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.

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 Scheme 1)	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 Fact. = 1.16			Mixed Upland Crops & Potatoes Fact. = 1.15			Sugar Cane Fact. = 1.20			Total Annual Requirement*	
	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 Fact. = 0.92			Mixed Upland Crops & Potatoes Fact. = 0.89			Sugar Cane Fact. = 0.98			Total Annual Requirement*	
	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						MONTHLY WATER REQUIREMENT					
	RICE (DOUBLE) 1600 ha		MIXED CROPS 1100 ha		GRAND TOTAL		RICE (DOUBLE) 1600 ha		MIXED CROPS 1100 ha		GRAND TOTAL	
	UNIT M^3/HA	SUB TOTAL $M^3 \times 10^3$	UNIT M^3/HA	SUB TOTAL $M^3 \times 10^3$	FIELD $M^3 \times 10^3$	DELIVERY $M^3 \times 10^3$	UNIT M^3/HA	SUB TOTAL $M^3 \times 10^3$	UNIT M^3/HA	SUB TOTAL $M^3 \times 10^3$	FIELD $M^3 \times 10^3$	DELIVERY $M^3 \times 10^3$
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	292	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
		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 basis 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

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.

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 $m^3 \times 10^6$					
		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

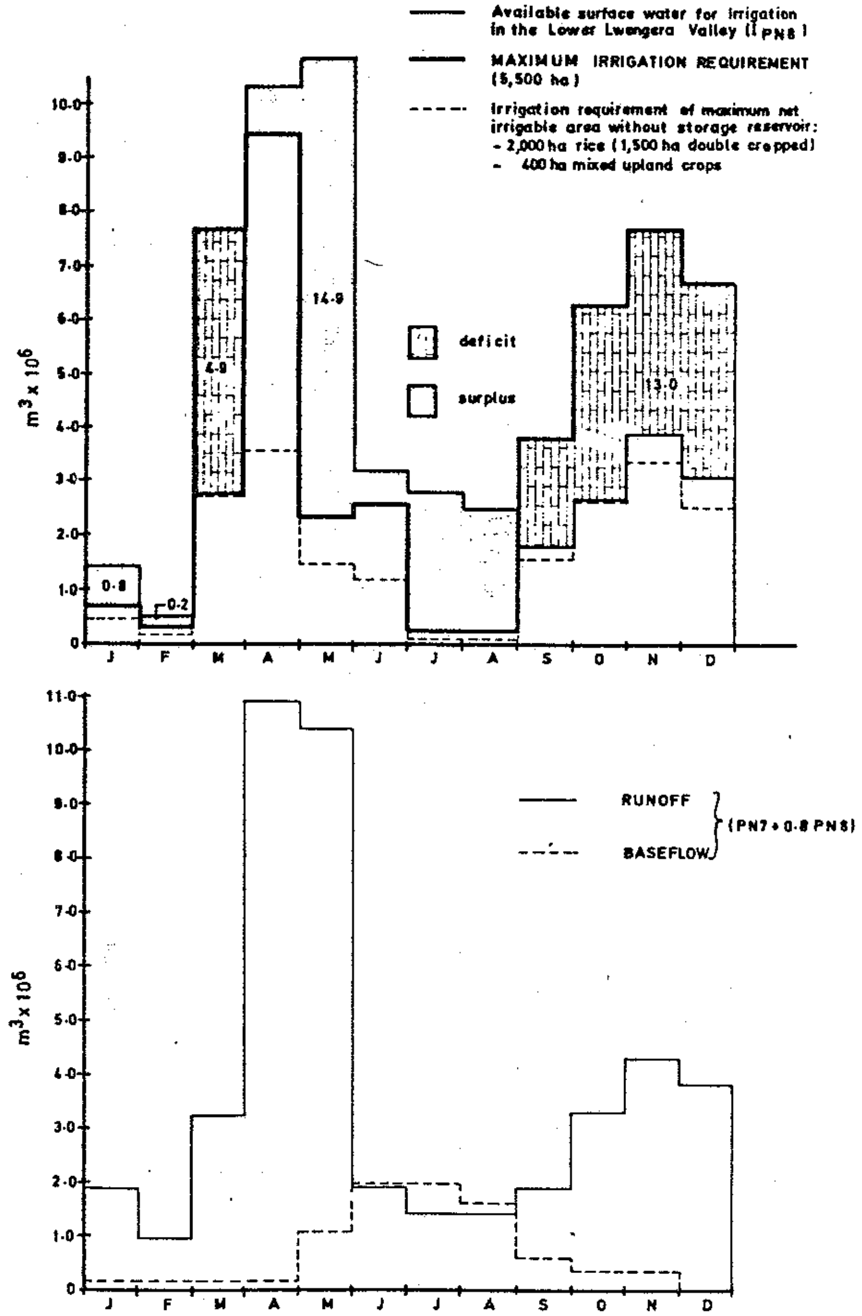


FIG.AG 5-1

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 ($= 0.20 \times 10^6 m^3$)

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 (with reservoir dam	Shs 150/ha 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:

$$S_v + \Sigma I_i = \Sigma [IR_i - 0.8 (R_i + B_i)_{PN8}] + \Sigma V_L(i)$$

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

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) RICE	UPLAND	(A) IR_i $m^3 \times 10^6$	(B) $0.8(R_i+B_i)$ in PN_8 $m^3 \times 10^6$	(A) - (B) $m^3 \times 10^6$	Σ(A)-(B) $m^3 \times 10^6$
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: Dryland ha	Present Land Use: Irrigated ha	Proved Minimum Irri-gable Area ha	Construction Costs: New Schemes	Construction Costs: Rehabi-litation of Schemes	Additional Gross Margins: New	Additional Gross Margins: Rehabi-lita-tion	Running Costs (O/M)
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 $m^3 \times 10^6$ (WITHOUT RESERVOIR)

Probability of exceedance	J	F	M	A	M	J	J	A	S	O	N	D	Year
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 x 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

D1 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	

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

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

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

E_1 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 $10^3 m^3$

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 crops[1)]	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)

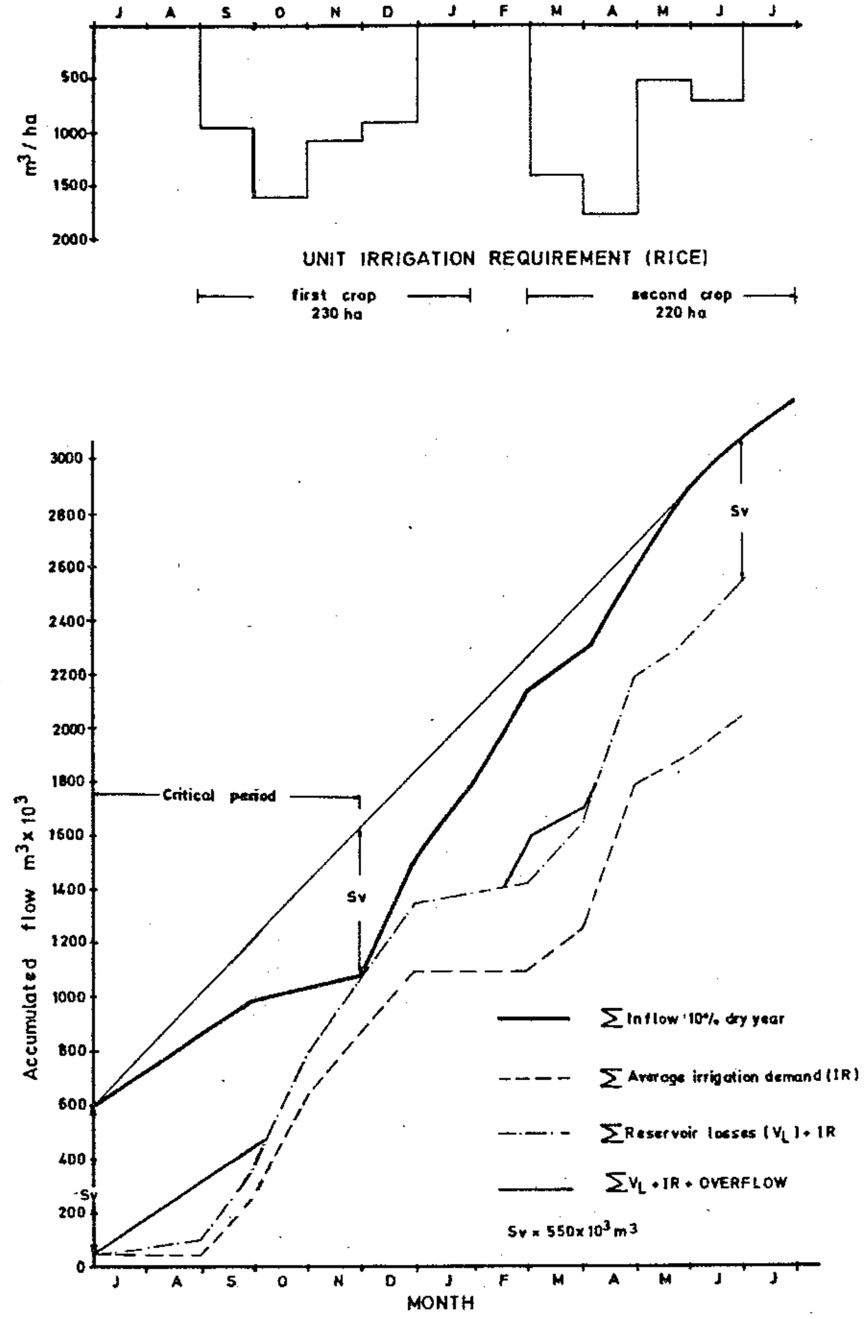


FIG AG 5-2

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)

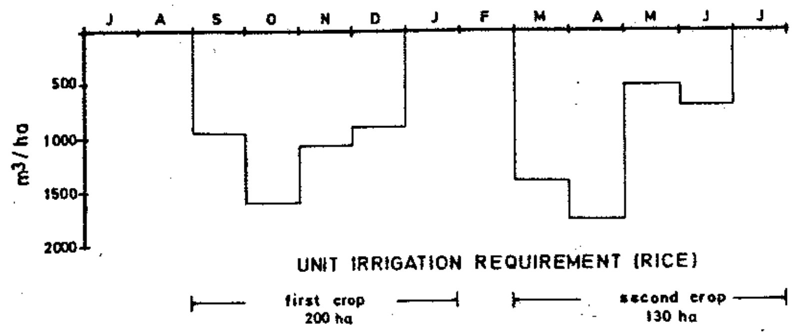
V_L = evaporation and seepage losses over critical period (m^3)

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).

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)



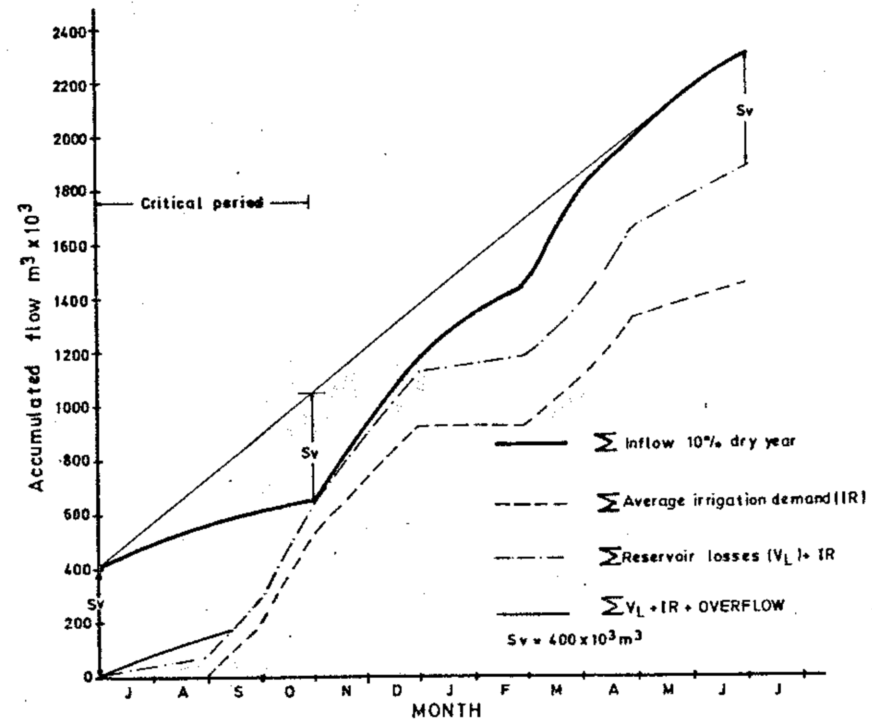


FIG. AG 5-3

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

	PS 8	PS 9
Effective storage volume	$310 \times 10^3 m^3$	$170 \times 10^3 m^3$
Total storage volume	$1,050 \times 10^3 m^3$	$700 \times 10^3 m^3$
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] $= 97.5\ (H^{5/2} + H^{3/2})$	$53 \times 10^3 m^3$	$38 \times 10^3 m^3$
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	670×10^3 m^3	$2{,}250 \times 10^3$ m^3
Total storage volume	$1{,}190 \times 10^3$ m^3	$3{,}600 \times 10^3$ 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	60×10^3 m^3	130×10^3 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 6.36×10^6	Sh 20.79×10^6
Additional gross margin	Sh 0.60×10^6	Sh 2.84×10^6
Running Costs	Sh 0.24×10^6	Sh 0.75×10^6
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 $M^3 \times 10^6$ (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

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.

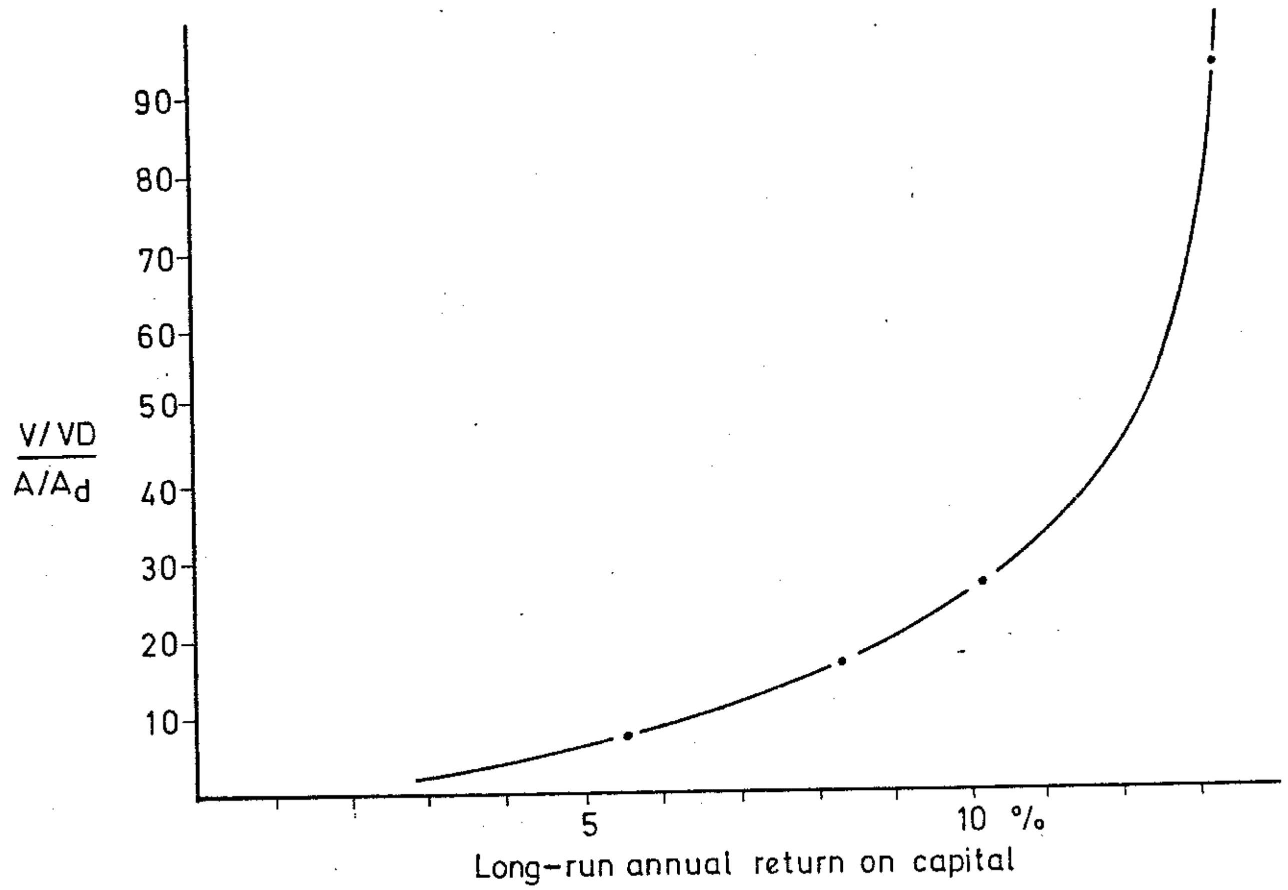
It has been tried below to derive a general relationship between significant characteristics of the schemes and the estimated long run return on capital. The characteristics are expressed in the dimensionless ratio:

$$V/VD : A/A_d$$

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
	Middle Lower Mkomazi Valley (with lake Manka reservoir)	7,345	-	1,720	1,720	7,345	5,510	1,720	1,720
Korogwe	Lower Lwengera Valley (without reservoir)	2,000	1,500	400	1,400	4,900	3,920	600	600
	Mashewa Swamps	450	-	-	-	500	-	-	-
	Kwamngumi project	-	-	-	-	-	-	-	-
	Misoswe irrigation scheme			15				40	15
Muheza	Mwakijembe irrigation scheme			500	350			500	5,000
	Lower Sigi							400	
Pangani	Lower Pangani Valley (sugar cane)				5,000				5,000
	Western and Central Usambaras			5,900	4,100			7,100	5,300
Lushoto	Kitivo-Lunguza Scheme	10				120	80	150	30
	Mnazi Scheme	-	-	-	-	150	60	-	-
	Mkalamo Project	2,500	2,000	1,450	1,450	5,000	4,000	3,000	3,000
Handeni	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: Rice S	Rice D	Upland S	Upland D	Estimated irrigation water consumption in 10% rainfall year $m^3 \times 10^6$/year	Construction costs for most likely feasible project area 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	174.27
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: Rice (ha)	Upland Crops (ha)	Assessment of: 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	YEARS ('77 '78 '79 '80 '81 '82 '83 '84 '85 '86 '87 '88 '89 '90 '91)
Mkomazi Valley	Rehabilitation Mombo Irr. Scheme (240 ha)	
	Development of New Irrigation Project (9,065 ha)	F S, PL & T, C (Head works), IMP
Lower Lwengera Valley	Rehabilitation (350 ha)	
	New Projects (3.150 ha)	FS&PL, IMP
Kwamngumi Project	Rehabilitation (160 ha)	
	Extension (500 ha)	PL, IMP
Lower Pangani Valley	Pilot Scheme (100 ha)	PL, C
	Development of New Project (3,245 ha)	FS, PL&T, R, IMP
Western Usambaras	Rehabilitation and Improvement (6,000 ha)	FS & PL, IMP
Kitivo Scheme	Rehabilitation (200 ha)	
Mnazi Scheme	Rehabilitation (100 ha)	
Mkalamo Irrigation Project	Hydrological and Soil Investigation	
	Development of New Project (4,350 ha)	FS, PL & T, IMP
Mnyusi and Segera Valley	Hydrological Investigations	
	Irrigation Projects (700 ha)	FS &PL, IMP

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

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