remaining areas of shifting cultivation, a grass phase could possibly replace the bush regeneration phase, while in the more permanent cultivation areas even a limited area of rotational pasture would assist in maintaining and improving soil fertility as well as providing valuable grazing and an extended growing season.

As with ranch development, there are many technical obstacles to overcome, and in that it represents a shift in land use a number of social problems would also be encountered. If it could be successfully introduced on a limited number of villages in suitable areas however, there is every possibility that over the long term this approach could have a dramatic effect both on the number and quality of stock owned by ujamaa villages and smallholders.

Improved Pasture Species

As mentioned earlier in this section, extensive field scale research is required before detailed recommendations can be made on the most suitable grass and legume species for any specific area. The following list of potentially suitable species is therefore provisional.

Grasses

Buffel Grass	Cenchrus ciliaris
Guinea Grass	Panicum maximum
Green Panic	Panicum maximum var. trichoglume
Rhodes Grass	Chloris gayana
Setaria	Setaria anceps
Singnal Grass	Brachiaria decumbens

Legumes

Glycine	Glycine wightii
Siratro	Macroptilium atropurpureum
Stylo	Stylosanthes guyanensis (Schofield)
Puero	Pueraria phaseoloides

Innoculum

In order to achieve satisfactory root nodulation and production in legumes it is usually desirable in innoculate all legume seed. At present it is virtually impossible to obtain innoculum of any type in Tanga Region - a deficiency which will have to be overcome if highly productive legume/grass pastures are to be established.

3.5.3 Water Supplies

To improve the efficiency of production from the existing livestock population and allow numbers to be increased, it will be necessary to improve and extend stock watering facilities.

This may be undertaken to a large extent in conjunction with the village water supply programme. There will however remain very large sections of the Region which will still not be adequately watered. Although it would be technically feasible for the State to provide water in these areas, the cost would be enormous. It is therefore suggested that most investment in stock watering facilities apart from the village supply schemes should be left to the villages themselves. Exceptions of course will occur, particularly along stock movement routes.

The approximate number and costs of livestock watering points within the individual village and grouped water supply schemes are analysed in Technical Report 8, Climate and Water Requirements.

3.5.4 Future Livestock Numbers

Stocking intensities for the year 1995 have been estimated per agro-economic zone on the assumption that:

(a) water is limiting; this is the present situation in relation to watering points

(b) water is not limiting; i.e. if costs are non-limiting in the construction of water supply systems for livestock.

To arrive at the estimates the following procedure was followed.

(1) Livestock units by agro-economic zone were calculated from the extrapolated survey data. Since poultry are insignificant contributors to grazing pressure, they have been excluded.

(2) The estimated increase in population densities between 1975 and 1995 were calculated in per cent per agro-economic zone (see Volume V, Chapter 2).

(3) The area available for grazing was evaluated by each agro-economic zone on the basis of:

  (a) livestock units per total agro-economic zone area (excluding forest reserves).

  (b) livestock units per grazing - and - unused-land are (deduction of built up areas, arable land etc. from the total).

  (c) ecological conditions in each agro-economic zone (estimates based on rainfall data).

  (d) soil types and topography of each agro-economic zone (estimates based on descriptions and field observations).

(4) The following assumptions were taken into consideration:

  (a) that livestock intensities would increase more than any increase in population density if the area available for grazing and the water supply for cattle were non-limiting

  (b) that areas heavily infected by tsetse flies seriously limit the possibilities to increase cattle numbers.

  (c) that marked increases in population numbers in densely populated areas will lead to a decrease in stocking intensities (expansion of arable land at the expense of the area available for grazing)

  N.B. poultry is not subject to the foregoing condition; numbers are likely to increase more than population densities.

The present and likely future carrying capacity of each agro-economic zone is summarised in the following Table.

Table AG 3-2 : PRESENT AND LIKELY FUTURE LIVESTOCK CARRYING CAPACITY BY AGRO-ECONOMIC ZONE

AEZ	Area Sq. km.	Present Carrying Capacity L.U./Sq.km. 1)	Likely 1995 Water Limiting L.U./Sq.km.	Carrying Capacity Water Non-Limiting L.U./Sq.km.
H1	2893	5.5	9.6	13.8
2	4572	9.7	16.5	21.3
3	2463	4.3	6.5	7.5
3/4	1254	27.2	30.0	30.0
4	2027	11.6	16.2	20.9
K1	286	34.6	27.7	27.7
2	1884	27.2	38.1	46.2
3	1585	20.9	27.2	31.4
L1	1317	82.0	57.4	57.4
1/2	653	60.9	42.6	42.6
2	1527	10.8	15.1	19.4
M1	1550	6.8	9.5	9.5
2	1219	24.5	19.6	19.6
3	1188	6.9	9.0	13.1
4	974	5.2	6.8	8.3
P1	976	7.4	11.1	13.0
2	448	29.7	44.6	52.0

1) Total area basis from Table AG 2.8 in chapt. 2.3.5

Table AG 3-3: LIVESTOCK NUMBERS BY AGRO-ECONOMIC ZONE

AE ZONE		1000 LIVESTOCK UNITS PER AE ZONE		
		1975	1995 Probable (water limiting)	1995 Possible (water not limiting)
Handeni	1	15.9	28	40
	2	44.0	75	97
	3	10.5	16	18
	3/4	34.1	38	38
	4	23.6	33	43
Korogwe	1	10.1	8	8
	2	50.5	71	86
	3	33.0	43	50
Lushoto	1	107.7	75	75
	1/2	38.2	27	27
	2	16.5	23	30
Muheza	1	10.3	14	14
	2	29.8	12	16
	3	8.2	11	16
	4	5.1	7	8
Pangani	1	7.2	11	13
	2	13.3	20	23
Total		458.0	512	602

3.5.5 Livestock Markets and Stock Routes

Livestock Markets

The main marketing centres in Tanga Region are located at:-

Secondary Market - Korogwe

Local or Town Markets

Handeni District - Handeni
Kiberashi
Songe
Balanga

Korogwe District - Manyata
Mkomazi
Kalalani

Lushoto District - Lushoto
Kwekanga
Mkundi
Malindi
Kivingo

Tanga District - Tanga Town

Further information on livestock marketing is given in TIRDEP: Tanga Regional Development Plan, 1975-80, Volume 3.

Stock Routes - Present

Almost all livestock in the Region are walked to market.

A large proportion of stock movement is essentially of stock to the local markets. The distances involved are thus short and in general there are no declared stock routes, nor any need for them. Water supply can certainly be a problem in the dry season, but this should be adequately covered by the village water supply schemes proposed in the Tanga Water Master Plan.

The main stock movements outside local areas are into Handeni Town from West Handeni, from Handeni Town to Korogwe, from Korogwe and Muheza to Tanga and less important routes down the Mkomazi Valley to Korogwe. The most important route, from Kiberashi to Handeni and Korogwe, has been studied in detail by TIRDEP[1].

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[1] TIRDEP, Working Paper No. 24, Improvement of Water Supply and Veterinary Services for the Handeni Cattle Stock Route.

In general the water supply situation is unsatisfactory along many of the routes, with large distances between watering points which often do not provide adequate supplies due to unserviceability.

Future Situation

As herd numbers and production efficiency increase, it is inevitable that more cattle will use the major stock routes, placing even to unserviceability.

It will therefore be desirable if consideration can be given to the provision of watering facilities on stock routes when individual or grouped village water supply schemes are being implemented.

3.6 UNIT IRRIGATION WATER REQUIREMENTS

3.6.1 Introduction

An important objective of the Water Master Plan is to investigate and to assess the availability of surface and/or groundwater for irrigation purposes. Since water is in most cases the limiting factor for agricultural development, it was felt necessary to determine the water requirements for irrigated crops. These figures in conjunction with the results of the soil survey will enable an assessment of the possible future water demand and the irrigation potentials in the Region. It should be noted that both hydrologic phenomena and water demand in a region or river catchment are of random nature. In matching demand and supply the stochastic nature of both has significant effects on planning the developments and use of water resources.

It was therefore considered useful to estimate irrigation requirements as random variables, in which random variations are superposed on seasonal or periodic fluctuations.

In respect to the evalution of the hydrological water balances only irrigation requirements for average and very dry conditions have been considered, with 50 % and 10 % probability of exceedance.

3.6.2 Meteorological Data

The available meteorological data for the Tanga Region (see Technical Report No.4,Vol. I) have been used as the basis for the determination of the consumptive use of irrigated crops.

The procedure of calculation of evaporation and potential evaportranspiration is discussed in Chapter 2.1. above. A summary of open water surface evaporation (E_O) values is given in Technical Report No.8. It should be mentioned that the processed data from "Wami Railway Station" have been omitted because of their obvious unreliability

Monthly rainfall figures were derived from the cumulative frequency curves for stations which have more than 20 years of records (see Technical Report No. 17). Frequency analyses were applied to some stations with less than 20 years of records, when they appeared to be essential for irrigation requirement assessment.

3.6.3 Procedure of Calculation

Potential crop evapotranspiration[1] (E_{po}) is defined as the actual evapotranspiration of the plant when soil moisture stress does not occur and the soil is evenly covered by the crop. E_{po} is always related to a certain reference value ("evaporative demand") which can either physically or emperically be derived from meteorological data. (see Chapter 2.1).

It was decided to use the evaporation of an open water surface (E_O) as the reference value, since crop factors, expressed as proportion of this value (E_{po}/E_O), could be provided for most of the crops in question

Effective precipitation has then been deducted from potential evapotranspiration to obtain the net irrigation requirement expressed in m^3/ha per month. Net requirements have to be adjusted for application losses in order to find the field irrigation requirements.

The arithmetic procedure can be generalised as follows

$$IR(i) = f(i) * E_O(i) - c * P(i) \quad \text{and}$$

$$\overset{\text{field}}{IR(i)} = IR(i) * \frac{1}{e_a}$$

where
$IR(i)$ = net requirement in month i
$f(i)$ = crop factor in month i
$E_O(i)$ = evaporation of open water surface in month i
$P(i)$ = total precipitation in month i
$c * P(i)$ = effective precipitation ($0 < c < 1.$)
$\overset{\text{field}}{IR(i)}$ = field requirement in month i
e_a = field application efficiency.

3.6.4 Stochastic Nature of Monthly Irrigation Requirement

Water requirement of an irrigated crop is composed of a random component superimposed on seasonal or periodic fluctuations. The chance aspects of irrigation water consumption result from the randomness in precipitation, evaporative demand, heat supply and similar climatic factors.[2]

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1) also referred to as "consumptive use"

2) Note that this random component in irrigation water consumption may be related to the random components in the water supply of rivers and groundwater acquifers.

In this Study irrigation requirements are deterministically derived from the stochastic variables evapotranspiration and precipitation. In order to estimate the requirements with a specific desired probability (for instance 10 and 50%) the randomness of the joint event, that a certain precipitation (P) and evaporation (E_o) occur simultaneously, must be known.

For this purpose the stochastical interdepence of P and E_o has been analysed in Technical Report No. 8, Sect.II . It could then be derived from numerical examples that a monthly irrigation requirement with a specific probability of exceedance can be directly computed from the individual (or marginal) probability distributions of E_o and P as follows:

Marginal probability of non-exceedance (in%)		Joint probability of exceedance of derived irrigation requirement
Evapotranspiration E_o	Precipitation P	IR
80	20	10% ("10% dry month")
80	60	50% (average month)
75	25	20 - 25%
75	75	65 - 70%

(for example IR (0.10) = f.E_o(0.80) - P_e(0.20), where P_e is effective precipitation, which is derived from P, see 3.6.6)

The monthly evaporation and precipitation values with a probability that is required to calculate the irrigation requirements for a "10 % dry" and "average" month are summarized in Table AG 3-4 and AG 3-5.

3.6.5 Irrigated Crops and Crop-factors

Unit irrigation water requirements are calculated for those for which ecological and agro-economical conditions were found to be favourable. Irrigation of some important estate crops has been reglected (tea, coffee, citrus) since their anticipated additional returns on invested capital proved to be too low.

Although rice is at present often grown under rainfed and sometimes dry conditions, additional and controlled water supply is considered indispensible if improved and high yielding varieties and two crops per year are contemplated.

Table AG 3-4

Table AG 3-4: EVAPORATION OF OPEN WATER SURFACE (E_o) IN MM/MONTH PER AGRO-ECONOMIC ZONE
PROBABILITY OF NON-EXCEEDANCE IS 0.80 (4 OUT OF 5 YEARS)
(REFERENCE VALUES FOR CONSUMPTIVE USE CALCULATION)

Agro-Economic Zone		Meteoro. Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Code	Number													
M P H	1^b, 3^a 1, 2 1^b	TANGA	190	162	193	171	161	144	144	140	141	164	171	187
M H	2, 3^b, 4 1^a	MLINGANO	194	178	180	150	130	123	119	133	147	164	162	184
M K L	1^a 1 1, $1/2^a$	AMANI	138	120	135	121	116	102	99	101	100	114	119	138
K H	2^b, 3^b 2	MOMBO	186	158	184	163	141	123	120	126	127	153	168	184
K H	3^a 3, 3/4, 4	SAME	170	145	168	157	126	110	112	114	122	144	154	168
L K	$1/2^a$, 2 2^a	KALIMAWE	189	160	189	171	153	122	121	116	125	174	173	186

Table AG 3-5: MONTHLY PRECIPITATIONS PER AGRO-ECONOMIC ZONE IN MM

Agro-Economic Zones	Weighted Average From Rainfall Stations	Probability of Non-Exceedance	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M2	Kiwanda, Muheza Fac. Ngomeni,Pongwe,Kigombe	0.20	10	12	44	112	120	20	22	25	21	38	41	33
		0.60	46	43	109	279	233	65	55	57	63	114	136	110
P1, M1^b	Pangani, Mwera Kiwanda, Hale	0.20	11	7	49	139	124	22	22	21	18	31	40	32
		0.60	45	40	112	246	236	65	57	57	59	90	122	99
P2, H1^b	Sakura	0.20	9	6	42	120	110	18	14	28	20	25	38	28
		0.60	40	36	130	240	200	62	80	60	55	80	115	90
M4	Mwakijembe	0.20	3	2	50	6	6	5	-	-	-	-	-	-
		0.60	40	39	88	80	71	35	-	-	-	-	14	30
K2^a	Magoma	0.20	11	9	40	70	68	8	12	9	3	7	10	24
		0.60	54	46	92	175	130	36	32	27	22	75	64	65
K2^b	Lwengera, Korogwe Mandera, Hale	0.20	11	10	35	154	130	17	15	17	8	24	2	9
		0.60	42	41	88	258	237	60	51	46	37	76	64	51
K3^a	Buiko, Mabogo	0.20	-	8	17	35	36	-	-	-	-	-	11	16
		0.60	81	39	72	89	69	25	4	3	2	18	48	47
K3^b	Mazinde S.E.,Kikwajuni	0.20	25	24	32	80	75	4	4	1	-	-	33	32
		0.60	60	61	93	151	170	25	16	11	16	23	66	116
L1^a	Lushoto, Magamba Lwandai	0.20	47	35	78	115	88	11	9	3	1	8	61	95
		0.60	98	85	160	188	167	30	28	14	8	40	116	173
L1^b	Mazumbai, Balangai Herkulu	0.20	23	25	53	127	156	24	22	18	13	14	32	46
		0.60	66	67	120	242	300	72	65	55	49	71	102	96

Table AG 3-5 (contd)

Agro Economic Zones	Weighted Average From Rainfall Stations	Probability of Non-Exceedance	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
L1/2^a	Lwandai, Malindi Shume	0.20	33	29	64	84	36	-	-	-	-	8	55	69
		0.60	89	70	132	153	74	5	5	3	7	35	110	193
L2,L1/2^b	Mnazi	0.20	5	1	28	40	11	-	-	-	-	-	60	120
		0.60	58	36	130	155	50	-	-	-	5	20	165	215
H1^a	Mzundu, Kwamgwe	0.20	4	15	55	113	66	6	12	10	14	24	12	11
		0.60	47	36	104	180	158	45	37	30	35	88	113	74

Calculations of water requirements have been carried out for those agro-economic zones where significant irrigation potentials can be found (see Chapter 3.8). Several agro-economic zones had to be divided in to sub-zones, due to strong differences in climate and rainfall pattern (see Chapter 2.4). The meteorological and rainfall stations which have been used to assess unit water requirements, as well as the boundaries of the agro-economic subzones are displayed in Fig AG 3-1.

Crop factors which relate evaporation (E_O) to potential evapotranspiration depend mainly on the growing stage and the type of crop and for a much less extent on the time of the year. Since no experimental values of these factors exist for Tanga Region, they were compiled from various publications. In Table AG 3-6 the applied crop factors are shown for the various proposed crops. It should be born in mind that the indicated planting dates and growing seasons can never to entirely fixed, since they depend very much on factors like labour and water availability, rainfall pattern and crop variety. Consequently the water requirement calculation allows for slightly moving planting dates, so as to obtain the average requirements per hectare.

3.6.6 Effective Precipitation

Effective precipitation is defined as the proportion of total precipitation which can be used by the plant for actual evapotranspiration. The unutilized part is distributed over surface run off, deep percolation and evaporation from ponds. The rate of utilization depends therefore on many factors such as rainfall intensity infiltration capacity, antecedent precipitation, soil moisture capacity, rootdepth, slope of land, irrigation method and potential evapotranspiration. It is obvious that taking into account all these factors would lead to undesirable complexity of the problem. In addition most of the factors are not known since one is dealing with monthly precipation values.

Coefficients to convert total into effective precipitation are summarized in Table AG 3-7.

For irrigated rice grown in levelled basins it is assumed that rainfall is effective upto 50, 100 and 150 mm in the respective first, second and third month after transplanting. In addition, a pre-irrigation of 50 mm is allowed for each rice crop.

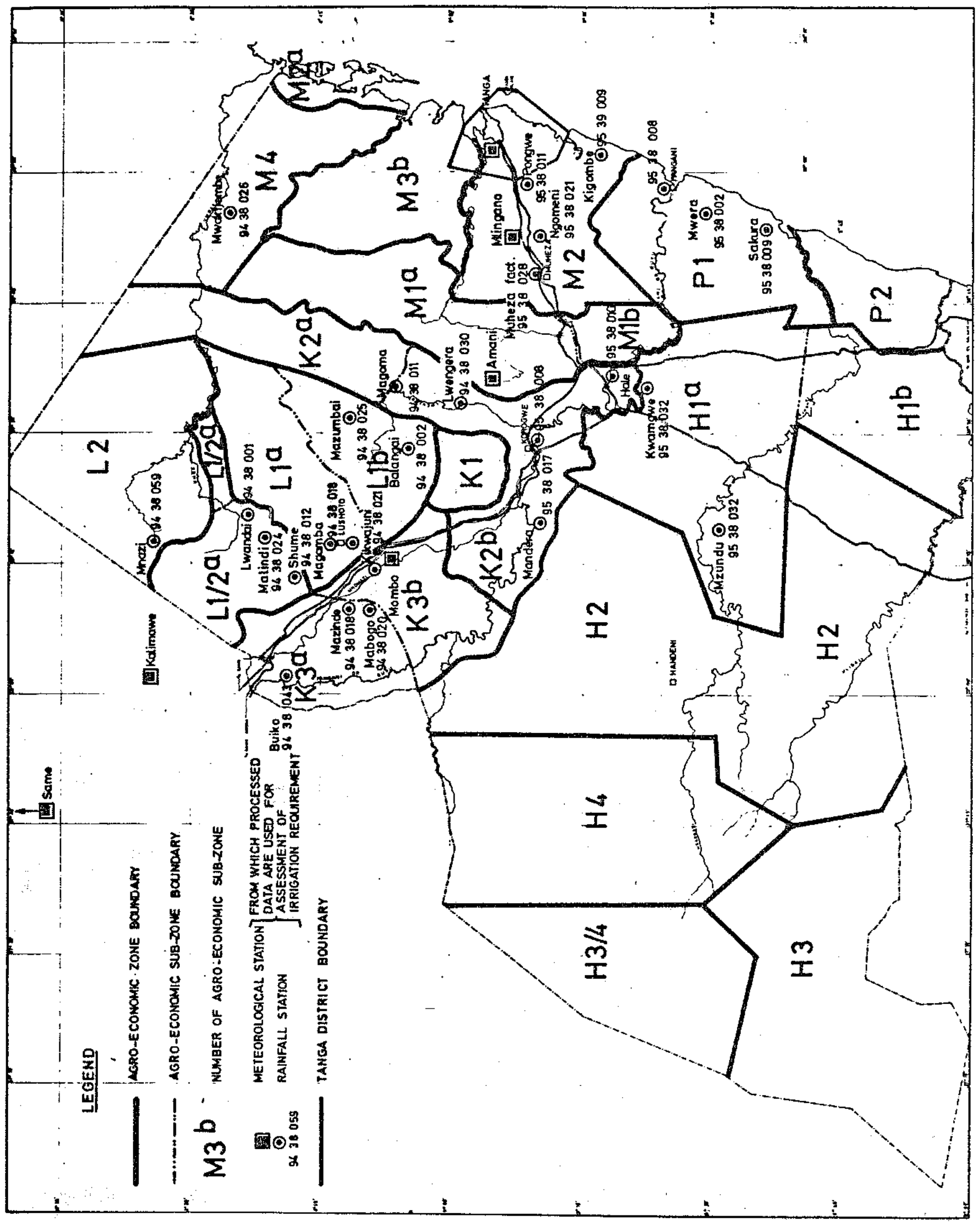

FIG. AG 3-1

Table AG 3-6: CROP FACTORS EXPRESSED AS PROPORTION OF MONTHLY EVAPORATION FROM AN OPEN WATER SURFACE (E_o)

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RICE	Early maturing IRRI varieties suitable for transplanting in lowland	RICE I				0.90	1.00	1.10	0.30 1)					
		RICE II	0.30 1)									0.90	1.00	1.10
BANANAS	Local varieties		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
MAIZE	Early maturing lowland varieties (hybrids or composites)	MAIZE I (4 m'th)			0.50	0.80	0.90	0.60						
		MAIZE II (5 m'th)	0.60								0.50	0.70	0.90	0.80
SUGAR CANE	High yielding BARBADOS varieties (Lowland) B 41227 B 47419	PLANT CROP I (14 m'th)	0.70	0.85	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.30 0.95	0.50 0.00 2)
		RATOON I (12 m'th)	0.20	0.30	0.50	0.70	0.90	0.95	0.95	0.95	0.95	0.95	0.95	0.00 2)
		PLANT CROP II (14 m'th)	0.95	0.95	0.95	0.95	0.30 0.95	0.50 0.00 2)	0.70	0.85	0.95	0.95	0.95	0.95
		RATOON II (12 m'th)	0.95	0.95	0.95	0.95	0.95	0.00 2)	0.20	0.30	0.50	0.70	0.90	0.95
COTTON	American Upland or UKA Varieties (5 months) 3)			0.30	0.70 0.30	0.80 0.70	0.90 0.80	0.50 0.90	0.50					
VEGETABLE CROPS, BEANS	Tomatoes peppers, egg plants, okra-cucumber, etc.	FIRST CROP			0.60	0.80	0.80	0.70						
		SECOND CROP	0.70									0.60	0.80	0.80
IRISH POTATOES	Highland (USAMBARAS) 4)		0.75	0.55 0.80	0.75 0.80	0.80	0.80							0.55

1) Irrigation is stopped 3 weeks before harvesting

2) Fields should dry out before cutting cane

3) Varying planting dates from Feb. to Mar.

4) Varying planting dates depending on rainfall pattern

3.6.7 Unit Water Requirements by Agro-Economic Sub-zone

All basic calculations of unit water requirements can be found in Technical Report No.8 Section II.

3.6.8 Annual Unit Water Requirement for a 10%[1] and Average Rainfall Year

Unit water requirements as calculated in Technical Report No. 8 are monthly values for 10% and 50% probability of exceedance. It should be note that summation of 12 monthly values with, for instance, a 10% probability, does not necessarily yield the annual water requirement in a 10% dry year.

Annual water requirements in a 10% rainfall year should therefore preferably be derived from actual rainfall and evaporation data of a selected 10% rainfall year (annual rainfall exceeded nine out of ten years) with an approximate "normal" distribution of rainfall.

Since only frequency distributions and not time series of evaporation are available for all stations (except Mlingano), it was not possible to directly calculate the total annual evapotranspiration for a specific 10 or 5o% rainfall year.

However, a direct calculation was possible for data from Mlingano station, which has complete monthly time series of Penman evaporation values. Annual water requirement calculations in agro-economic zone M_2 were made for two specific years of which the annual rainfall was equal to about the rainfall with a respective 10 and 50% probability total requirements obtained by summation of the 10 or 50% monthly requirements. The average ratios of annual water requirements for a 10% dry year (or average year) to the sum of 10 (or 50%) monthly requirements were then assumed to be applicable to all agro-economic zones in Tanga Region. It must be borne in mind that the so obtained ratios are only a rough approximation, because they depend very much on the distribution of rainfall and evaporation in the selected 10 or 50% dry year.

Since rainfall distribution affects the irrigation requirement of rice more than for other crops, the conversion from monthly to annual requirements was additionally estimated for agro-economic zone K_3^b (evaporation distribution in 10 and 50% rainfall year was synthesized for this purpose). The results are summarized in Table AG 3-9.

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[1] Specific year with annual rainfall nearest the 10% probability of non-exceedance for the rainfall station chosen.

Table AG 3-7 EFFECTIVE PRECIPITATION

Ratio of consumptive use to total precipitation $(f{*}E_o : P)$	Coefficient to convert total precipitation into effective precipitation	
	Fine textured soil	Medium textured soil
0	0.00	0.00
0 - 0.2	0.10	0.20
0.2 - 0.4	0.20	0.30
0.4 - 0.6	0.30	0.40
0.6 - 0.8	0.40	0.50
0.8 - 1.0	0.50	0.60
1.0 - 2.0	0.60	0.70
2.0 - 3.0	0.70	0.80
3.0 - 4.0	0.80	0.90
4.0 - 5.0	0.90	1.00
5.0	1.00	1.00

3.6.9 Irrigation Method and Application Efficiency

An assessment of field application efficiencies has to be made in order to determine the irrigation requirement on field level. The following Table shows the assumed efficiencies for the proposed irrigation methods.

Table AG 3-8 FIELD APPLICATION EFFICIENCY

Crop	Soil texture	Irrigation method	Application efficiency %	
			Actual	Improved
Rice	Fine	Basins (levelled)	50	70
Bananas	Medium	Furrows	50	60
Maize	Medium	Borders	60	70
Sugar Cane	Fine	Furrows	-	60
Cotton	Medium	Furrows (furrow basins)	-	60
Vegetables Beans	Medium	Furrows	60	70
Irish Potatoes	Medium	Furrows	60	70

Table AG 3-9 CONVERSION FROM MONTHLY TO ANNUAL IRRIGATION REQUIREMENTS

Crop	Rice		Sugar Cane	Vegetables	Maize	Bananas
Derived from data in A.E. Zone	M_2	K_3^b	M_2	M_2	M_2	M_2
Sum of 10% monthly requirements in m^3/ha	10,978	12,405	12,847	7,624	9,188	22,561
Annual requirement of 10% dry year in m^3/ha	8,961 (1970)	11,491 (1959)	10,623 (1970)	6,464 (1970)	8,348 (1970)	19,211 (1970)
Ratio	1.23	1.08	1.21	1.18	1.10	1.17
Applied conversion factor	1.16	1.16	1.20	1.15	1.15	1.15
Sum of 50% monthly requirements in m^3/ha	8,153	8,722	7,903	3,599	5,025	15,615
Annual requirement of 50% dry year in m^3/ha	8,318 (1953)	10,134 (1960)	8,054 (1953)	4,037 (1953)	6,378 (1953)	15,625 (1953)
Ratio	0.98	0.86	0.98	0.89	0.79	0.99
Applied conversion factor	0.92	0.92	0.98	0.89	0.89	0.89

Conversion factors for Irish potatoes and cotton were assumed to be equal to the average factor for vegetables, maize and bananas.

3.7 UNIT LIVESTOCK WATER REQUIREMENTS

3.7.1 Introduction

Many factors affect the water requirements of the various classes of livestock, including

- breed
- size
- condition
- milk yield
- climate
- pasture conditions
- quantity and type of feed
- distance to grazing and watering points
- required safety margin
- management system
- frequency of watering

In this section the requirements of livestock for drinking water (other than water supplied from pasture or short term surface ponding) are analysed assuming that:

Water requirement = Maximum water requirement less rainfall factor less pasture factor

3.7.2 Maximum Water Requirement/Temperature Factor

Temperature is the major factor affecting maximum water requirement, and the following relationship is likely (Livestock Unit Basis).

Mean Temperature °C	Max Water Requirement l/LU/day
18	19.4
20	20.8
22	22.2
24	23.6
26	25.0
28	26.4

These data refer to Bos indicus cattle and local sheep and goats. European breeds would require approximately 40% more water.

Water demand is also affected by relative humidity, with high RH values reducing demand. In genral terms RH is higher at the coast than inland and is higher during and after the long rains than at other periods, but insufficient data is available for the region for these variations to be accurately quantified. They are thus assumed to be adequately covered by the temperature, rainfall and pasture factors.

Table AG 3-10: LIVESTOCK UNIT WATER REQUIREMENTS

Dry Year (Litres/LU/Month)

AEZ	J	F	M	A	M	J	J	A	S	O	N	D	Year
H1	710	390	590	530	530	620	620	660	650	720	520	720	7260
H2	710	390	590	530	530	620	620	660	650	720	520	720	7260
H3	540	290	370	510	490	590	590	450	580	640	450	680	6180
H3/4	540	290	370	510	490	590	590	450	580	640	450	680	6180
H4	710	390	590	530	530	620	620	660	650	720	520	720	7260
K1	530	450	550	660	250	470	460	460	600	450	330	520	5730
K2	710	390	590	530	530	620	620	660	650	720	520	720	7260
K3	500	600	810	740	710	690	690	690	660	760	750	710	8390
L1	530	450	550	660	250	470	460	460	600	450	330	790	5730
L1/2	530	450	550	660	250	470	460	460	600	450	330	520	5730
L2	750	690	620	560	660	640	650	660	630	550	520	710	7640
M1	680	480	550	220	220	260	270	420	460	340	500	540	4740
M2	780	570	790	400	510	710	730	720	690	540	620	600	7660
M3	780	570	790	400	510	710	730	720	690	540	620	600	7660
M4	750	690	620	560	660	640	650	660	630	550	520	710	7640
P1	780	570	790	400	510	710	730	720	690	540	620	600	7660
P2	780	570	790	400	510	710	730	720	690	540	620	600	7660

Average Year (Litres/LU/Month)

AEZ	J	F	M	A	M	J	J	A	S	O	N	D	Year
H1	570	500	430	350	370	520	640	650	630	670	550	560	6440
H2	570	500	430	350	370	520	640	650	630	670	550	560	6440
H3	500	320	390	220	360	580	570	580	580	600	490	510	5700
H3/4	500	320	390	220	360	580	570	580	580	600	490	510	5700
H4	570	500	430	350	370	520	640	650	630	670	550	560	6440
K1	510	450	360	220	220	460	570	580	580	500	350	500	5300
K2	520	500	430	350	370	520	640	650	630	670	550	560	6440
K3	620	600	650	500	590	680	690	690	660	750	720	770	7920
L1	510	450	360	220	220	460	570	580	580	500	350	500	5300
L1/2	510	450	360	220	220	460	570	580	580	500	350	500	5300
L2	750	670	600	530	650	620	640	650	630	540	390	600	7270
M1	510	450	330	220	220	310	310	410	290	280	220	330	3880
M2	780	710	630	360	240	470	590	570	540	540	430	620	6480
M3	780	710	630	360	240	470	590	570	540	540	430	620	6480
M4	750	670	600	530	650	620	640	650	630	540	390	600	7270
P1	780	710	630	360	240	470	590	570	540	540	430	620	6480
P2	780	710	630	360	240	470	590	570	540	540	430	620	6480

3.7.3 Pasture Factor

The pastures grazed by livestock contain varying percentages of water, dependent on seasonal conditions and their stage of growth. Four classes are considered.

	Dry Matter %	Water Supplied from Pasture 1/LU/month
0	70 +	-
1	50 - 70	100
2	40 - 50	200
3	40 -	300

3.7.4 Rainfall Factor

During periods of moderate to heavy rainfall, livestock are able to obtain a high proportion of their water requirements from water on plant surfaces or temporarily stored in pools on the ground. This factor is difficult to quantify but for calculation purposes one 1/LU/month is deducted per millimetre of rainfall received during that month, up to a maximum of 2/3 total requirement.

3.7.5 Livestock Unit Water Requirements by Agroeconomic Zone

The calculation of water requirements by agro-climatic zone are given in Technical Report Number 8. The results of these analyses are given in the following Table AG 3-10 for:

a) A 10% dry year, i.e. the specific year nearest the 10% probability of non-exceedance for the rainfall station chosen

b) An average year, based on mean monthly rainfall data.

If these data are used for the design of livestock watering schemes the following points should be borne in mind.

- peak requirements normally exceed average requirements by at least 25%, and an additional margin of safety is also required.
- allowance must of course be made for seepage, evaporation and silting for earth dams, and for pump breakdown in pump schemes.

3.8 IRRIGATION AND DRAINAGE

At present irrigation in the Tanga Region is of very little importance and widely neglected. Considerable virtualy unused areas, however, seem to be well suited for irrigation, in particular the major alluvial valleys. Since the Water Master Plan is aimed at providing a future allocation scheme of potential water resources, an assessment of irrigation potentials and corresponding water demand is a logical part of this Study.

This chapter is dealing with the assessment of potential irrigable areas, as far as the soils and physiography are concerned. Based on these potential areas the potential water demand will be estimated in the next section, which is to provide the basic data for the water balance per sub-catchment area. Analysis of both potential demand and potential resources will furthermore lead to the evaluation of potential irrigation projects (section 5).

Drainage can not be regarded as a separate subjects since it is in most cases an inevitable part of land improvement. The most suitable irrigation areas are commonly floodplains or alluvial valleys, which are mutatis mutandis poorly drained and have sometimes waterlogged soils. Irrigation of these areas will cause a rise of the watertable and consequently the danger of salinization. A proper drainage system is therefore required, which has to prevent the irrigation area from seasonal flooding as well.

The potential areas are briefly discussed by administrative districts belowand their location is displayed on Drawing AG 3-1.

A KOROGWE DISTRICT

A1 UPPER MKOMAZI VALLEY

Development proposals[1] are available for the upper valley of the Mkomazi river (from Bendera to Mikocheni), however, technical problems may arise in training the ill-defined water coarse. In order to ascertain the water supply during the irrigation season, the river flow has to be regulated in conjunction with the Kalimawe Dam Authority.

Since the greatest part of this area is located in Kilimanjaro Region it is beyond the scope of this Report. Water requirements for irrigation however will have to be estimated for the water balance. The maximum net irrigable area has been estimated at some 800 ha.

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[1] See Technical Report No 20, Section III

A2 MIDDLE LOWER MKOMAZI VALLEY

The Mkomazi Valley downstream of Lake Manka offers good possibilities for mechanized irrigated agriculture, but on the other hand presents some serious technical problems. A first development proposal has been made by Halcrow & Partners[1] for a part of this valley (from Mazinde to Mombo) and several smaller investigations have been undertaken since.

Since the discharge of the Mkomazi river is in no way sufficient for large scale irrigation (with double cropping), it is assumed that additional water can be diverted from the Pangani river and conveyed to the Mkomazi Valley[2].
The technical feasibility of this assumption has been subject of a separate study (AHT: Reconnaissance Study Lower Mkomazi Valley, Oct. 1976).
The valley is sometimes only a few kilometers wide and the ill-defined meandering river will have to be trained and canalised. The irrigation area can be commanded only by contour canals along the upper edges of the valley bottom. These canals will be very long, the longitudinal gradient in the valley is about 1 per thousand, which means in turn that a great number of intake weirs in the river can be avoided.

Highly saline soils, which lie in long discontinous strips on either side of the valley, should not be brought under irrigation if better lands are still available, since some serious technical and economical problems may emerge from reclamation.

Irrigation is therefore confined to the clay flats, the silty river levees and the alluvial fans of tributaries, which implies that irrigation plots will be irregularly distributed over the area. Drainage of the clay flats is poor because of low gradients and heavy textures so that the water table tends to be high and the groundwater dangerously saline. Supply of additional irrigation water will alter the annual water balance and requires much attention to drainage. Leaching of the soils with water might become necessary in the dry season, if the electro-conductivity tends to increase.

Soils which will still be flooded or waterlogged during several months in the rainy season after the irrigation and drainage system has been implemented, should most preferably be confined to irrigated rice cultivation.
The remaining suitable soils of the valley, which tend to be light in some areas, can be used under well drained conditions for upland crops under borderstrip and/or furrow irrigation. The length of the plots will mainly depend on the soil intake characteristic and the slope of the land.

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[1] W. Halcrow & Partners; <u>The Development of the Pangani River Basin</u>, London 1962.

[2] Waterrights at Hale for hydropower do restrict the flows which may be diverted and hence storage of water in Lake Manka will be inevitable if the potential area is to be irrigated.

From a prelimanary aerial photo interpretation the following approximate areas were derived:

Total area downstream of Majengo and below an average commanding level of about 1430 ft (50,000 Maps) : 25,800 ha.[1]

	Suitable Soils for		Area not considered suitable (ha)	
AEZ	Rice ha	Upland crops ha	Saline soils or back swamps	Foot slopes or undulating upland ha
K_3^a	2,700	1,600	830	820
K_3^b	5,660	2,500	1,450	2,100
K_2^b	1,680	1,190	360	4,880

For calculation of the potential irrigation demand it is assumed that the net irrigable area equals 80% of the total suitable area. Since annual rainfall increases substantially towards the southern edge of the valley, irrigation of upland crops has been considered unfeasible in AEZ K_2^b.

The total net irrigable area therefore amounts to 11,200 ha of which about 8,000 ha are solely suited for rice.

Detailed information on soil suitable for irrigation has been provided in the Reconnaissance Study of the Lower Pangani Valley. Irrigation of suitable areas above the commanding level (foot hills) by pumping from the main canals is not further considered.

In order to ensure a regular water supply throughout the whole year, especially if more intensive agriculture is contemplated, an independent Irrigation Authority should be responsible for the main and secondary irrigation network, assisted by field officers and ditchriders. The tertiary distribution systems can then be operated and maintained by the involved cooperative irrigators or Ujamaa Villages.

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[1] Assumed dead storage level in Lake Manka is 1435 ft

The already recommended Pilot project (see chapt. 3.2) should preferably be implemented on the existing Mombo Irrigation Scheme for two reasons:

(1) rehabilitation and eventually extension of the neglected scheme will anyhow be necessary;

(2) no additional works have to be undertaken to supply irrigation water (water will be abstracted from the of Soni river) and the scheme can be operated independently the future development of irrigation projects in the Mkomazi valley.

A3 LOWER LWENGERA VALLEY

In the Lwengera Valley (main tributary of the Pangani river) heavy textured, dark brown clay soils are situated in narrow strips along the river. The soils are imperfectly drained vertisols, which are not or hardly saline and therefore only suited for rice cultivation if water is available. In addition a few better drained areas occur on the edge of the valley bottom (alluvial fans of small tributaries), which are suited for upland crops.

The total lower valley covers an area of about 17,000 ha, which comprises some 8,000 ha of flat irrigable land, the remainder being hilly land and undulating upland. The southern part of the valley, south of the railway Muheza-Korogwe and along the Pangani river, is only considered very marginaly suitable for irrigation since it is poorly drained and regularly flooded by both the Pangani river and some of its tributaries.

The potential net irrigable area (north of the railway) is estimated at 4,900 ha suitable for rice and some 600 ha suitable for uplands crops.

Irrigation of the footslopes and uplands (pumping) is not likely to be feasible, since in particular the western edge of the valley, receives sufficient rainfall ($\approx$1200 mm) for good upland cropping.

For detailed planning of irrigation lay-out and water distribution, topographical surveys on a scale of 1:5,000 are required. Small village irrigation projects can be developed on both sides of the river and existing schemes should be repaired and improved. Water can be abstracted directly from the Lwengera river or its tributaries (e.g. Nkole river) by simple weirs and intake structures. Special attention should be paid to the drainage of low lying swampy areas, even if rice is to be grown. Bananas and coconut trees can be grown along the riverbed and do not require special irrigation.

Rehabilitation of existing schemes is recommended prior to any further development and the improved Mahenge scheme (Nkole river) is proposed to become a pilot or demonstration project.

In the southern part of the valley at present some rice is grown by flooding in the wet season. If reclamation and drainage of this area is possible, it could alternatively be used for pasture land.

A4 MASHEWA SWAMPS

Heavy textured soils similar to those in the lower Lwengera Valley occur north of Magoma in the narrow valley of the Kumba and Mvilingano rivers (tributaries of the Lwengera river), but here the soils tend to be rather saline ("gleyic solonchak"). The valley is covered by swampy vegetation and is virtually unused. Drainage is very poor and surface runoff accumulates on the valley bottom.

It has previously been proposed to dam the valley and to store water in the swamps for irrigation purposes in the lower Lwengera valley. Since the catchment area of the Mvilingano and Kumba rivers (PN 6) is situated in a relatively low rainfall area, it is doubtful whether sufficient runoff can be trapped to fill the reservoir.

It is therefore alternatively proposed to reclaim the swamps and to improve them for rice cultivation in the main wet season (March-July). A relatively simple irrigation system can be applied to distribute runoff water to the rice fields. The total net potential area has been estimated at 500 ha.

A5 KWAMNGUMI

The existing rice irrigation project (and fishponds) of the Prisoners Camp along the Pangani river seem to be apt for rehabilitation and extension. The soils are of the alluvial type and similar to those in the Lwengera valley and therefore only suited for rice. It is estimated that controlled rice irrigation can be extended to an area of some 500 ha.

B MUHEZA DISTRICT

B1 MISOSWE IRRIGATION SCHEME

A small valley (about 300 ha) of the Mruka river (tributary of the Sigi river) at the slopes of the Eastern Usambaras, has been the subject of an irrigation proposal. A storage reservoir and main supply channel are under construction and are due to command an area less than 150 ha with mainly upland crops (deep red and yellowish clay loams).

Irrigation of upland crops, however, must be considered very doubtful since average rainfall exceeds 1300 mm per year in this area.

B2 LOWER SIGI

Small scale irrigation along the Lower Sigi river (sub-catchment SI4) has been considered by Kilimo. Soils are well drained deep sandy loams and only suitable for upland crops if brought under irrigation. The total area has arbitrarily been estimated at some 400 ha, for which water will have to be pumped from the river at a total lift of about 20 to 30 metres.

B3 MWAKIJEMBE IRRIGATION PROJECT

Near Mwakijembe village an irrigation project has been previously proposed (see Technical Report No. 8). Irrigation in this area along the Umba has good prospects, since the very erratic rainfall pattern causes complete crop failures in almost every year.

The proposed area of some 500 ha is situated at the south bank of the deep-cut river. Soils are moderately to well drained clays and sands, with a low content of organic matter in the top soil and considered susceptible to erosion. Maize, vegetables and beans are proposed as the most suitable crops.

Since the slopes of the proposed irrigable land are quite steep, surface irrigation of upland crops would require intensive land-levelling and anti-erosive measures. Sprinkler irrigation might therefore be considered as a feasible alternative.

Construction of a weir across the river upstream of the area, as it was previously proposed, is outweighed by the easier pumping solution.

C PANGANI DISTRICT

C1 LOWER PANGANI VALLEY

Although the heavy dark saline clay soils of the Lower Pangani Valley (downstreams of the Pangani Falls) are at first sightconsidered suitable for lowland rice, irrigated sugar cane has alternatively been proposed in chapter 3.2. The special problems involved in rice and sugar cane growing on these soils have been examined in a special study (see AHT: Reconnaissance Study of Lower Pangani Valley, Oct. 1976).

Irrigation of the poorly drained clay plains requires special attention to the following features:

(1) Longitudinal gradient of the river is rather low (0.15%) in the concerned area.

(2) The suitable plains are highly scattered and irregularly shaped. One intake structure at the upstream edge of the area, with a left and right bank contour canal, does therefore not seem to be feasible.

(3) Pumping of irrigation water from the river requires a great number of low lift pumping plants, for which electricity could be provided by either the sugar mill or the Hydro-Power Plant at Pangani Falls at relatively cheap rates.

(4) Electro-conductivity of the Pangani water varies between 0.8 and 1.0 mmhos/cm. When sugar cane is grown, allowance should be made for leaching of salts in the soil profile. A land reclamation phase should precede the construction of any irrigation scheme.

(5) Drainage of the irrigated land requires a dense network of deep drains. Free discharge towards the river however is, at least in the downstream part of the area, only possible during very low tide (tidally influenced watertable) and pump drainage in the rainy season will most probably be necessary. Drainage and irrigation pumps could possibly be combined but it should be noted that the drainage requirement in the rainy season (4 to 5 l/s/ha) is about 4 times as high as the average irrigation requirement (1.2 l/s/ha).

(6) Most of the clay plains are very flat, which will influence the most economical furrow length (mechanized) farming) in an unfavourable way.

(7) The high organic matter in the topsoil (30-40 cm) makes the construction of canals and ditches in this soil rather difficult. Costs of an open main distribution system should therefore be compared with a pipe distribution network, although the strongly swelling clays may give rise to serious foundation problems.

The potential suitable gross area (clay plains) is estimated at some 7,000 ha, whereas the net irrigable area is estimated at 5,000 ha. Assuming that the peak irrigation requirement is about 2 l/s/ha, 10 m^3/sec will be abstracted from the river at maximum. The subsequent possible advance of the salt intrusion front upstream the river should be investigated (damage to coconut plantations downstream of the proposed area!).

D LUSHOTO DISTRICT

D1 WESTERN AND CENTRAL USAMBARA IRRIGATION COMPLEX

Extension and improvement outlines for the traditional slope irrigation in the Usambara Mountains are of a more complex nature and should be subject to a special study.

An assessment of potential irrigable areas can in fact only be made in conjunction with the definition of the ecological development targets in the mountains.

However, as a first approach and for the purpose of the Water Master Plan it has been assumed that the existing irrigation area can only be potentially extended by about 10%, since:

1) high land (and population) pressure is already a fact and should be released;

2) erosion hazard on the irrigated steep slopes and the need for better water conservation are factors against irrigation extension;

3) forest protection and reafforestation interfere with agricultural enterprises;

4) existing schemes can be much improved and the cropping intensified;

Irrigation will be restricted to the growing of vegetables, beans and Irish potatoes, since their returns per m^3 of water are expected to be higher than from other crops.

In addition irrigation of maize and other field rowcrops on the steep slopes raises many erosion problems, which are not easy to control. Irrigation should therefore as much as possible be confined to the valley bottoms and the gentle slopes and both terracing and contour irrigation should be introduced.

The total potential irrigation area has been estimated at some 7,100 ha, the exact location depending on the water and soil availability, the situation of multi-purpose storage facilities and so on.

D2 UPPER UMBA FLOOD PLAIN

The flood plain of the upper Umba river, just at the toe of the Usambara massive near Mlalo, offers excellent possibilities for irrigated agriculture. The soils of the highly flat plain are fairly heavy dark red to yellowish clays with a granular structure and have good yield potentials. The imperfectly to poorly drained soils near the river are considered only suitable for rice (frequently flooded in the rainy season). Maize, beans and possibly cotton should be grown under surface irrigation on the deeper, well drained soils (clay loams) at the outer edge of the plain (along the footslopes of the mountains). Tail water from the irrigated upland crops can be used to flood the lower lying rice fields, in view of obtaining a high water application efficiency. Special attention will have to be paid to the bilharzia problem since it appears that this area is heavily infested.

The existing irrigation schemes (Kitivo and Lunguza) could be rehabilitated and substantially extended, but water seems at first sight the major constraint. The potential irrigable area is therefore arbitrarily confined to the suitable soils on the right bank of the Umba river and is estimated at some 1,500 ha. A pilot scheme for both irrigated and dry farming is recommended.

D3 MNAZI FLOOD PLAIN

The dark grey-brown clay soils ("chromic vertisols") along the Mbaluma river near Mnazi Village are more saline than in the Umba plain and therefore also considered only suitable for rice. However, extension of the irrigation schemes will face some serious water supply problems, unless sufficient storage facilities can be found. The catchment area (UM_1) is situated in a very low rainfall zone.

The potential net irrigated area is estimated at some 1,200 ha of rice and 100 ha of mixed upland crops.

Downstream of the Mnazi scheme, about 300 ha of rice and 50 ha of maize could be irrigated on narrow alluvial strips along the river near Kivingo and Antakea village. Here, too, the bilharzia infestation requires special attention.

E HANDENI DISTRICT

E1 MKALAMO IRRIGATION PROJECT (MSANGASI FLOOD PLAIN)

A feasible dam site exists in the Msangasi river, somewhat upstreams of Mkalamo Railway Station[1].

At an embankment height of 35 meters the maximum impounding capacity of the reservoir will be 74 million m^3. However, most part of the year the river dries up completely and runoff has a rather erratic character. In addition, no records are available of past floods. It is therefore at this stage rather difficult to predict the safe yield of the reservoir, the time distribution of runoff in this case being more important than the total annual runoff.

The proposed irrigation area is the Msangasi flood plain and is situated at the toe of the escarpment about 20 km from the seashore, where the population increased as a result of the railway line works. At present the area is overgrown by a thick mantle of vegetation and sometimes flooded by the Msangasi river. The river bed in the flood plain is ill-defined and some overflow lakes can be found ("Mbuga" land).

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[1] Dolfi, D.: Reconnaissance Report on a Scheme in the Coastal Plain. The Msangasi River Basin in Tanganyika Dar es Salaam 1963

The topographical lay-out of the area seems to be suitable for irrigation. Once the river flow is controlled no major drainage problems are expected in the flood plain. Soil-samples from two pits in the concerned area indicate low salinity and alkalinity hazard (0.2-0.9 mmhos/cm and PH 6.7 to 7.0) and show sandy loam to loamy sand textures.

The soils of the proposed area can be divided in imperfectly drained heavy textured "mbuga" land which is only suitable for rice (4,500 ha) and the better drained light textured undulating coastal plains suited for irrigated upland crops (2,000 ha) but requiring special attention.

Detailed investigations are required to determine the most suitable crop pattern, irrigation method and drainage requirements.

Finally it should be mentioned that the area is served by a good communication system, viz. an all-weather road of 40 km to the trunk road Dar es Salaam - Tanga and the railway Tanga - Dar es Salaam, which passes at the western edge of the area.

It should be noted that part of the proposed irrigation area is located in the Pangani district (A-E zone P_2).

E2 MNYUSI VALLEY

The flood plain of the Mnyusi river, along the road Korogwe - Handeni is one of the typical "Mbuga" areas, which can be found in several places of the Region. Mbuga are poorly drained alluvial plains the soils of which are heavily textured and flooded during several months and dry up during the rest of the year, the vegetation being adapted to this situation.

Reclamation of these waterlogged areas would be possible without high costs, but irrigation possibilities are predominantly restricted by the water availability. Most of the mbuga soils are considered only suitable for rice cultivation, whereas some of the surrounding footslopes might be suited for upland crops. At present local smallholders manage to grow a little rice during the very wet years, but with improved water supply and drainage systems the potentially irrigable area could be increased to some 2,400 ha, mainly rice.

The possibility of diverting water from the Pangani river and conveying it over a distance of about 5 km to the upper edge of the valley should be examined for its feasibility.

E3 SEGERA VALLEY

Similar considerations as for the Mnyusi plain hold true for the Segera valley. However, water supply will become a much greater problem, since the Pangani river is rather remote and irrigation directly from the Segera river depends solely on the storage possibilities, the river being dry most of the year. The total irrigable net area has been estimated at some 1,650 ha, once again mainly suited for rice (imperfectly drained black clays, non-saline).

E4 MZUNDU VALLEY

A long narrow strip of poorly to moderately well drained, dark clays and sands in the Msangasi valley near Mzundu village also offers potentials for mainly irrigated rice This valley is similar to the mbuga areas since it has stagnant drainage conditions with marshy vegetation. Significant irrigation is only possible if storage facilities can be found. The total potential irrigable area is estimated at some 1,000 ha.

Similar smaller valleys and mbuga areas can be found along various rivers in the Handeni district which offer possibilities for very small scale irrigation. They are not further considered in the water balance and may only be reconsidered after successful experience is obtained from one of the previous "mbuga" projects.

3.9 POTENTIAL LAND USE

3.9.1 General

The term 'Potential Land Use' is not well defined and can be differently interpreted, dependent on the particular planning objectives.

In the pure sense of the word, potential land use should describe and indicate all possibilities or purposes for which a certain land or soil type can be used. However, if strictly following this definition, most of Tanga Region for example could potentially be used as Game Reserve or National Park.

Consequently a more specific definition of potential land use is required. In the context of this study potential land use is therefore defined as the most feasible or recommendable land use, resulting from the interaction of physical potentials and the principle development objectives in Tanga Region.

Since development objectives are not exactly defined in large parts of Tanga Region, it is assumed that agriculture in general and the cultivation of food and cash crops in particular deserves highest priority in the development areas with fast expanding rural population.

Consequently in this predominantly agricultural appraisal, forest and grazing are in general not considered as a high potential type of land use.

3.9.2. Determination of Potential Land Use

The potential use of each specific land or soil type has been derived from a synthesis of all available information, in particular:

- Soil Survey Map (Drawing PE 5-1)
- Land Capability Map (Drawing PE 8-1)
- Erosion Hazard Map (Drawing PE 9-1)
- Present Land Use Map (Drawing AG 2-6)
- Agro-Climatic Zones Map (Drawing AG 2-10)
- Impact of Agricultural Drought (Drawing AG 2-9)
- Water Resources and Irrigation Potentials (Drawing AG 3-1)
- Notes on Rainfed and Dry Farming (Chapters 3.2 and 3.3 of this Volume, and Technical Report No. 20).

If rainfed agriculture appeared to be possible, the choice of crops was mainly restricted by relevant soil characteristics, climatic conditions and sometimes local development objectives. Whenever applicable, priority has been given to locally preferred staple food crops like maize.

It was then attempted to determine the most feasible type of land use for each distinguished soil unit (see Soil Map, Drawing PE 5-1). In many cases a group of feasible crops have been indicated for a particular soil type, the final choice depending on the economics and local preferences.

A distinction has been made between "well" and "moderately" suitable for the different kinds of crops, for grazing and forest, dependent on the particular constraints encountered. For instance, if soils and climate are well suited for maize growing, but erosion hazard exists, maize was marked "moderately" suited in that particular case.

3.9.3 Potential Land Use Map

On Drawing AG 3-2, entitled "Potential Land Use", the physical boundaries of the identified types of land use are displayed.

In addition, land use types having similar characteristics were grouped together and classified according to their agricultural potential, with priority for food and cash crops.

The following 9 land use classes could be distinguished:

H.I High Potential Mountain Areas

Comprise mainly the more gently sloping parts of the Eastern and Western parts of the Usambara Mountains and the Nguru (or Kilindi) Mountains. Suited for tea, coffee, maize, vegetables and for forest.

H.II High Potential Undulating Upland Areas

Comprise exclusively the eastern and southern foot slopes of the Eastern Usambara Mountains and the eastern part of the undulating uplands. Suited for sisal, sunflower,maize,pulses and tree crops.

H.III High Potential Irrigation Areas

Comprise the Lower Mkomazi, Lower Pangani, Lwengera and Lukigura Valleys, Upper Umba Flood Plain, the Lower Msangasi Flood Plain and the tidal coconut irrigation area in the very Lower Pangani Valley. Suited for irrigated rice, mixed upland crops and vegetables.

M.I Moderate Potential Undulating Upland Areas

Comprise a large part of the Western Usambara Footslopes, eastern foothills of the Nguru Mountains and the well-drained, medium textured deep soils of the Coastal Plain. The areas receiving well distributed rainfall are suited for sisal, maize and pulse crops. The areas with lower rainfall and less favourable distribution are suited for sorghum, millet, pulses and forest.

M.II Moderate Potential Lowland Areas

Comprise the Msangasi Valleys, mbuga lands and some alluvial valleys along the Umba and Mbalamu river. Suited for combined irrigated and rainfed cropping of rice, maize and vegetables and for grazing if water resources are not sufficient.

L.I Low Potential Mountain Areas

Comprise the drier part of the Western Usambara Mountains (Malindi, Mlalo). Suited for sorghum, pulse crops, forest and occasionally tree crops.

L.II Low Potential Upland Areas

Comprise the central part of Handeni district, the sandy soils in the Coastal Plain, the northern footslopes of the Usambara Mountains (bordering the Umba Steppe) and part of Western Handeni. Suited for sorghum, millet, pulse crops and forest on the clay and loamy soil types receiving too low rainfall. Suited for cashewnuts, coconut and cassava on the sandy soil types, receiving adequate rainfall.

V.I Very Low Potential Areas

Comprise a large part of Handeni and the south of Pangani district, the outer mountain slopes of the Usambara Mountains, the steep mountain slopes of the Nguru Mountains and the northern part of the Muheza district (Coastal Plain). Suitability restricted to grazing and forest.

R No Agricultural Potential

Comprise most of the land north-east of the Usambara Mountains (Umba Steppe, partly Mkomazi Game Reserve) and the north-west part of Handeni district (actually known as Masaai Steppe, or Handeni controlled area). Not suited for any type of modern agriculture and may therefore be considered for Game Reserve, controlled area. Traditional grazing and game cropping may be envisaged as well.

4. POTENTIAL WATER DEMAND

4.1 SYNOPSIS

The assessment of potential water demand[1] both for irrigation and livestock is obligatory for the eleboration of a general water balance for the 1995 situation. Since potential water demand can exceed the available amount of water, the water balance yields a first impression of water deficits and surpluses in the demarcated catchment areas. Subsequently, potential water demand will have to be adjusted for the potential water resources and hence has a feedback impact on the final Water Master Plan.

4.2 IRRIGATION REQUIREMENT

4.2.1 Potential Irrigable Area

In order to compute the potential water demand for irrigation an assessment of the potential irrigable land has been given in Chapter 3.8. The assessment was based on the soil survey, field surveys of existing irrigation areas, previous studies and existing project proposals (see also Drawing AG 3-1). The potential or proposed projects are discussed in Chapter 3.8.

The net potential irrigable areas, which are shown overleaf (Table AG 4-1), are all rough estimates and have to be verified by detailed soil and topographical surveys. The selection of irrigated crops and crop patterns has been treated in Chapters 3.2 and 3.6.

4.2.2 Potential Irrigation Requirements by Sub-Catchment Area

Unit irrigation requirements which are discussed in Chapter 3.6 have been multiplied by the above-mentioned areas to obtain the potential water requirement per catchment area, an example of which is given in Table AG 4-4.

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1) "Potential demand" means the most likely maximum water requirement, when constraints on water availability are disregarded.

Table AG 4-1

POTENTIAL IRRIGABLE AREAS AND CROP HECTARAGE[1)]

Water-Source (river)	Description Irrigation Area	Sub-Catchment Area No.	A - E Subzone No.	Net Irrigable Area (HA)				
				Rice	Upland Crops	Sugar Cane	Veget. Beans	Irish Potat.
MKOMAZI	Upper Mkomazi valley Bendera-Mikocheni (Upstream of Lake Manka)	PN_2	K_3^a	500	300	-	-	-
MKOMAZI & SONI & VURUNI & PANGANI	Middle Lower Mkomazi valley[2)]	PN_2	K_3^a	1,300	780	-	-	-
	Majengo-Mombo (based on preliminary aerial photo interpretation)	PN_3	K_3^a	800	500	-	-	-
			K_3^b	2,500	1,120	-	-	-
	Lower Mkomazi valley	PN_3	K_3^b	1,200	520	-	-	-
	Mombo-Gomba-Maurui	PN_5	K_3^b	920	280	-	-	-
			K_2^b	1,280	-	-	-	-
	Total Middle Lower Mkomazi Valley			8,000	3,200			

1) Existing projects are included in the Net Irrigable Areas

2) See also W. Halcrow & Partners, Development of the Pangani River Basin, Vol.II B, 1962

Table AG 4-1 (contd.)

Water-Source (river)	Description Irrigation Area	Sub-Catchment Area No.	A - E Subzone No.	Net Irrigable Area (Ha)				
				Rice	Upland Crops	Sugar Cane	Veget. Beans	Irish Potat.
KUMBA MVILINGANO	Mashewe Swamps (north of Magoma)	PN_6	K_2^a	500	-	-	-	-
LWENGERA NKOLE	Lower Lwengera Valley Downstream of Magoma	PN_8	K_2^b	4,900	600	-	-	-
PANGANI	Kwamngumi Prisoners Camp (Fish Ponds)	PC_6	K_2^b	500	-	-	-	-
PANGANI	Lower Pangani Valley, downstream of Pangani Falls	PN_9	M_1^b	-	-	500	-	-
		PC_8	M_1^b	-	-	700	-	-
		PC_9	P_1^b			3,500	-	-
		PS_{12}	H_1	-	-	300	-	-
	Total Lower Pangani Valley					5,000		
MSANGASI	Mkalamo Irrigation Project (East of the railway Korogwe-Dar es Salaam)	MS_7	$P_2(P_1)$	800	500	-	-	-
			H_1^b	3,700	1,500	-	-	-
	Mzundu Valley	MS_5	H_1^a	900	100	-	-	-
MBALUMA	Mnazi Plain	UM_1	L_2	1,200	100	-	-	-
	Kivingo-Antakea	UM_1	L_2	300	50	-	-	-

Table AG 4-1 (contd.)

Water Source (river)	Description Irrigation Area	Sub-Catchment Area No.	A - E Subzone No	Net Irrigable Area (HA)				
				Rice	Upland Crops	Sugar Cane	Veget. Beans	Irish Potat.
UMBA	Kitivo-Lungunza (Upper Umba flood plain)	UM_2	L^2	200	500	-	-	-
			$L1/2^b$	250	550	-	-	-
	Mwakijembe Irrigation Project	UM_5	M_4	-	350*	-	150	-
VARIOUS RIVERS AND STREAMS	Western Usambara Irrigation Complex	UM_1	L_2	-	-	-	150	50
		UM_2	$L1/2^a$	-	-	-	450	300
			$L_1{}^a$	-	-	-	600	150
		PN_4	$L1/2^a$	-	-	-	400	300
			$L_1{}^a$	-	-	-	1,800	500
		PN_6	$L_1{}^b$	-	-	-	1,350	350
		PN_7	$L_1{}^a$	-	-	-	550	150
	Total Usambaras						5,300	1,800
MRUKA	Misoswe Irrigation Scheme1)	SI_3	M_2	50	250	-	-	-
SIGI	Lower Sigi (Unidentified strip along Sigi river)	SI_4	$M_2/M_3{}^6$	=	400	-	-	-

* only maize

Table AG 4-1 (contd.)

Water Source (river)	Description Irrigation Area	Sub-Catchment Area No.	A - E Subzone No.	Net Irrigable Area (HA)				
				Rice	Upland Crops	Sugar Cane	Veget. Beans	Irish Potat.
MNYUSI	Mnyusi Valley	PS_8	H_2	900	700	-	-	-
		PS_9	H_2	1,000	150	-	-	-
		PS_{10}	$H_1{}^a$	200	50	-	-	-
SEGERA	Segera Valley	PS_{11}	$H_1{}^a$	1,350	300	-	-	-

Table AG 4-2

ASSESSMENT OF POTENTIAL IRRIGATION REQUIREMENT FOR AN APPROXIMATE 10% DRY YEAR (IN $M^3 \times 10^6$) PER SUB-CATCHMENT AREA.

Sub-Catchment Area	Rice			Mixed Upland Crops & Potatoes			Sugar Cane			Total Annual Requirement*	
	Fact. = 1.16			Fact. = 1.15			Fact. = 1.20				
	Ha	Sum I	Annual Sub-Total II	Ha	Sum I	Annual Sub-Total II	Ha	Sum I	Annual Sub-Total II	Field	Delivery
UM 1	1,500	20.23	17.44	350	2.96	2.57				20.01	22.24
UM 2	450	6.01	5.18	2,550	21.95	19.09				24.27	26.96
UM 5				500	2.89	2.51				2.51	2.79
PN 2	1,800	21.74	18.74	1,080	14.25	12.39				31.13	34.59
PN 3	4,500	56.77	48.94	2,140	23.15	20.13				69.07	76.74
PN 4				3,000	12.96	11.27				11.27	12.52
PN 5	2,200	26.72	23.03	280	2.99	2.60				25.63	28.48
PN 6	500	2.71	2.34	1,700	8.37	7.28				9.61	10.68
PN 7				700	2.94	2.56				2.56	2.84
PN 8	4,900	60.49	52.15	600	6.57	5.71				57.86	64.29
PN 9							500	6.72	5.60	5.60	6.22
PC 6	500	5.98	5.16							5.16	5.73
PC 8							700	8.80	7.33	7.33	8.15
PC 9							3,500	47.03	39.19	39.19	43.55
PS 8	900	11.36	9.79	100	.91	.79				10.58	11.76
PS 9	1,060	12.62	10.88	150	1.37	1.19				12.07	13.41
PS10	250	3.36	2.90	50	.46	.40				3.30	3.66
PS11	1,350	17.06	14.71	300	2.91	2.53				17.24	19.15
PS12							300	4.03	3.36	3.36	3.73
MS 5	900	11.36	9.79	100	.91	.79				10.58	11.76
MS 7	4,500	53.81	46.39	2,000	18.54	16.12				62.51	69.46
SI 3	50	.55	.47	250	3.39	2.95				3.42	3.80
SI 4				400	5.42	4.71				4.71	5.24

I : Sum of 10% monthly requirements
II: Sum = Fact. * Annual Sub-Total
* : Field requirement = 0.9 * delivery requirement.

Table AG 4-3

ASSESSMENT OF POTENTIAL IRRIGATION REQUIREMENT FOR AN APPROXIMATE AVERAGE YEAR (IN $M^3 \times 10^6$) PER SUB CATCHMENT AREA

Sub-Catchment Area	Rice			Mixed Upland Crops & Potatoes			Sugar Cane			Total Annual Requirement*	
	Fact. = 0.92			Fact. = 0.89			Fact. = 0.98				
	Ha	Sum I	Annual Sub-Total II	Ha	Sum I	Annual Sub-Total II	Ha	Sum I	Annual Sub-Total II	Field	Delivery
UM 1	1,500	16.70	17.04	350	2.00	2.25				19.29	21.43
UM 2	450	5.01	5.11	2,550	13.29	14.93				20.04	22.27
UM 5				500	1.47	1.65				1.65	1.84
PN 2	1,800	15.10	16.41	1,080	10.19	11.45				27.86	30.96
PN 3	4,500	39.35	42.77	2,140	16.57	18.62				61.39	68.21
PN 4				3,000	7.61	8.55				8.55	9.50
PN 5	2,200	18.67	20.29	280	2.15	2.42				22.71	25.23
PN 6	500	2.02	2.20	1,700	3.41	3.83				6.03	6.70
PN 7				700	1.75	1.97				1.97	2.18
PN 8	4,900	40.76	44.30	600	5.28	5.93				50.24	55.82
PN 9							500	5.09	5.19	5.19	5.77
PC 6	500	4.16	4.52							4.52	5.02
PC 8							700	7.12	7.27	7.27	8.07
PC 9							3,500	35.62	36.35	36.35	40.39
PS 8	900	6.81	7.40	100	.65	.73				8.13	9.04
PS 9	1,000	7.57	8.23	150	.97	1.09				9.32	10.35
PS10	250	1.89	2.05	50	.33	.37				2.43	2.69
PS11	1,350	10.21	11.10	300	1.94	2.18				13.28	14.75
PS12							300	3.05	3.11	3.11	3.46
MS 5	900	6.81	7.40	100	.65	.73				8.13	9.04
MS 7	4,500	35.17	38.23	2,000	12.74	14.31				52.54	58.38
SI 3	50	.41	.45	250	2.13	2.39				2.39	2.84
SI 4				400	3.41	3.83				3.83	4.26

I : Sum of 50% monthly requirements
II:: Sum = Fact. * Annual Sub-Total
* : Field requirement = 0.9 * delivery requirement

Table AG 4-4

POTENTIAL MONTHLY IRRIGATION WATER REQUIREMENT FOR CATCHMENT AREA PN_2
(AGRO-ECONOMIC ZONE: K_3^a)

NOTE :- Field requirement = 0.9 x delivery requirement

	10% PROBABILITY OF EXCEEDANCE („Dry year")						50% PROBABILITY OF EXCEEDANCE („Average year")					
	MONTHLY WATER REQUIREMENT				GRAND TOTAL		MONTHLY WATER REQUIREMENT				GRAND TOTAL	
	RICE (DOUBLE) 1600 ha		MIXED CROPS 1100 ha				RICE (DOUBLE) 1600 ha		MIXED CROPS 1100 ha			
	UNIT M^3/HA	SUB TOTAL M^3X10^3	UNIT M^3/HA	SUB TOTAL M^3X10^3	FIELD M^3X10^3	DELIVERY M^3X10^3	UNIT M^3/HA	SUB TOTAL M^3X10^3	UNIT M^3/HA	SUB TOTAL M^3X10^3	FIELD M^3X10^3	DELIVERY M^3X10^3
JAN	1700	2720	1170	1287	4007	4452	543	868	620	682	1550	1722
FEB	197	315	610	671	986	1096	-		330	363	363	403
MAR	837	1339	980	1078	2417	2686	51	81	620	682	763	848
APR	1631	2609	1340	1474	4083	4537	860	1376	890	979	2355	2617
MAY	1376	2201	1180	1298	3499	3888	904	1446	890	979	2425	2694
JUN	1100	1760	1140	1254	3014	3349	743	1188	880	968	2155	2394
JUL	240	384	540	594	978	1087	183	2292	480	528	820	911
AUG	-		180	198	198	220	-		170	187	187	208
SEPT	-		470	517	517	574	-		420	462	462	513
OCT	936	1497	1030	1133	2630	2922	720	1152	820	902	2054	2282
NOV	1861	2977	1190	1309	4286	4762	1332	2131	890	979	3110	3456
DEC	2291	3665	1300	1430	5096	5662	1849	2958	950	1045	4003	4448
	M	19467		12243				11492		8756		

With the exception of the Usambara Irrigation Complex, bananas, maize, cotton, beans and vegetables have been taken together and are denominated "mixed upland crops". Unit irrigation requirements for mixed crops have been derived in order to simplify water demand computations, assuming a certain typical crop-pattern in each of the relevant agro-economic subzones (see Technical Report No. 8, Section II). Adopted mixed crop patterns are based on the existing crop distributions, with a slight decrease in the maize and banana area and an increase in the cotton area in the drier zones. It must be emphasized that the optimum crop patterns could only have been determined on the bas of cost/benefit analysis for the various projects, taking into account the returns and marketing prospects for the individual crops.

Monthly average irrigation requirements (50% probability of exceedance) have been calculated for each of the potential projects and are graphically presented on Drawing AG 3-1, together with available surface water for irrigation (entitled "Irrigation Potentials")

Total annual irrigation requirements by subcatchment area for both a 10% dry year and an average year have been derived from the monthly values, by applying the conversion factors described in Chapter 3.6. All water demand values are delivery requirements, which include 10% conveyance and operation losses (see Tables AG 4-2 and AG 4-3).

Annual irrigation demand, expressed in $m^3 \times 10^3/Km^2$ per sub-catchment area are shown in a diagramatic from on Drawing WE 3-2 entitled "Water Balance of Catchment Areas", together with the potential surface water resources.

4.3 POTENTIAL LIVESTOCK WATER DEMAND

The present and likely future livestock water demand is calculated in Table 4-5 overleaf for an average and a 10% dry year (10% probability of non-exceedence).

Table AG 4-5: POTENTIAL LIVESTOCK WATER DEMAND

Source of Data	Technical Report 8	Section 3.5			Section 3.7		(a) x (b)					
		Livestock Popn. (a) L.U. x 10^3			Unit=Livest. Water Demand (b) litres		Total Water Demand m^3 x 10^3					
							Average Year			10% Dry Year		
AEZ	ACZ 1)	1975	1995 low 2)	1995 high 2)	Average Year	Dry Year	1975	1995 low 2)	1995 high 2)	1975	1995 low 2)	1995 high 2)
H 1	9	16	28	40	6440	7260	103.40	120.32	257.60	116.16	203.28	290.40
2	9	44	75	97	6440	7260	283.36	483.00	624.68	319.44	544.50	704.22
3	11	11	16	18	5700	6180	62.70	91.20	102.60	67.98	98.88	111.24
3/4	10	34	38	38	5700	6180	193.80	216.60	216.60	210.12	234.84	234.84
4	9	24	33	43	6440	7260	154.56	212.52	276.92	174.24	239.58	312.18
K 1	4	10	8	8	5300	5730	53.00	42.40	42.40	53.70	45.84	45.84
2	6	51	71	86	6440	7260	328.44	457.24	553.84	370.26	515.46	624.36
3	7	33	43	50	7920	8390	261.26	340.56	396.00	276.87	360.77	419.50
L 1	4	108	75	75	5300	5730	572.40	397.50	397.50	618.84	429.75	429.75
1/2	4	38	27	27	5300	5730	201.40	143.10	143.10	217.74	154.71	154.71
2	8	17	23	30	7270	7640	123.59	167.21	218.10	129.88	175.72	229.20
M 1	3	10	14	14	3880	4740	38.80	54.32	54.32	47.40	66.36	66.36
2	1	30	12	16	6480	7660	194.40	77.76	103.68	229.80	91.92	122.56
3	1	5	12	16	6480	7660	32.40	77.76	103.68	38.30	91.92	122.56
4	8	8	7	8	7270	7640	58.16	50.89	58.16	61.12	53.48	61.12
P 1	1	7	11	13	6480	7660	45.36	71.28	84.24	53.62	84.26	99.58
2	1	13	20	23	6480	7660	84.24	129.60	149.04	99.58	153.20	176.18
Total		459	513	602	-	-	2791.37	3133.26	3782.46	3085.05	3544.47	4204.60

Notes :
1) Agroclimatic Zone
2) Low = probable, water limiting, High = possible, water non-limiting
3) Difference between this Table and the data of chapter 2.7, Volume VII are due to rounding.

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5. EVALUATION OF POTENTIAL IRRIGATION AND LAND IMPROVEMENT PROJECTS

5.1 GENERAL

5.1.1 Procedures

Since potential irrigation water demand for 1995 has been assessed almost irrespectively of the potential water availability, it will be necessary to adjust the irrigation potentials to potential resources.

Monthly potential irrigation demand is therefore compared with monthly base flow and run-off values per sub-catchment area, in which allowance is made for future domestic, industrial and livestock water supply (see also drawing AG 3-1). The base flow and run-off per sub-catchment are synthetic figures which are derived from a simple rainfall/run-off relationship (see Volume II). This relationship is applied to a specific year of which the rainfall has a 10% probability of non-exceedance (hereafter called: 10% rainfall year). Whenever available, historical stream-flow records have been considered as well.

Groundwater resources have not been taken into account, since their amount is nowhere sufficient to be exploited for major irrigation schemes.

If the potential irrigation requirements exceed the available amount of water in one or more months, three possible adjustments can be envisaged:

(1) Examine storage facilities and provided they are available, balance inflow (run-off + base flow) against potential draw-off over some critical period.

(2) If storage of water is not feasible, reduce either the net irrigable area or change cropping patterns and match irrigation requirements to water availability during the critical period.

(3) Envisage the possibility of importing excess water from a different catchment system to meet the potential requirements.

The optimum water allocation plan may result in a combination of the above mentioned adjustments.

5.1.2 Reliability of Results

The applied irrigation requirements[1] are monthly mean values (50% of exceedance), which are subsequently compared with available water in a 10% rainfall year.

The so derived maximum areas which can be irrigated in a 10% rainfall year must be considered as the "proved minimum area"that can be irrigated in about 8 to 9 years out of 10 (20 to 10% probability). However, in most cases a higher risk is accepted in irrigation design (25 to 30% probability), which implies that the final irrigation project would probably be designed for a greater area than the "proved minimum area". In the case of storage reservoirs it is difficult to judge, whether the ultimate project area can be greater than the "proved minimum area". This depends on the sequences of high and low run-off years, for which approved time series of discharge data are required.

In addition the following should be noted: the calculated run-off and baseflow figures for a 10% rainfall year are spread over the year according to an approximate "normal" distribution"(see Volume II). This procedure however has a smoothening effect, i.e. it gives lower than actual values for the wetter periods and higher than actual values in the drier periods if compared with measured river flows. Consequently, the applied water balance procedure for a "normal distribution" 10% rainfall year, may, in general, result in a too favourable "proved minimum area".

Considering the combined effect of the higher risk and the too favourable "normal distribution" of available water, it can be concluded that the potential project areas are, in general, equal or slightly greater than the "minimum proved areas" found here.

The indication of maximum irrigable areas in this Section must therefore be considered as a first approach in view of the elaboration of a potential water resources development plan, bearing in mind the wide margin of accuracy of data and procedures which is inherent in large-scale planning.

It is obvious that the final design of the individual irrigation projects should be based on adequatly measured flow data over long periods.

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1) In order to avoid over-estimation of the maximum irrigable land, delivery water requirements have been calculated for 15% conveyance losses, notwithstanding the 10% which has been used to assess the potential water demand in the previous section.

5.1.3 Economic Consideration

The above-mentioned water balance appraisal yields in the first place an assessment of the physically possible irrigation potentials in the Tanga Region, the considered constraints being soils, water and physiography. Further, the various irrigation projects have additionally been subject to a simple cost-benefit analysis, resulting in a "long-run return on capital" value. This enables the selection of non-profitable projects and priority ranking when capital becomes a constraint in future development.

Return on capital has been defined as the ratio of

> increment in gross margins less operation and maintenance cost and depreciation (net additional benefits)

to

> total required capital (investment)

The additional benefits have been determined for a "with" and "without" case under future conditions (1995) assuming that fertilizer is not applied. The gross margins are calculated against a shadow labour price of 3/- per hour (see Chapter 3.4). The opportunity price of capital (interest) has not been costed and benefits as well as costs are not discounted to present value. It is further assumed that the usefull lifetime of small and large storage reservoirs is 25 and 40 years respectively.

Finally it should be mentioned that costs and benefits are only assessed for those project areas which can be irrigated in a 10% rainfall year ("proved minimum" conditions). The resulting return on capital values must therefore be strictly considered as a comparative economic valuation of the distinguished potential projects.

5.2 PROJECT EVALUATION BY DISTRICT

A_1 Middle Lower Mkomazi Valley

The possibilities of irrigation in the Lower Mkomazi Valley have been studied in more detail, the results of which have been presented in the "Reconnaissance Study of the Lower Mkomazi Valley" (Oct. 1976).

If the maximum suitable area in the valley is to be brought under controlled irrigation, water will have to be diverted from the Pangani River.

However possible diversions are restricted by the downstream waterrights of Hale Power Station (19.9 m^3/s) and vary consequently considerably over the year. If considering the possibility of direct diversion to the Mkomazi valley, the maximum irrigable area will be limited by the minimum possible diversion, which in dry years approximates 0 m^3/s.

Therefore, the lake Manka Reservoir proposal was found to be the only feasible solution, if the maximum area is to be irrigated. Excess water during the wet seasons should be abstracted from the Pangani river near Buiko to a maximum of 10 m^3/s and stored in the reservoir, for which a dam across the Mkomazi river (Majengo) of 11.5 m height is required.

The total net irrigable area, assuming a dead storage level in the reservoir of 1415 ft, was assessed as follows:

Agro-Economic Sub-Zone	Irrigation Suitability Class (U.S.B.R.)		
	1 (upland crops)	2 (upland crops)	4 (Rice)
K_3^a	-	305	2.905
K_3^b	-	1,413	4,439
Total	-	1.718 ha	7.344 ha

The irrigation of the lower valley downstream of Gomba Gorge was not considered feasible, because:

- difficulties in conveying water to that part of the valley exist
- it is a very poorly drained area, catching flood water from the Soni and Vuruni river
- it receives more rainfall than the middle-lower Mkomazi valley

From simulating of reservoir operation over the last 10 years, plotting possible diversions against drawoff (irrigation demand and reservoir losses), the following conclusions could be drawn:

Dry Years	Critical Period	Required storage volume in m^3 x 10^6					
		Pattern I			Pattern II		
		Upland*	Rice Single	Rice Double	Upland*	Rice Single	Rice Double
		1,718 ha	7,344 ha	5,508 ha	1,718 ha	7,344 ha	-
1966-1967	Aug-March (8 months)	67			-		
1973-1975	Oct-March (18 month)	150			88		

* Upland crops are irrigated in both seasons

A storage volume of 105x $10^6 m^3$ was considered to meet the irrigation requirements of pattern I (rice 75% double cropped) in at least 9 or 8 years out of 10. In approximately one out of 10 years the rice area cannot be double cropped. The dead storage volume was estimated at 11 x $10^6 m^3$.

Costs of the irrigation project are summarized in Table AG 5-1.

Table AG 5-1: COSTS OF MKOMAZI IRRIGATION PROJECT

Sh x 10^6

Item	Costs	Annual running Costs
Intake structure, diversion channel (10 m^3/s) Earth dam (11.5 m)	10.82	0.27
Irrigation and drainage system (9,065 ha)	350.26	5.32

The long run return on capital was found to range between 3.9 and 4.9.

Prior to constructing the new irrigation project, it is recommended to rehabilitate the existing Mombo Irrigation Scheme (240 ha). After the head works and reservoir dam at Manka Lake have been completed, Mombo irrigation scheme will be incorporated in the final Mkomazi Irrigation Project, receiving then water from the reservoir instead of taking it from the Soni river.

The total amounts of water to be released from the reservoir are presented in Table 5-2.

Table AG 5-2 WATER REQUIREMENT OF MKOMAZI IRRIGATION PROJECT (9,065 ha) in m^3 x 10^6

Prob. of exceedance	J	F	M	A	M	J	J	A	S	O	N	D	Year
10%	13.2	1.7	12.6	17.5	12.8	12.9	3.0	0.4	1.0	11.4	17.5	18.3	105.4
50%	6.0	0.6	11.9	15.2	6.7	9.6	1.6	0.3	0.7	7.3	10.9	8.9	86.6

SURFACE WATER BALANCE FOR LWENGERA VALLEY
IN 10% RAINFALL YEAR

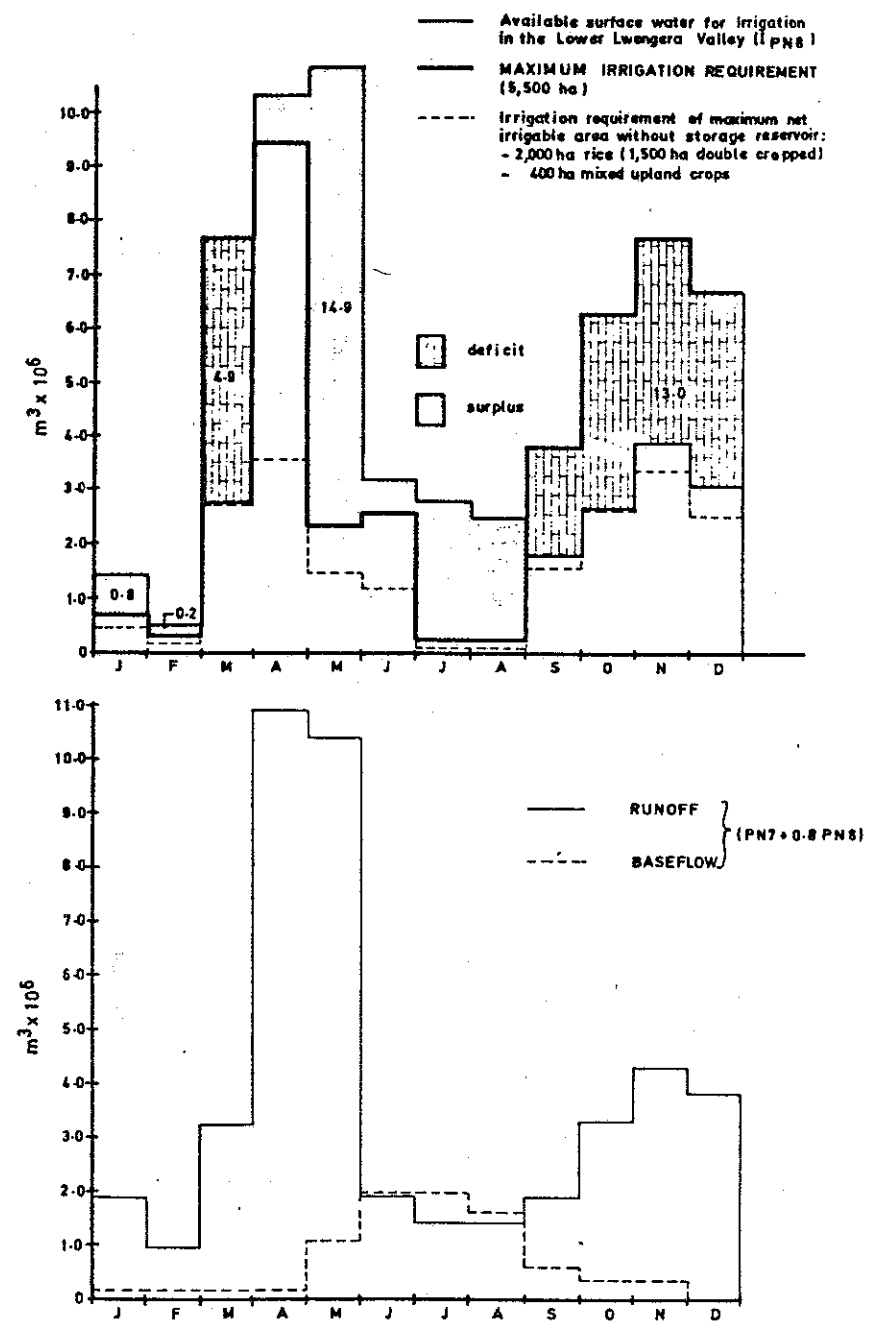

FIG.AG 5-1

A_2 Lower Lwengera Valley

a) Without Storage Reservoir

The available water for irrigation in a 10% rainfall year has been estimated for each month as follows:

$$I_{PN8} = R_{PN7} + 0.8R_{PN8} + (B_{PN7} + 0.8B_{PN8} - C) - $$
$$- (D_{PN7} + D_{PN8}) - IR_{PN7}$$

where

I_{PN8} = available irrigation water in lower Lwengera Valley (catchment area PN8), north of the railway.

R_{PN7}, R_{PN8} = direct run off from catchment area PN7, PN8

C = compensation downstream (= 0.20 x $10^6 m^3$)

D_{PN7}, D_{PN8} = future domestic, industrial and livestock water demand in catchment area PN7, PN8

IR_{PN7} = estimated future irrigation water requirement in catchment area PN7

It is assumed that the proposed irrigation area north of the railway receives surface water from about 80% of the catchment area PN8.

Run-off contribution from catchment area PN6 is not considered in this appraisal, since it is relatively unimportant and is for a great part consumed in the swampy areas north of Magoma (Mashewa).

The so obtained monthly I_{PN8} values are displayed in Fig. AG 5-1. It can be concluded that the potential net area of 5,500 ha (4,900 ha rice and 600 ha mixed crops) cannot be irrigated with the available surface water. The critical months March and October limit the irrigable area to respectively 2,400 ha in the main rainy season (2000 ha rice and 400 ha mixed crops) and 1,900 ha in the second rainy season (1,500 ha rice and 400 ha mixed crops).

An assessment of costs and benefits is given in Table AG 5-3.

Table AG 5-3 COSTS AND BENEFITS IN Sh x 10^6 (WITHOUT RESERVOIR) FOR LOWER LWENGERA VALLEY

Crop	Present Land Use		Proved Minimum Irrigable Area ha	Construction Costs		Additional Gross Margins		Running Costs (O/M)
	Dryland ha	Irrigated ha		New Schemes	Rehabilitation of Schemes	New	Rehabilitation	
Rice	-	350	2000[1]	33.50	1.58	5.61	0.58	1.32
Mixed[2] upland crops	200	-	400	6.08	-	0.81	-	.23
Bananas	(150)	(50)	(150)	-	-	-	-	-
		Total	2400	39.58	1.58	6.42	0.58	1.55

[1] 1500 ha double cropped.

[2] 50% maize and 50% beans

Total net additional benefits are 7.00 - 1.55 = Sh 5.45 x 10^6 per year, whereas total required capital is Sh 41.16 x 10^6 which yields an annual return on capital of 13.2%

The costs of construction have been assessed by applying the following average unit rates:

- irrigation costs	Shs 8,800/ha
- drainage of mbuga soils (valley bottom; rice)	Shs 5,700/ha
- levelling rice basins	Shs 5,000/ha
- leveling upland crops:	Shs 5,600/ha
- Rehabilitation existing schemes	Shs 4,500/ha
- Improvement road infrastructure	Shs 800/ha
- Management of schemes	Shs 150/ha
(with reservoir dam	Shs 200/ha)

Operation, maintenance and depreciation has been estimated at 2.5% of total capital value.

b) With Storage Reservoir

From Fig. AG 5-1 it can be seen that irrigation of the potential suitable area requires a storage reservoir which balances inflow from April to August (surplus) against peak drawoff from September to December (deficit). It is also evident that the irrigation of the maximum area (5,500 ha) can never be attained, since the total water deficit is greater than the total water surplus.

A possible dam site exists some 11 km south of Magamo village, but a considerable area of cultivable land in the valley would be flooded. It is therefore out-weighted by a more favourable dam site (in catchment area PN_7), some 9 km upstream of Magamo at the head of the narrow Lwengera Valley. (See Volume VII, Chapter 3-5).

The maximum yield of this reservoir has been assessed by the mass curve procedure. A theoretical volume (S_V) of some 10 x $10^6 m^3$ could be stored when the inflow mass curve of a 10% rainfall is considered, the critical drawoff being from June to April. (future irrigation and domestic water demand in catchment PN_7 has been deducted from the inflow).

Additionally, monthly run-off volumes for a series of 26 years have been calculated for PN_7. A volume greater than 10 x $10^6 m^3$ could theoreticaly be stored when the inflow curve of a 10% run-off year[1] is applied (1930). For the purpose of project evaluation however only the least favourable inflow mass curve is considered (10% rainfall year).

The maximum irrigable area has now been derived from the following simplified water balance applied to the critical drawoff period:

$$S_V + \Sigma I_i = \Sigma \left[IR_i - 0.8 \ (R_i + B_i)_{PN8} \right] + \Sigma V_{L(i)}$$

where
S_V = storage volume
I_i = reservoir inflow in month i
i = 1,2, ..., 11 (June,....,April)
IR_i = total irrigation requirement in month i
R_i+B_i = run off and baseflow from catchment PN_8 in month i
$V_L(i)$ = evaporation and seepage losses from reservoir in month i

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[1] Total annual run-off exceeded nine in ten years.

Cumulative inflow from June to April in a 10% rainfall year is about 2.2 x $10^6 m^3$ and V_L has been estimated as 1.7 x $10^6 m^3$ (see Volume VII, Chapter 3). Further, by trial and error the following maximum area and the corresponding cumulative drawoff from the reservoir were derived:

i	MONTH	NET AREA (HA)		(A) IR_i m^3 x 10^6	(B) $0.8(R_i+B_i)$ in PN_8 m^3 x 10^6	(A) - (B) m^3 x 10^6	Σ(A)-(B) m^3 x 10^6
		RICE	UPLAND				
1	JUNE	3,200	400	1.7	2.1	-	-
2	JULY	3,200	400	0.1	1.8	-	-
3	AUG	-	400	0.1	1.6	-	-
4	SEPT	2,400	400	2.5	1.4	1.1	1.1
5	OCT	2,400	400	4.2	2.1	2.1	3.2
6	NOV	2,400	400	5.1	2.7	2.4	5.6
7	DEC	2,400	400	3.8	2.3	1.5	7.1
8	JAN	2,400	400	0.5	1.2	-	7.1
9	FEB	-	400	0.2	0.7	-	7.1
10	MAR	3,200	400	4.6	1.2	3.4	10.5
11	APR	3,200	400	5.8	6.6	-	10.5

Hence, the total drawoff of 10.5 x $10^6 m^3$ is balanced against storage volume + inflow (10.0 + 2.2 m^3 x 10^6) less the reservoir losses (1.7 x $10^6 m^3$).

The required dam in the Lwengera river will have the following approximate characteristics:

Effective storage	8.3 x $10^6 m^3$
Total storage	11.7 $10^6 m^3$
Full supply water depth	21.9 m
Dead storage water depth	5.0 m
Total dam height	26.0 m
Catchment area	245 km^2

The cost of the dam is estimated at Sh 53 x 10^6, assuming a concrete gravity dam with a volume of 26,300 m^3.

Costs and benefits of the reservoir alternative are shown in Table AG 5-4

Table AG 5-4 : COSTS AND BENEFITS IN SH x 10^6 (WITH RESERVOIR) FOR LOWER LWENGERA VALLEY

Crop	Present Land Use		Proved Minimum Irrigable Area ha	Construction Costs		Additional Gross Margins		Running Costs (O/M)
	Dryland ha	Irrigated ha		New Schemes	Rehabilitation of Schemes	New	Rehabilitation	
Rice	-	350	3200[1]	57.86	1.58	10.88	0.58	2.26
Mixed upland crops	200	-	400	6.08	-	0.81	-	.23
Bananas	(100)	(50)	(150)					
			DAM	53.00	-			1.33
			Total	116.94	1.58	11.69	0.58	3.82

1) 75% double cropped

The long-run annual return on capital amounts then to

$$\frac{(11.69 + 0.58) - 3.82}{116.94 + 1.58} = 7.1\%$$

c) Conclusion

From a pure economic point of view there would be no inducement to recommend the reservoir alternative, since the cost of the expensive gravity dam outweighs the gain in irrigable area (lower return on capital).

However it must be borne in mind that this Study is dealing with preliminary investigations, and a final decision can only be taken after sufficient river flow data are available. For this purpose two automatic water level recorders have been installed in the Lwengera river. Planning and design of the reservoir dam should further be based on flow measurements over a period of at least 10 years. In addition an adequate rainfall-run off relationship for the considered catchment area would enable the generation of synthetic flow data over the past. Reservoir operations could then be simulated over a series of more then 25 consecutive years, which should be considered as the ultimate minimum for proper reservoir design.

It is recommended to improve the existing small irrigation schemes and to extend the irrigation area in the coming 10 years to a maximum of 2,400 ha (2,000 ha rice and 400 ha upland crops), for which no reservoir is required (first stage). The feasibility of extending the irrigation area up to 3,600 ha (for which the reservoir is required) can be examined independently of the realisation of the first stage.

Reclamation of the poorly drained southern part of the valley will have to be studied in detail and is provisionally costed at some 7 million shillings (about 2,000 ha). Irrigation of this area is no doubt impossible, unless the water could be abstracted from the Pangani river.

The final irrigation requirements of sub-catchment area PN 8 (First stage, 2,400 ha) are summarised in Table AG 5-5.

Table AG 5-5 IRRIGATION REQUIREMENT LOWER LWENGERA VALLEY (PN 8) in m^3 x 10^6 (WITHOUT RESERVOIR)

Probability of exceedance	MONTH OF THE YEAR												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
50%	0.4	0.2	2.7	3.4	1.0	1.1	0.1	0.1	1.5	2.6	3.2	2.6	20.9
10%	1.0	0.4	3.0	3.6	1.1	2.6	0.3	0.1	2.1	4.0	4.9	4.1	23.4

A3 Mashewa Swamps

Analysis of the run-off and baseflow data in a 10% rainfall year for sub-catchment PN6 (from which domestic and irrigation demand in the Usambaras is deducted) shows that some 450 ha of a single rice crop can be irrigated in the major wet season (March-July). When analysing the data from a 10% run off year (1943), about 550 ha of rice could be irrigated from March - July.

It may therefore be concluded that little or no physical constraints exist to irrigate the potential rice area (single cropped) of 500 ha.

Costs of the scheme are estimated at Sh 8.9 x 10^6 and net additional benefits at Sh 0.57 x 10^6 , resulting in an annual return on capital of 6.4%

(land reclamation and drainage	: Sh 9,000/ha
irrigation	: Sh 8,000/ha
Roads	: Sh 800/ha)

A4 Kwamngumi Project

Extension of the existing rice irrigation scheme to an area of some 500 ha does not face any physical constraint as such. However, water will be diverted from the Pangani river which causes a slight change in the Pangani water balance (see Volume VII, Chapter 2 and 3). Costs and benefits of the scheme are assessed as follows:

Rehabilitation (160 ha)	: Sh 720 x 10^3
Construction (340 ha)	6,900 x 10^3
Total	7,620 x 10^3
Net additional gross margins (75% double cropped)[1]	: 1,420 x 10^3
Running costs	450 x 10^3
Long run annual return on capital	12.7%

---

1) Benefits from fishponds are discounted.

B Muheza District

B1 Misoswe Irrigation Scheme

The catchment area of the proposed dam site is estimated at 13 km^2, the direct run-off in a 10% rainfall year being 170,000 m^3 only.

The theoretical maximum storage volume is estimated at some 85,000 m^3 (from inflow mass curve), the critical drawoff period being from November to April. Allowing for dead storage and losses it follows that the reservoir yield in the critical period is about 15,000 m^3/month, which enables the irrigation of some 15 ha of mixed crops.

It is obvious that this project is economically not feasible and it is therefore recommended to abandon any further investment in the scheme.

B2 Mwakijembe Irrigation Scheme

Assuming that the Kenya downstream waterrights can be altered in a satisfactory manner (defined as minimum flow for Kenya instead of maximum abstraction) the feasibility of irrigating the proposed 500 ha has been examined by analysing the flow records of the Umba river at Mwakijembe (station 1B4A).

If the lowest discharges are considered, i.e. 1965 (excluding the extremely dry year 1974), it follows that 500 ha of upland crops can be irrigated from February to April and another 350 ha when strictly confined from October to January.

The annual return on capital of this scheme is estimated at 2.3% when sprinkler irrigation would be applied.

The project is therefore not recommended when judging from an economic angle. It may, however on a smaller scale (50 to 100 ha), be justified from a social angle in order to guarantee the subsistence level of the villagers. The most suitable project location would then still have to be selected.

It is obvious that the actual Tanzanian waterrights (5 cu. secs at maximum) are insufficient to irrigate 500 ha and would limit the maximum irrigable area theoretically to about 320 ha.

B_3 Lower Sigi

Irrigation of 400 ha of upland crops is not limited by the available surface water in the Sigi river, not even if the future water supply scheme for Tanga Town (Mabayani dam) is taken into account (see Drawing AG 3-1). However, careful irrigation is required on the sandy undulating upland soil, preferably by sprinkler irrigation systems.

The total costs are estimated at Sh 8.2 x 10^6 (Sh 20,500/ha) with additional gross margins for beans, maize, cotton and sorghum, estimated at Sh 0.52 x 10^6 and annual running costs of irrigation at Sh 0.88 x 10^6 (total pumping head of about 75 meter). The project is therefore very unlikely to be feasible and not further recommended for detailed investigations.

C Pangani District

C_1 Lower Pangani Valley

Irrigation development in the valleys of the lower Pangani river has been subject to a special study (see Reconnaissance Study of Lower Pangani Valley). This study was confined to a gross area of 4,175 ha, comprising the most compact and easily irrigable part of the valley.

It was recommended to investigate in more detail the possibilities of both sugar cane and rice on a pilot scheme.

The most characteristic results of the study are summarized in Table AG 5-6.

The long run return on capital ranges from 8.5 to 10.0% per annum for the sugar project and from 2.0 to 7.6% for the rice project, both depending on the anticipated yields.

There are no physical constraints to extend the project area to some 5,000 ha of net irrigable land, but the decision should depend on the results of the pilot scheme and the detailed feasibility study.

Table AG 5-6 CHARACTERISTICS OF PROPOSED ALTERNATIVES FOR LOWER PANGANI VALLEY

Description	Net irrigable area ha	Costs[1]		Total required capital Sh x 10^6	System	
		Capital Shx10^6	O/M Shx10^6		Irrigation	Drainage
Sugar cane project (estate)	3,245	178.0	5.04	620-628[2]	furrow	subsoil
Rice - project (small-holder)	3,245	141.4	2.60	151.8	basins	open
Pilot Scheme	100	5.4	.15	11.9	various systems	

1) Respectively construction and O/M of irrigation, drainage and road network

2) Including sugar mill

Average water requirements for the first stage of the project are given in Table AG 5-7

Table AG 5-7 AVERAGE WATER REQUIREMENTS FOR LOWER PANGANI VALLEY (3,245 ha) IN $M^3 \times 10^6$ 1) (SUBCATCHMENT PC 9)

Crop	J	F	M	A	M	J	J	A	S	O	N	D	Year
Sugar	4.3	4.2	3.3	2.3	2.7	2.1	2.4	2.7	3.4	3.4	4.1	2.7	37.5
Rice[2]	.3	-	2.7	1.9	-	3.6	-	-	1.6	1.9	3.1	3.7	18.8

1) Calculated for 15% conveyance losses

2) 75% double cropped in short rainy season (Sept-Jan)

D Lushoto District

D_1 Western and Central Usambara Irrigation Complex

The potential irrigation water demand in the Usambara mountains has been evaluated through the analysis of direct run-off and baseflow per sub-catchment area. The available surface water, after deduction of future domestic water demand, imposes in some catchments a constraint on potential irrigation when no storage reservoirs are considered.

An assessment of the conditional[1] maximum irrigation areas is given in Table AG 5-8.

Table AG 5-8 ASSESSMENT OF MAXIMUM IRRIGABLE AREA IN THE USAMBARAS IN 10% RAINFALL YEAR

Sub catchment area	Agro-economic sub-zone	Net area in ha		Average irrigation demand $10^3 x 10^6$/year	Remarks
		Vegetables Beans	Irish Potatoes		
UM 1	L_2	-	-	-	-
UM 2	$L_1/2^a$	150	-	2.4	Vegetables and beans only from December to May
	L_1^a	450	150		
PN 4	$L_1/2^a$	400	300	9.2	Without additional reservoirs
	$L_1/^a$	1800	250		
PN 6	L_1^b	1350	350	4.3	Doubtful if sufficient land can be found
PN 7	L_1^a	550	150	2.2	
	Total	4700	1200	18.1	

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[1] On condition that the land can be made available.

The major part of the irrigable area can be found in the catchments of the Soni river (PN4) and the Mvilingano river (PN6).

The net areas in Table AG 5-8 indicated could be substantially increased if a number of storage reservoirs could be constructed. The reservoir potentials (water supply and irrigation) are briefly described in Chapter 3.5 of Volume VII, however more information on the location of the various potential schemes is required to assess their feasibility for irrigation purposes.

A major potential reservoir site, for instance, exists some 11 km north of Soni village on the Soni (or Mkusu) river. The storage capacity is estimated at 17 x $10^6 m^3$, yielding some 13 x $10^6 m^3$ in a 10% run off year (See Volume VII, Section 3.5.5). The construction of the reservoir however cannot be recommended before it has been proved that landtenure, reafforestation, soil and water conservation and other development targets do not interfere with additional irrigation developments in the commandable area of the reservoir.

Prior to all irrigation development in the Usambara mountains (rehabilitation as well as extension of schemes), detailed soil and hydrological investigations are required and ecological development plans to be established.

For final water balance purposes of the Pangani river the adjusted irrigation requirements of the Soni catchment (PN4) and Lwengera catchment (PN 6,7 and 8) are given in Table AG 5-9.

Table AG 5-9 IRRIGATION REQUIREMENT OF SONI AND LWENGERA CATCHMENTS IN M^3 x 10^6

Catchment	Prob.	J	F	M	A	M	J	J	A	S	O	N	D	Year
Soni	10%	0.9	0.9	1.2	1.1	1.5	1.0			1.0	2.5	1.9	1.7	12.0
	50%	0.5	0.4	0.4	0.8	0.8	0.6			0.8	1.8	0.9	1.1	9.2
Lwengera	10%	1.9	1.1	5.0	5.4	4.4	4.0	0.4	0.1	2.8	6.1	6.9	5.9	36.9
	50%	0.9	0.8	3.5	4.1	4.2	3.1	0.1	0.1	1.8	3.7	3.6	3.5	29.8

D_2 Upper Umba Flood Plain

No feasible dam sites can be found in the vicinity of the proposed area, according to a first reconnaissance of potential reservoir sites (Chapter 3.5.5, Volume VII). The irrigation possibilities are therefore limited by the available surface water in sub-catchment UM_2 (462 km^2).

The presently irrigated area along the Umba river (Kitivo-Lunguza) receives water directly from the upper Umba catchment (upstream of Kitivo intake:157 km^2). Run-off and baseflow data for both a 10% rainfall (1950) and 10% run-off year (1964), also compared with available flow records (station 1B1B at Kitivo) have been analysed. If future water demand in the Usambara mountains is deducted from the available surface water (including irrigation demand of 150 ha near Mlalo village), not more than 10 ha of rice (from March-May) can be irrigated in a 10% rainfall year.

Additionally the irrigable area in a 50% rainfall year has been estimated in order to analyse the sensitivity of the procedure to different probabilities of rainfall (Table AG 5-10).

Table AG 5-10 ASSESSMENT OF IRRIGABLE AREAS FOR KITIVO-LUNGUZA IRRIGATION SCHEME

Crop	Rice (ha)		Upland Crops (ha)	
Growing season	Mar-May	Oct-Jan	Mar-June	Sept-Jan
10% rainfall year (1950)	10	-	-	-
50% rainfall year (1966)	80	120	150	30
Average of 10% and 50% rainfall year	30	60	100	-

Although careful interpretation of these figures is required, these figures do not justify the proposed extension, of the Kitivo Irrigation Scheme to some 500 ha or more.[1]

Provisionally, it is recommended to envisage in the first place the rehabilitation of part of the existing scheme (160-200 ha). Detailed studies and the recently installed automic water level recorders should provide the required information for the decision on whether extension can be further considered or not. Research on cropping patterns in view of optimising the irrigation water demand should be performed during the rehabilitation phase.

More land in the flood plain could possible by irrigated when water is additionally diverted from the Mtolu river, which joins the Umba river at the eastern edge of the proposed area (catchment area of Mtolu is approximate 300 km^2). The technical feasibility of this proposal is not further investigated. However, the river dries up in some months according to field observations, which makes the possibility of diverting water for irrigation purposes rather doubtful.

The costs and benefits of the recommended rehabilitation have been estimated in table AG 5-11.

Table AG 5-11 COSTS AND BENEFITS OF KITIVO-LUNGUZA REHABILITATION PROGRAMME (200 ha) Sh x 10^6

Crop	Net Irrigable Area (ha)				Additional Gross Margin
	Present Situation		After Rehabilitation		
	Single	Double	Single	Double	
Rice	60	-	80	40	0.13
Upland[a)] crops	50	20	120	20	0.11
				Total	0.24
Cost of rehabilitation (Sh 4,500/ha): O/M + depreciation					0.90 0.11
Estimated return on capital:					14.4%

a) Beans, maize cotton and sorghum. Bananas can be grown along irrigation channels and the river, gross margins of which are equal in both the "with" and "without" case

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1) Irrigators are complaining about insufficient water at present. Time distribution of run-off has become erratic, probably due to deforestation near Mlalo village (low baseflow and high peak run-off).

D3 Mnazi Flood Plain

Similar water constraints as for the Umba plain apply also to the Mnazi irrigation scheme. Analysis of run-off and base flow from the upper catchment of the Mbaluma river (100 km^2 above intake) for a 10 and 50% rainfall year gave the following results:

Table AG 5-12 ASSESSMENT OF IRRIGABLE AREAS FOR MNAZI IRRIGATION SCHEME

Crop	Rice	
Growing season	Mar-May	Oct-Jan
10% rainfall year (1970)	-	-
50% rainfall year (1963)	150	60
Average of 10 and 50% rainfall year	80	30

Bearing in mind that many difficulties were faced in assessing run-off and in particular baseflow data for the UM_1 catchment area (flow data are not available), the figures in Table AG 5-12 require updating in the future.

The previous proposed extension to 200 ha 1) must however be considered as too optimistic and since feasible storage facilities are absent, only improvement of the existing area under irrigation (about 100 ha) can be recommended. The costs are roughly estimated at

- rehabilitation weir, intake and main canal: : Sh 200 x 10^3
- land levelling (100 ha): Sh 150 x 10^3

Total: Sh 350 x 10^3

- O/M costs : Sh 20 x 10^3

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1) See Chapt. 2.6

D4 Kivingo-Antakae

Irrigation along the Mbaluma river downstream of Mnazi (near Kivingo village) is theoretically not possible, if the synthetic run-off data are considered. However, irrigation in the very wet years can still be possible, the total area depending on the hazard of flood flow. For the purpose of the Water Master Plan, it is assumed that the maximum irrigable area in a 10% dry year is less than 10 ha and is therefore not further considered.

E Handeni District

E1 Mkalamo Irrigation Project

The potential dam site is situated at the outlet of the Msangasi sub-catchment areas MS 1 to MS 6. In order to get a safe idea about the potential reservoir inflow, only run-off from the 3 direct overlaying catchments (MS 4,5 and 6) are taken into account, assuming that run-off and baseflow from the 3 most remote catchment areas is either consumed by evaporation in Mbuga areas or recharges the shallow aquifers in the catchments MS1-MS3.

From the inflow mass curve($\sum_4^6 MS_i$) in a 10% rainfall year it could be derived that a maximum of 13.2 x $10^6 m^3$ can be stored, the critical drawoff period being from June-November.

The total annual yield is estimated at 31.3 x $10^6 m^3$, being inflow (35.5 x $10^6 m^3$) less reservoir losses (4.2 x $10^6 m^3$).

After matching the cumulative irrigation demand in the critical period to the shape of the inflow mass curve (minus losses) 1), it can be concluded that a maximum of some 2,500 ha of rice (of which about 2,000 ha can be double cropped) and some 1,450 ha of upland crops can be irrigated, for which a dam with the following characteristics is required:

Effective storage volume : 11.1 x $10^6 m^3$
Total storage volume : 15.7 x $10^6 m^3$
Full supply water depth : 18.9 m
Dead storage water depth : 3.0 m
Dam height : 24.0 m
Embankment volume of dam : 149 x $10^3 m^3$

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1) See mass curve procedure under E_2 (Mnyusi valley)

Costs and benefits are summarized in Table AG 5-13:

Table AG 5-13 COSTS AND BENEFITS OF PROPOSED MKALAMO IRRIGATION SCHEME IN SH x 10^6

Crop	Proved minimum net area ha Single	Double	Construction cost	Additional gross margins	Running costs
Rice	2,500	2,000	50.8	9.0	1.8
Mixed upland crops1)	1,450	1,450	22.0	4.2	0.8
	Dam	Dam	5.2	-	0.2
		Total	78.0	13.2	2.8

1) Maize, beans, vegetables and bananas

The long run annual return on capital amounts to

$$\frac{13.2 - 2.8}{78.0} = 13.3\%$$

If the run-off in a 50% rainfall year is alternatively routed through the reservoir with the above dimensions, it follows that approximately 5,000 ha of rice (of which 4,000 ha double cropped) and 3,000 ha of upland crops could be irrigated from the reservoir. The total inflow amounts then to 147.8 x $10^6 m^3$, the critical drawoff period being from June to September (4 months).

In the final design of the dam the feasibility of a greater storage volume should also be considered in order to allow for sufficient flood protection in the wet years.

From the foregoing it may be concluded that physical and economic conditions for irrigation development seem to be rather promising. It should however be noted that calculated run-off data from the Msangasi catchment are considered less accurate, due to the little information of areal rainfall distribution over the extensive catchment area. In addition, the few available flow records are not reliable.

EXAMPLE RESERVOIR MASSCURVE OPERATION
(CATCHMENT AREA PS8, DAM TYPE II)

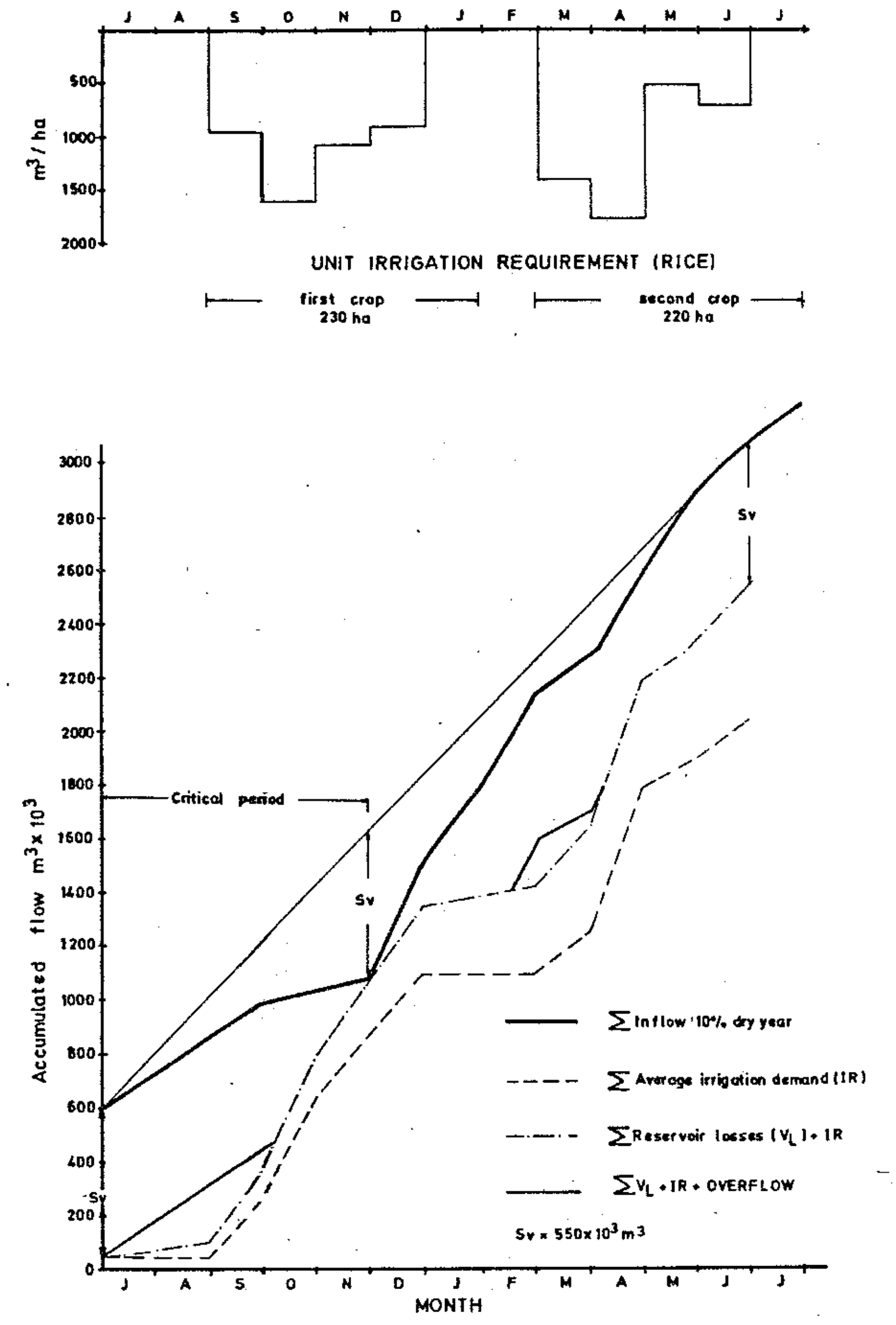

FIG AG 5-2

It is therefore recommended to continue hydrological investigations for some years as well as to undertake a soil survey before commencing a feasibility study for the proposed irrigation scheme. The newly extended hydrometeorological observation network in the Msangasi catchment area is to provide the required basic data.

E_2 Mnyusi Valley

The proposed irrigation area is mainly located in catchment area PS. 10, which receives surface water from both catchment area PS8 and PS 9.

Analysis of run-off and baseflow[1] show that significant development of irrigation is only possible by balancing run-off (mostly in one or two month only) against drawoff.

General feasibility of storage reservoirs just upstream of the valley is classified as moderate (type II) in both PS8 and PS9 (Drawing No. WE 11-1, Vol. VII). However major potential dam sites are not yet localised. The following assessment of maximum irrigable area must therefore be considered as a theoretical example, assuming that a feasible damsite exists on or near to the required place. The characteristics of the theoretical required dams have been derived from the generalised information on storage reservoirs in Chapter 3.5 and 3.6 of Volume VII.

Further the maximum irrigable area is derived by matching cumulative irrigation demand plus losses to the cumulative inflow, which is shown in Fig. AG 5-2 and 5-3.

The maximum irrigable area (A max) during the critical drawdown period can in general be estimated as follows:

$$A_{max} = \frac{S_V + I - V_L}{IR} \quad \text{(ha)}$$

where

S_V = Storage volume in m^3

I = inflow over a critical period (m^3)

V_L = evaporation and seepage losses over critical period (m^3)

IR = unit irrigation required in critical period in m^3/ha

The critical period will be determined by the interaction of inflow and peak demand and is for PS8 5 months (July-November) and for PS9 4 months (July-October).

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[1] Baseflow in these catchments is zero in a 10% year for almost all months. Since this was considered as an underestimation, average base flow of a 10 and 50% rainfall year has been applied for this exercise.

EXAMPLE RESERVOIR MASSCURVE OPERATION (CATCHMENT AREA PS9, DAM TYPE II)

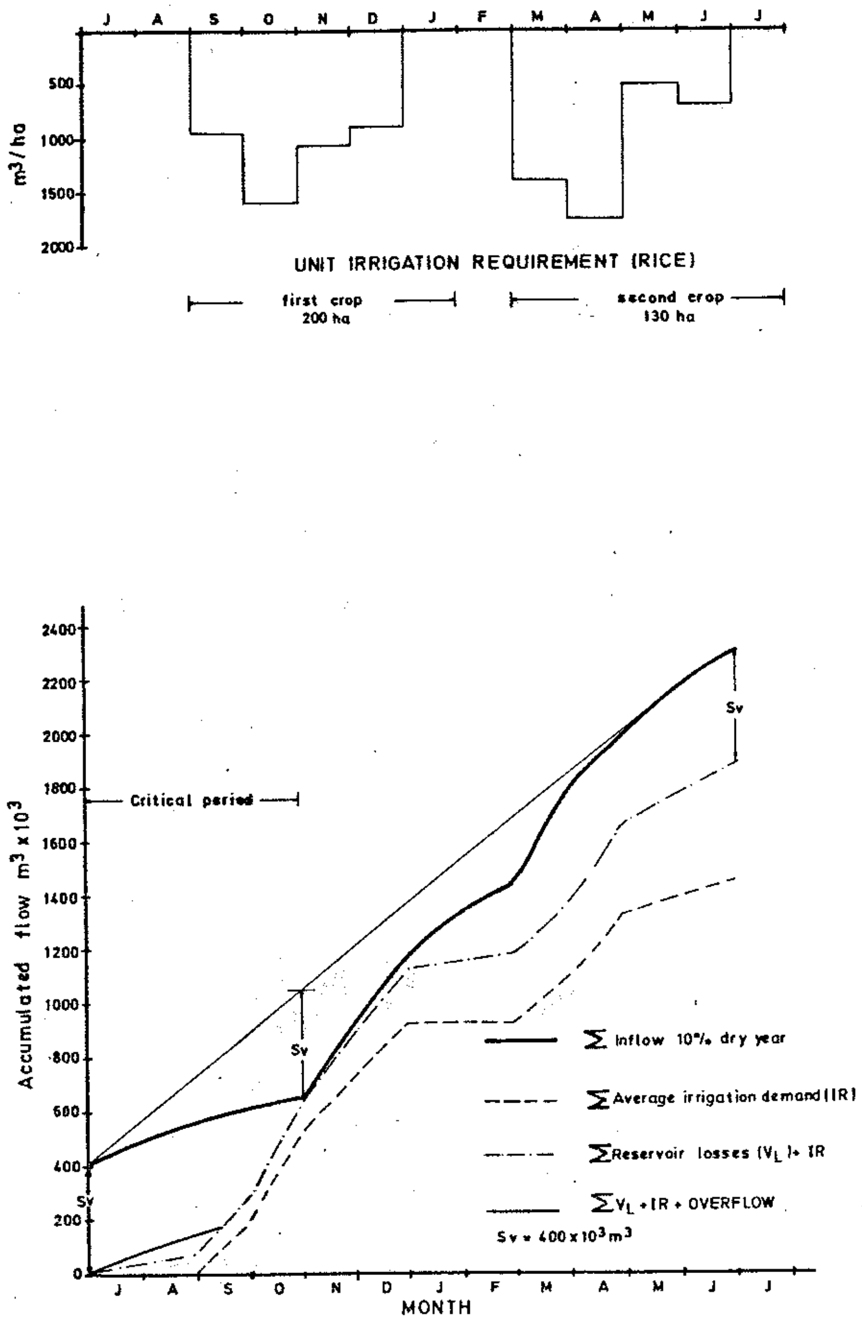

FIG. AG 5-3

The characteristics of the theoretical required storage reservoirs are summarised below:

	PS 8	PS 9
Effective storage volume	310 x $10^3 m^3$	170 x $10^3 m^3$
Total storage volume	1,050 x $10^3 m^3$	700 x $10^3 m^3$
Full supply depth	9.1 m	7.4 m
Dead storage depth	6.3 m	4.9 m
Total dam height (H)	12 m	10.5 m
Dam volume[1] = 97.5 $(H^{5/2} + H^{3/2})$	53 x $10^3 m^3$	38 x $10^3 m^3$
Catchment area	399 km^2	200 km^2
Irrigable area (rice)	230 ha	200 ha
Double cropped area	220 ha	130 ha

Costs and benefits of the irrigation scheme are assessed in Table AG 5-14

Table AG 5-14 COSTS AND BENEFITS OF MNYUSI VALLEY IRRIGATION IN SH x 10^6

Item	Present Land Use (ha)		Proved Minimum Project Area (ha)		Construction Costs	Additional Gross Margins	Running Costs
	Single	Double	Single	Double			
Irrigated rice	100	-	430	350	8.73	1.35	0.31
Dam PS 8					1.90	-	0.08
Dam PS 7					1.40		0.06
Total:					12.03	1.35	0.35

Long run return on capital is subsequently estimated at

$$\frac{1.35 - 0.35}{12.03} = 8.3\%$$

---

[1] See Chapter 3, Volume VII

Considering the theoretical case that runoff and baseflow could be diverted straightforward to the irrigation area by intake structures (no reservoirs) only 180 ha of rice could be irrigated in the main wet season with almost no double cropping possible. The return on capital would then be 0.4 %.

The alternative of diverting the water from the Pangani river is not further considered. When the maximum possible amount of water at Buiko will be diverted to Lake Manka, the remaining flow in the Pangani river during the driest month will be just sufficient to quarantee Hale's waterrights of 19.9 m^3/s. Allocation of additional waterrights on the Pangani river between Buiko and Hale seems therefore not quite realistic.

It must further be noted that water for domestic purposes in the considered sub-catchment areas can as far at it is not supplied by the Handeni Trunk Main probably be supplied reservoirs as well, since the domestic requirements are small compared to irrigation demand.

For establishing the water balance of the Pangani river the irrigation requirements for the potential schemes (catchment areas PS 8, 9 and 10) are shown in Table AG 5-15.

Table AG 5-15: IRRIGATION REQUIREMENTS MNYUSI VALLEY IN $M^3 \times 10^6$ (430 ha)

Probability of exceedance	MONTH OF THE YEAR												YEAR
	J	F	M	A	M	J	J	A	S	O	N	D	
10%	0.2	-	0.5	0.6	0.5	0.4	0.1	-	0.5	0.8	0.9	0.7	4.5
50%	-	-	0.5	0.6	0.2	0.2	-	-	0.4	0.7	0.4	0.4	3.7

E 3 Segera Valley and Mzundu Valley

A similar procedure has been followed to assess the maximum irrigable area in the Segera Valley (catchment area PS 11) and the Mzundu Valley (MS 4). The results are summarised below:

	Segera (PS 11)	Mzundu (MS 4)
Dam type	II	III
Effective storage volume	670 x 10^3 m^3	2,250 x 10^3 m^3
Total storage volume	1,190 x 10^3 m^3	3,600 x 10^3 m^3
Full supply water depth	9.7 m	12.5 m
Dead storage water depth	4.4 m	5.1 m
Dam height	12.7 m	15.5 m
Dam volume	60 x 10^3 m^3	130 x 10^3 m^3
Catchment area	150 km^2	500 km^2
Single rice crop area	210 ha	800 ha
Double rice crop area	130 ha	750 ha 1)
Capital cost	Sh 6.36 x 10^6	Sh 20.79 x 10^6
Additional gross margin	Sh 0.60 x 10^6	Sh 2.84 x 10^6
Running Costs	Sh 0.24 x 10^6	Sh 0.75 x 10^6
Return on capital	5.6 %	10.1 %

It should be noted that irrigation in the Mzundu valley will interfere to a certain extent with the inflow in the proposed storage reservoir in the Msangasi river (Mkalamo project). If both projects are to be simultaneously considered, allowance should be made for this effect.

Table AG 5-16: IRRIGATION REQUIREMENTS SEGERA VALLEY (PS 11) IN M^3 x 10^6 (210 ha)

Probability of exceedence	MONTH OF THE YEAR												YEAR
	J	F	M	A	M	J	J	A	S	O	N	D	
10%	0.1		0.2	0.2	0.2	0.2	0.1		0.2	0.5	0.6	0.4	2.3
50%	-		0.2	0.2	0.1	0.1	-		0.2	0.3	0.2	0.2	1.6

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1) This high rate of double cropping can only be achieved with increased technology.

E_4 Other Valleys

Similar considerations as discussed in E_2 and E_3 can be given for many other small valleys, where regular irrigation is only possible if storage facilities exist (intermittent rivers).

The feasibility of small scale irrigation in such valleys which have suitable soils (mostly 'mbuga' soils) depends among other things on the storage characteristics of the required dam in relation to the maximum irrigable (and double cropped) area.

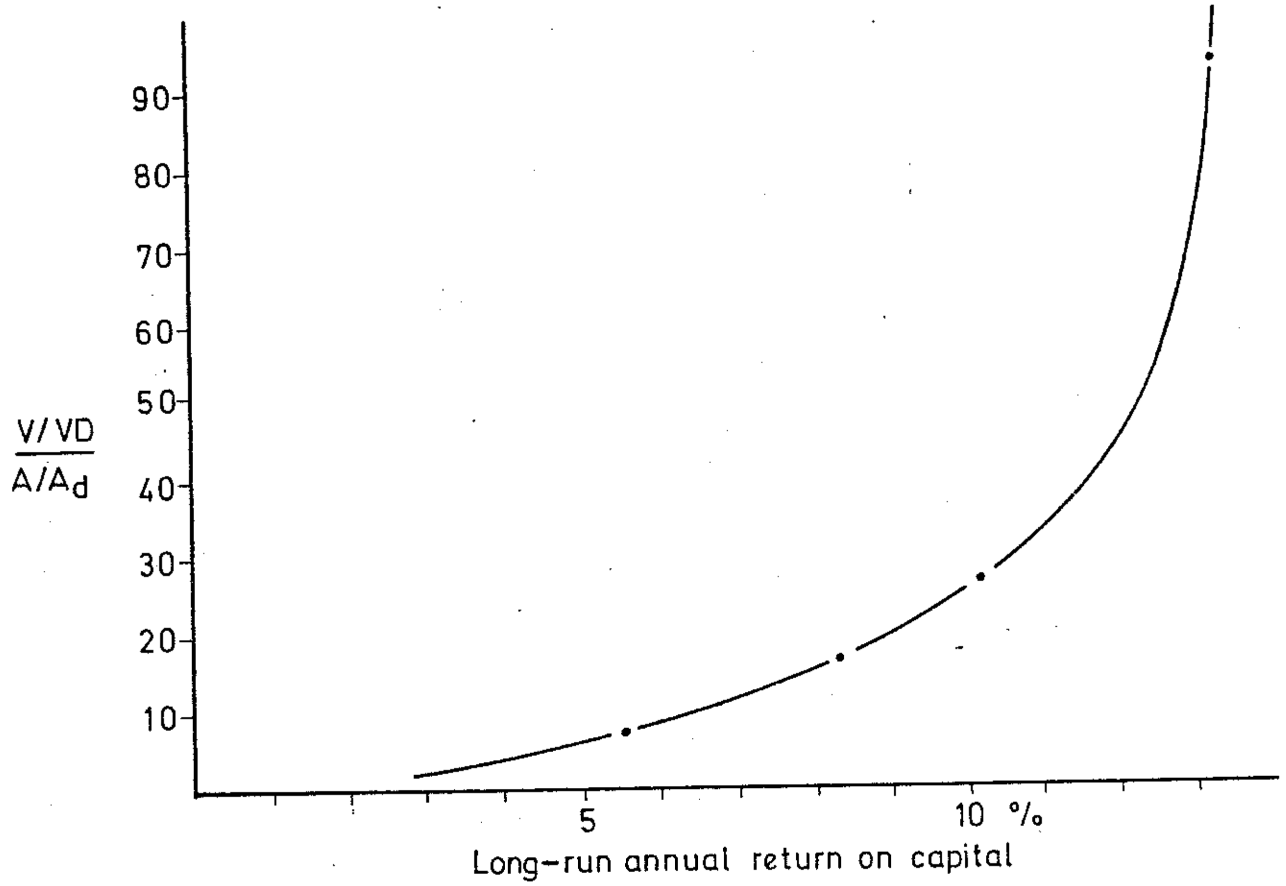
It has been tried below to derive a general relationship between significant characteristics of the schemes and the estimated long run return on capital. The characteristics are expressed in the dimensionless ratio:

$$V/VD: A/A_d$$

where V/VD is the ratio of storage to dam volume, and A/A_d is the ratio of total irrigation are to double cropped area.

From the previous appraisals the following relation could be derived:

	$\frac{V/VD}{A/A_d}$	Return on capital %
Mkalamo project	92	13.3
Mzundu valley	26.0	10.1
Mnyusi valley	15.6	8.3
Segera valley	6.9	5.6



From the foregoing approximate relationship, the following general conclusion can be drawn, bearing in mind that not all determinant factors of the schemes could have been taken into account:

> If for any potential project the ratio of V/VD to A/Ad is less than 8, the feasibility is considered doubtful. Such projects should not be further considered, if still better possibilities are available.

If multi-purpose reservoirs are contemplated, different appraisal criteria should be applied.

Notice in the graph that return on capital must have an assymtotical boundary (13-14%), due to the decreasing proportion of dam construction costs.

5.3 SUMMARY AND PROJECT PHASING

In Table AG 5-17 a summary of the assessed irrigable areas is presented together with the estimated irrigation water consumption under 10% rainfall conditions (see also Drawing WE 7-2).

Based upon the foregoing evaluation of irrigation potentials, a summary of projects which are provisionally recommended for detailed feasibility studies is given in Table AG 5-18. The total "feasible" irrigation potential is estimated at some 27,670 ha, for which a total capital (at present value) of Sh 707.29×10^6 is required.

Phasing of project implementation should be considered in relation to the regional development outlines and has to be adapted to the available funds.

Nevertheless, the increasing foodshortage and land pressure will most likely require an accelarated development of potential resources. Assuming that funds can be made available, an example of possible project phasing is presented in Table AG 5-19 for the coming 15 to 20 years.

Finally it must be emphasised, that implementation and management of the potential projects will inquestionably require the extension and re-organisation of the present Irrigation Division, both on national and regional level. An Irrigation Enactment should therefore be passed by the government in which legislation of landtenure, water rights, gazetting, operation and maintenance should be regulated. More details on proposed organisation and management of water development projects are given in chapter 8 of Volume VII.

Table AG 5-17

Table AG 5-17: ASSESSMENT OF PHYSICALLY POTENTIAL IRRIGABLE AREAS IN TANGA REGION

District	Name or location	Net maximum irrigable area in ha							
		10% rainfall year				50% rainfall year			
		Rice		Upland		Rice		Upland	
		S	D	S	D	S	D	S	D
Korogwe	Middle Lower Mkomazi Valley (with lake Manka reservoir)	7,345	-	1,720	1,720	7,345	5,510	1,720	1,720
	Lower Lwengera Valley (without reservoir)	2,000	1,500	400	1,400	4,900	3,920	600	600
	Mashewa Swamps	450	-	-	-	500	-	-	-
	Kwamngumi project	-	-	-	-	-	-	-	-
Muheza	Misoswe irrigation scheme			15				40	15
	Mwakijembe irrigation scheme			500	350			500	5,000
	Lower Sigi							400	
Pangani	Lower Pangani Valley (sugar cane)				5,000				5,000
Lushoto	Western and Central Usambaras			5,900	4,100			7,100	5,300
	Kitivo-Lunguza Scheme	10				120	80	150	30
	Mnazi Scheme	-	-	-	-	150	60	-	-
Handeni	Mkalamo Project	2,500	2,000	1,450	1,450	5,000	4,000	3,000	3,000
	Mnyusi Valley	430	350	-	-	700	450	-	-
	Segera Valley	210	130	-	-	450	325	-	-
	Mzundu Valley	800	750	-	-	1,600	1,500	-	-

Note: S = Single cropped
D = Double cropped

Table AG 5-17 (contd.)

District	Name or location	Most likely feasible project area				Estimated irrigation water consumption in 10% rainfall year	Construction costs for most likely feasible project area
		Rice		Upland			
		S	D	S	D	$m^3 \times 10^6$/year	Sh x 10^6
Korogwe	Middle lower Mkomazi Valley (with lake Manka reservoir)	7,345	5,510	1,720	1,720	105.4	361.08
	Lower Lwengera valley (without reservoir)	3,000	2,100	500	500	20.9	57.85
	Mashewe swamps	500	-	-	-	2.4	8.90
	Kwamngumi project	500	375	-	-	5.0	7.62
Muheza	Misoswe irrigation scheme			0	0	0.2	-
	Mwakijembe irrigation scheme			500	350	3.1	9.05
	Lower Sigi			400	400	4.3	8.20
Pangani	Lower Pangani Valley (sugar cane)			5,000	5,000	57.7	274.27
Lushoto	Western and Central Usambaras					18.1	-
	Kitivo-Lunguza scheme	60	30	100	-	0.1	0.72
	Mnazi scheme	80	30	-	-	0.0	0.32
Handeni	Mkalamo Project	2,750	2,200	1,600	1,600	31.3	85.36
	Mnyusi Valley	470	380	-	-	3.7	12.84
	Segera Valley	230	140	-	-	1.6	6.77
	Mzundu Valley	850	750	-	-	7.1	21.81
	Total	15,944	11,633	9,723	9,573	261.2	

Note: S = Single cropped
D = Double cropped

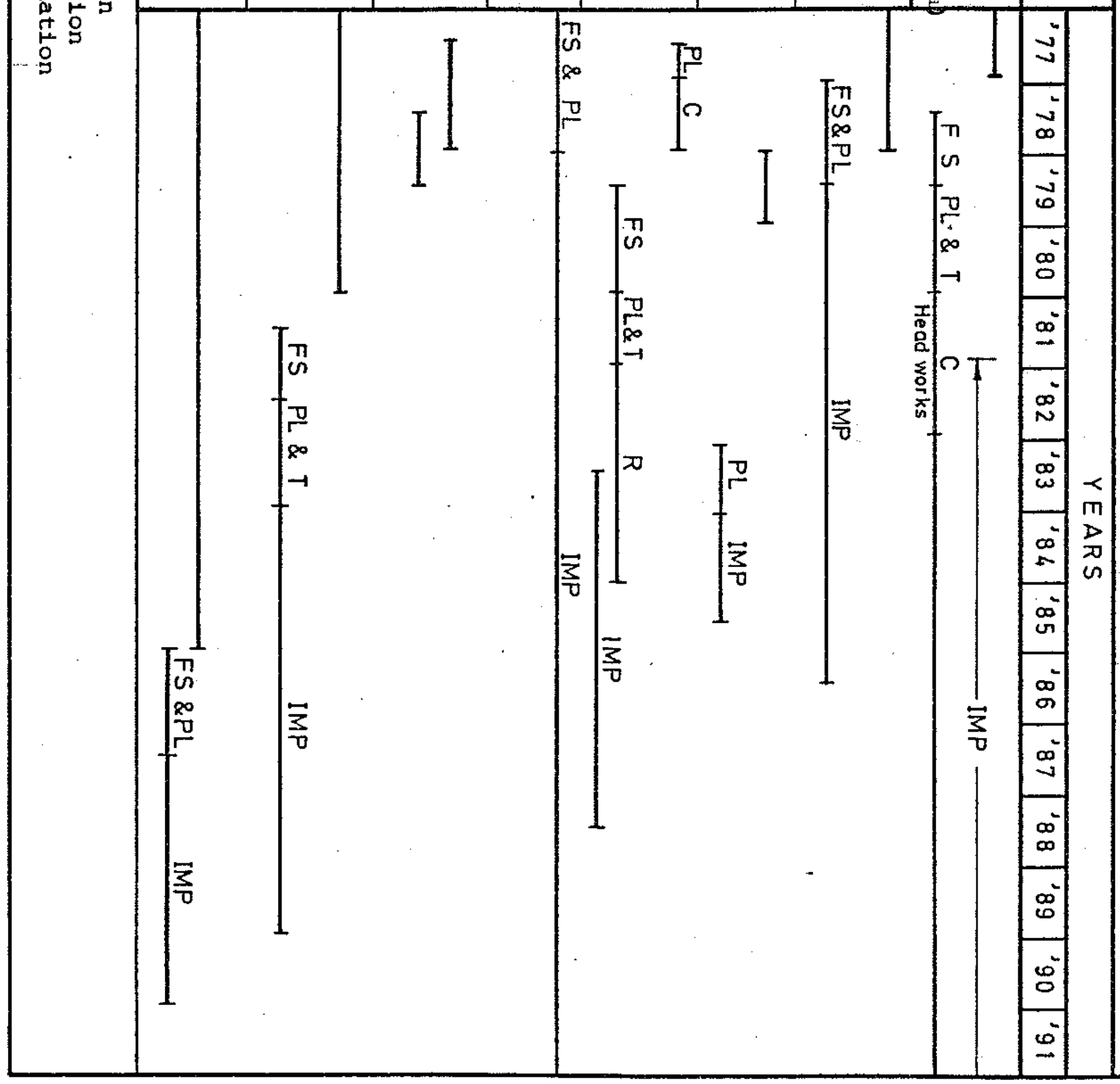
Table AG 5-18 SUMMARY OF POTENTIAL IRRIGATION PROJECTS RECOMMENDED FOR DETAILED FEASIBILITY STUDIES

District	Name or location	Recommended Net Project Area		Assessment of		
		Rice ha	Upland Crops ha	Capital Costs Sh x 10^6	Running Costs (O/M) Shx10^6	Long Run Return On Capital (min-max) %
Korogwe	Rehabilitation of Mombo Scheme	(240)	-	1.20	(0.12)	9.2-17.5
	Middle Lower Mkomazi Valley	7,345	1,720	361.08	5.59	2.7-3.6
	Lower Lwengera valley (including rehabilitation of 350 ha), without reservoir	3,000	500	57.85	1.97	6.1-13.2
	Kwamngumi project including - rehabilitation	500	-	7.62	0.45	12.7
Pangani	Lower Pangani Valley -Pilot Scheme -Rice Project 1st stage -Sugar Project 1st stage	 (40) 3,245 -	 (60) - (3,245)	 5.37 141.40 (178.00)	 0.15 2.60 (5.04)	 - 2.0- 7.6 8.5-10.0
Lushoto	Western and Central Usambaras (Mainly rehabilitation)	-	6,000	26.55	1.83	-
	Rehabilitation Kitivo Scheme	90	120	0.90	0.11	0.0-14.4
	Rehabilitation Mnazi Scheme	100*	-	0.35	0.02	-
Handeni	Mkalamo Project	2,750	1,600	85.36	3.07	11.9-13.3
	Mnyusi Valley	470	-	12.84	0.47	6.9- 8.3
	Segera Valley	230	-	6.77	0.25	5.2- 5.6
	Total	17,730	9,940	707.29	16.51	

* Single cropped

Table AG 5-19: PHASING OF IRRIGATION PROJECT IMPLEMENTATION

NAME	DESCRIPTION
Mkomazi Valley	Rehabilitation Mombo Irr. Scheme (240 ha) Development of New Irrigation Project (9,065 ha)
Lower Lwengera Valley	Rehabilitation (350 ha) New Projects (3.150 ha)
Kwamngumi Project	Rehabilitation (160 ha) Extension (500 ha)
Lower Pangani Valley	Pilot Scheme (100 ha) Development of New Project (3,245 ha)
Western Usambaras	Rehabilitation and Improvement (6,000 ha)
Kitivo Scheme Mnazi Scheme	Rehabilitation (200 ha) Rehabilitation (100 ha)
Mkalamo Irrigation Project	Hydrological and Soil Investigation Development of New Project (4,350 ha)
Mnyusi and Segera Valley	Hydrological Investigations Irrigation Projects (700 ha)



F.S = Feasibility study
PL = Planning
T = Tendering
C = Construction
IMP = Implementation
R = Land reclamation

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