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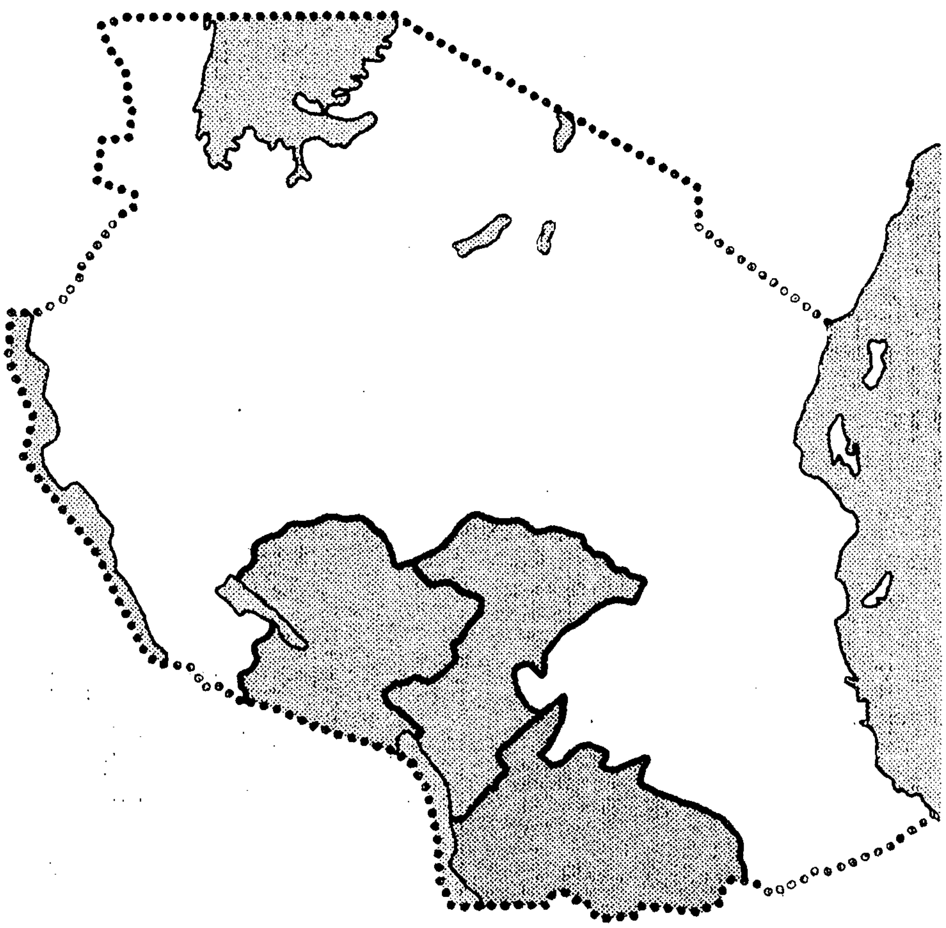
DANISH INTERNATIONAL DEVELOPMENT AGENCY • DANIDA

WATER MASTER PLANS FOR IRINGA, RUVUMA AND MBEYA REGIONS

IRRIGATION AND HYDROPOWER
VOLUME 11



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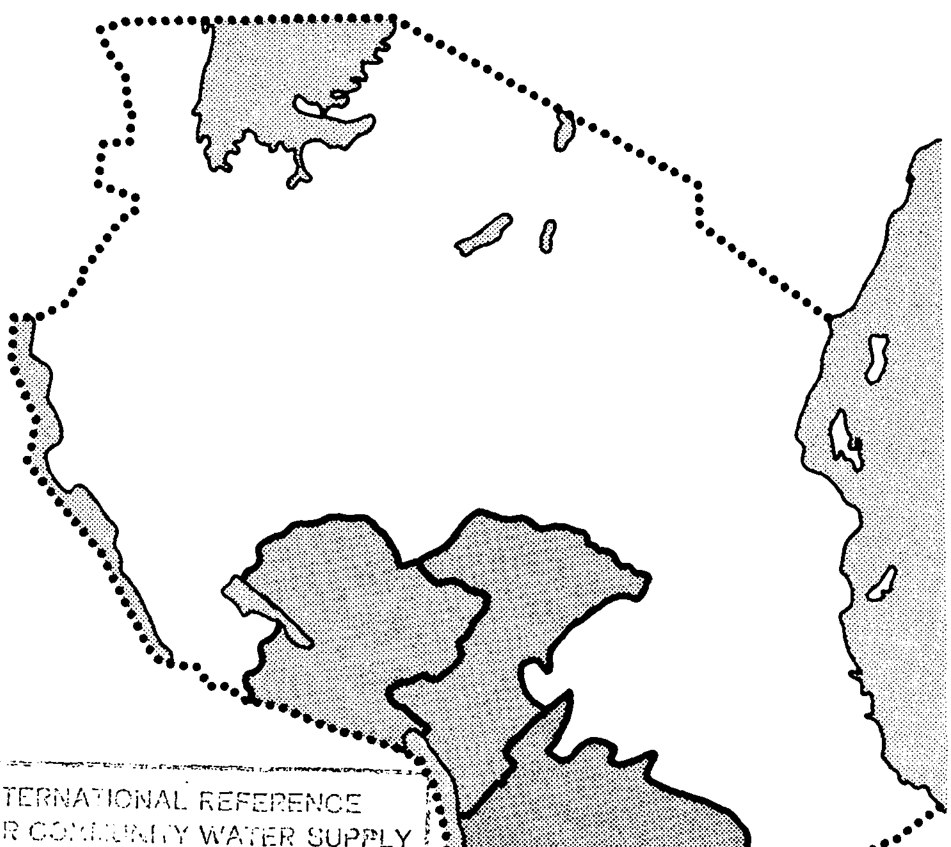

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GUIDE TO WATER MASTER PLANS FOR IRINGA,RUVUMA AND MBEYA

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THE CHAPTERS REFERRED TO ARE THOSE WHERE THE MAIN DESCRIPTIONS APPEAR.

THE REFERENCE CODE 5A/6 MEANS, VOLUME 5A, CHAPTER 6.

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(cont'd)

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1. INTRODUCTION

1.1 Scope and Approach

Whereas the Water Master Planning effort has had as its objective to investigate the availability of and demand for water resources for all human purposes, emphasis has been put on the immediate goal of providing villages water supply for domestic use and animal watering. These needs are essential for human life,and consequently of highest priority for the allocation of available water resources.

In terms of quantity the demand for water for village water supply purposes is generally relatively small compared to the total water availability, and the majority of the total water resource can be allocated for productive purposes such as irrigation. Hence, from a water resource allocation point of view, investigation of the availability and demand for water for irrigation is an important aspect.

A limited investigation of the irrigation potential in Iringa, Ruvuma and Mbeya Regions has been undertaken as part of the present study. The main objective of this investigation has been to review the agricultural conditions, identify the present extent of irrigation in the regions, and evaluate the potential for future irrigation, considering the natural conditions and resources, as well as the economic, institutional and other factors affecting the feasibility of irrigation development.

The investigation has been carried out on the basis of review of existing information, and discussions with central and regional government officials, personnel from on-going projects and the local population.

The three regions under review are at very different stages with respect to irrigation development and planning. Whereas in Ruvuma Region only small scale village irrigation is practised, large schemes are implemented or under study in Iringa Region. A Regional Integrated Development Programme (RIDEP) has been prepared for Iringa Region, and RIDEP teams are currently working in both Iringa and Mbeya, while no such planning has started in Ruvuma Region. For these reasons the information collected in the present study is very inhomogeneous, and the following outline of irrigation potential for the three regions is therefore different, in substance as well as in form. Thus the description of the potential development in Mbeya Region is most conveniently divided geographically, while for Iringa Region focus on specific project potentials has been the most natural approach. No particular structure has been logical for the rather short description of irrigation possibilities in Ruvuma Region.

Appendix 1.1 containing a few "Terms and Definitions" related to irrigation development is included after Chapter 7 and References.

1.2 Background

The great majority of Tanzania's population of some 18 million people live on the land as peasant producers. Approximately 50% of the Gross National Product stems from agriculture, and half of this is produced by peasant producers, mostly at subsistence level, and mostly on holdings under 5 ha in size.

Some 75% of Tanzania's export is derived from agriculture, the main cash crops being cotton, coffee, tea, sisal, cashew nuts, and cloves from Zanzibar.

The great majority of peasant producers are fully dependent upon rainfed agriculture.

In the regions under review there is generally ample food, but even so food shortages occur for the following main reasons:-

- Peasant producers normally plan for only a small surplus for sale, say 5 - 10%, mainly as a safety margin.
  When approximately twice every ten years (notably 1974/75 and 1979/80) rains are a semi-failure, and crop production drops to probably half of normal, severe problems arise, and up to 90% of the population suddenly needs to acquire basic food from elsewhere.
- There has been a shift in population from rural to urban areas. This growing urban population can no longer be fed by surplus production from peasant producers within reasonable distance from the main urban areas.

- There has been a shift in the demand, particularly amongst the urban and suburban population, towards products like wheat and rice rather than the traditional maize and sorghum.

In recognition of the critical importance of the agricultural sector the Government of Tanzania is giving high priority to agricultural development. Key elements of the Government's strategy for development are:-

- Better use of land resources
- Irrigation development so as to rduce dependence on rainfed agricultural production
- Encouragement of mechanised village communal farms
- Better provision and distribution of farm inputs
- Reduction of past harvest losses
- Strengthening of credit facilities for small farmers.

During the recent Food Strategy Workshop in Arusha (November 1981) Government emphasis on food production was reiterated and stressed.

While all the above mentioned points are to a large degree interrelated and must go together, it is perhaps in the field of irrigation and in the tapping of the country's vast and under utilised water resources that the greater potential for a rapid development of agricultural production lies, both in food crops and in some cash crops such as tea, coffee and cocoa, etc.

1.3 Institutions

The primary responsibility for irrigation development rests with the Irrigation Division of the Ministry of Agriculture (KILIMO), and with this Ministry's Regional Agricultural Development Offices (RADO).

KILIMO undertakes the planning and implementation of irrigation schemes, small, medium and large scale, while the National Agricultural and Food Corporation (NAFCO) takes care of the operation and management of all large scale, mechanised irrigation projects.

The Rufiji Basin Development Authority (RUBADA) is consulted in all matters regarding water resources planning and utilisation in the Rufiji Basin. Matters relating to hydrology, hydrogeology and water appropriation (water rights) are handled by MAJI.

Finally, irrigation development is a key aspect of any Regional Integrated Development Programme (RIDEP), and close coordination with these programmes is required as part of any feasibility study for irrigation projects. An integrated development plan exists for Iringa Region for the period 1976-81, and work on the next programme is on-going. Regional Integrated Development Planning is also under way in Mbeya Region, whereas no RIDEP activities have started in Ruvuma Region yet.

2. PHYSIOGRAPHY

2.1 Topography

Mbeya, Iringa and Ruvuma Regions form the south-western part of Tanzania. The regions lie between 32° and 38° eastern longitude, and between 7° and 12° southern latitude, and have common borders with Mozambique, Malawi (Lake Nyasa) and Zambia. The total area covered by the three regions is approximately 177,000 km^2, of which Mbeya Region covers 60,500 km^2, Iringa Region 56,500 km^2 and Ruvuma Region 60,000 km^2 (cf. Figure 2.1).

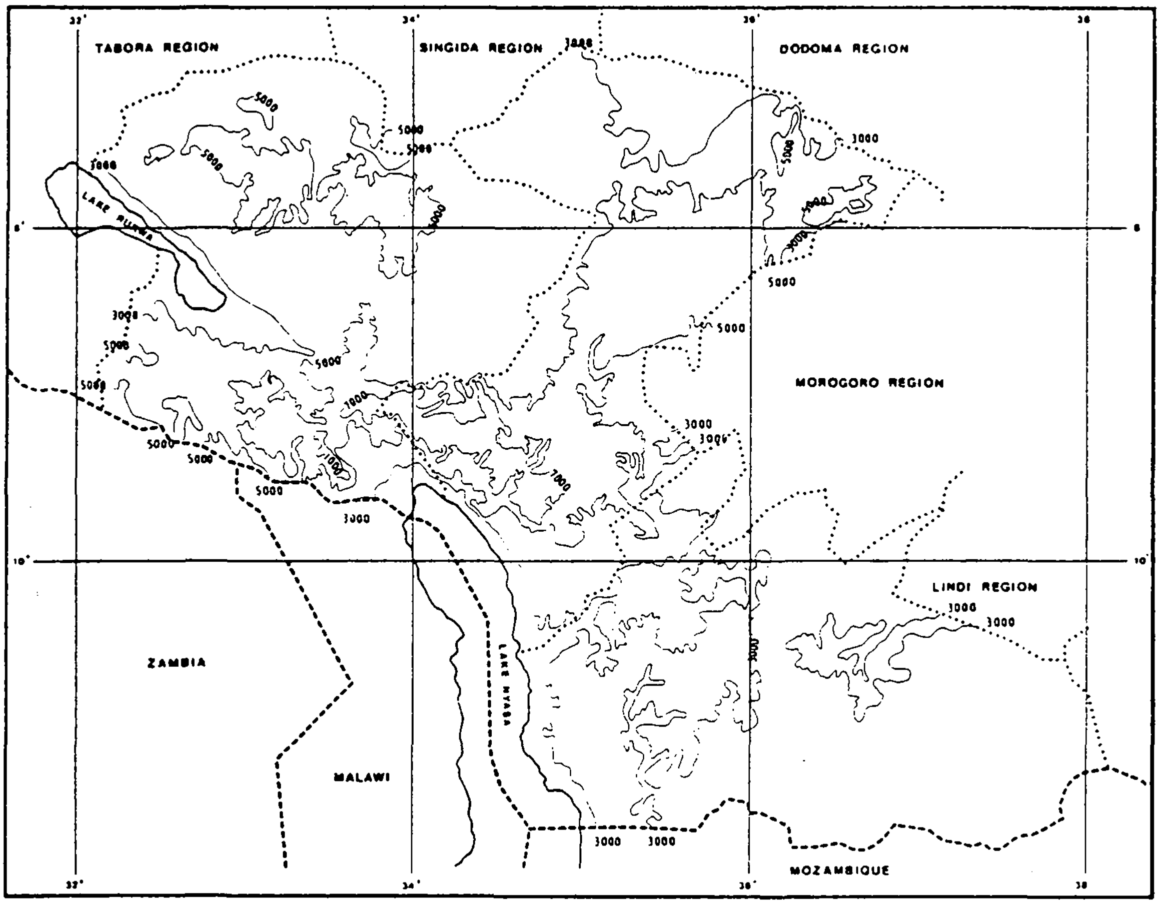


Figure 2.1 - Main topographic features. (Levels in feet)

The area is generally known as the Southern Tanzanian Highlands, a mountainous and hilly area dominated by the Mporotos and Mbeya ranges in Mbeya Region, the Kipengere and Livingstone mountain ranges in southern Iringa Region and the Udzungwa mountains separating Iringa and Morogoro

Regions. Northern Iringa and Mbeya Regions are relatively flat, high plains, cut by the eastern Rift Valley in which the Great Ruaha river runs, and the western Rift Valley with Lake Rukwa.

The mountainous areas of Ruvuma Region are of lesser altitudes than those of Iringa and Mbeya Regions, and most of the region is covered by undulating hills. The mountain areas are found in the western part of the region bordering Lake Nyasa.

Altitudes vary from below 500 m to well over 2,000 m above sea level in the Mporoto and Kipengere ranges. The highest peak of the Southern Highlands is the (no longer active) volcano Mount Rungwe with an altitude of 2,960 m above sea level.

The characteristic features of the regions, apart from the Rift Valley system, are the surrounding uplifted and warped plateaus. Covering nearly 90% of the total study area, the plateaus represent by far the most common landform. They are separated by fault-lines and erosion scarps, and are the result of steady erosion that has taken place since the Late Jurassic period.

The oldest plateaus are found at the highest levels from 1,800 to 3,000 m above sea level (i.e. the Mporoto and Kipengere ranges in Mbeya and Iringa Regions). They are remnants of the oldest landforms, the Gondwana, and overlook a vast, very smooth pediplain, the African erosion surface, at 1,200 to 1,800 m above sea level. Compared to the surrounding plateaus, the African surface is extremely flat and is characterised by broad valleys, in which rivers have now reached a mature state.

The post-African surface, another pediplain, situated about a hundred metres lower than the African surface, is moderate to heavily dissected, thus forming a more irregular and unstable terrain. This is due both to its younger age, and to faulting in connection with the Rift Valley system.

The remaining parts of the regions are occupied by areas where deposition of material has taken place notably the Rukwa Trough, the Usangu Flats and the Rungwe Volcanics in and around Rungwe District.

The Rungwe Volcanics, with the Rungwe Mountain (2,960 m a.s.l.) as its centre of eruption, forms an area of pronounced topographical relief. The craters, lava flows and volcanic ash cover make the volcanic area completely different from the rest of the study area. In contrast, the two main depressions, the Usangu Flats and the Rukwa Trough, are very flat because of their depositional nature, with the exception of minor local erosion features. These flats occupy parts of the valley floors of the eastern and the Rukwa-Nyasa rifts, which, during an early period, joined at location of the Rungwe Volcanic Province.

2.2 Climate

The climate of the project area is determined by its location close to the equator and the Indian Ocean.

Located between 7 and 12 degrees southern latitude the climate is tropical, with high temperatures in the lowland areas, low wind speeds, high humidity of the air and no cold season.

The vicinity of the warm Indian Ocean places the three regions in an area in which the general circulation of the atmosphere exhibits large seasonal changes, thus creating considerable seasonality in rainfall, cloudiness and surface wind conditions.

A brief account of the main climatic features of the project area follows. The significance of these features for the rainfall pattern in the regions is briefly discussed in Volume 7, Chapter 3.

Four distinct periods characterise the general circulation, and hence the climate of the study area.

From December through February the area is situated between a relatively high pressure over northern Africa and the Arabian peninsula, and a large low pressure at about 10 to 15 degrees South. Air masses moving from high to low pressure areas in this period give rise to the rather dry north-east monsoon (Kaskazi), which, despite its relative dryness, does produce considerable rainfall in the regions. One of the reasons for this is the encounter between the north-east monsoon and air masses from the south-east at the inter-tropical convergence zone, the effect of which frequently extends north into southern Tanzania.

From about March this zone moves northward towards the equator, placing the regions under the influence of the convergence between air masses from the southern and northern hemispheres. This situation dominates the climate through May and causes the heaviest rains of the year.

From about June to September the synoptic situation shows relatively little variation. During this period the project area is under the influence of the south-east monsoon (Kusi) which carries air from a large high pressure area over South Africa and adjacent parts of the Indian Ocean to a very strong low pressure over Saudi Arabia. Coming largely from the South African winter this monsoon is rather dry and cold, and the regions experience a pronounced dry season in this period.

The main convergence returns to Tanzania in October, reaching the project area in November and causing the onset of the rainy season. The convergence zone traverses the country rather quickly on its southward journey to its "summer" location south of the country.

It follows from the above discussion that wet and dry seasons, rather than warm and cold, characterise the climate of the three regions and influence the life style of the population. The rainy season from November through May is the primary growing season in the area, and the only one in large parts of it, unless irrigation is provided. The dry season lasts from about June to October and is responsible for the severe water supply problems experienced in the driest areas.

The main climatic features of hydrological interest are illustrated in Figures 2.2, 2.3 and 2.4, which indicate the spatial and temporal variation of rainfall, potential evapotranspiration and temperature.

As explained above, the majority of the rainfall occurs in the rainy season from November through May. Mean annual rainfall varies from less than 500 mm per year in northern Iringa Region tomore than 2,600 mm per year in the wet area north of Lake Nyasa. In any given year, however, the actual rainfall may vary significantly from the figures in Figure 2.2, which are averages over long periods of record. Rainfall in the area is subject not only to high spatial variability due to the characteristic convectional pattern explained above, but also to considerable variation from year to year, the actual range of annual rainfall in the regions being from less than 250 mm per year to more than 3,100 mm per year.

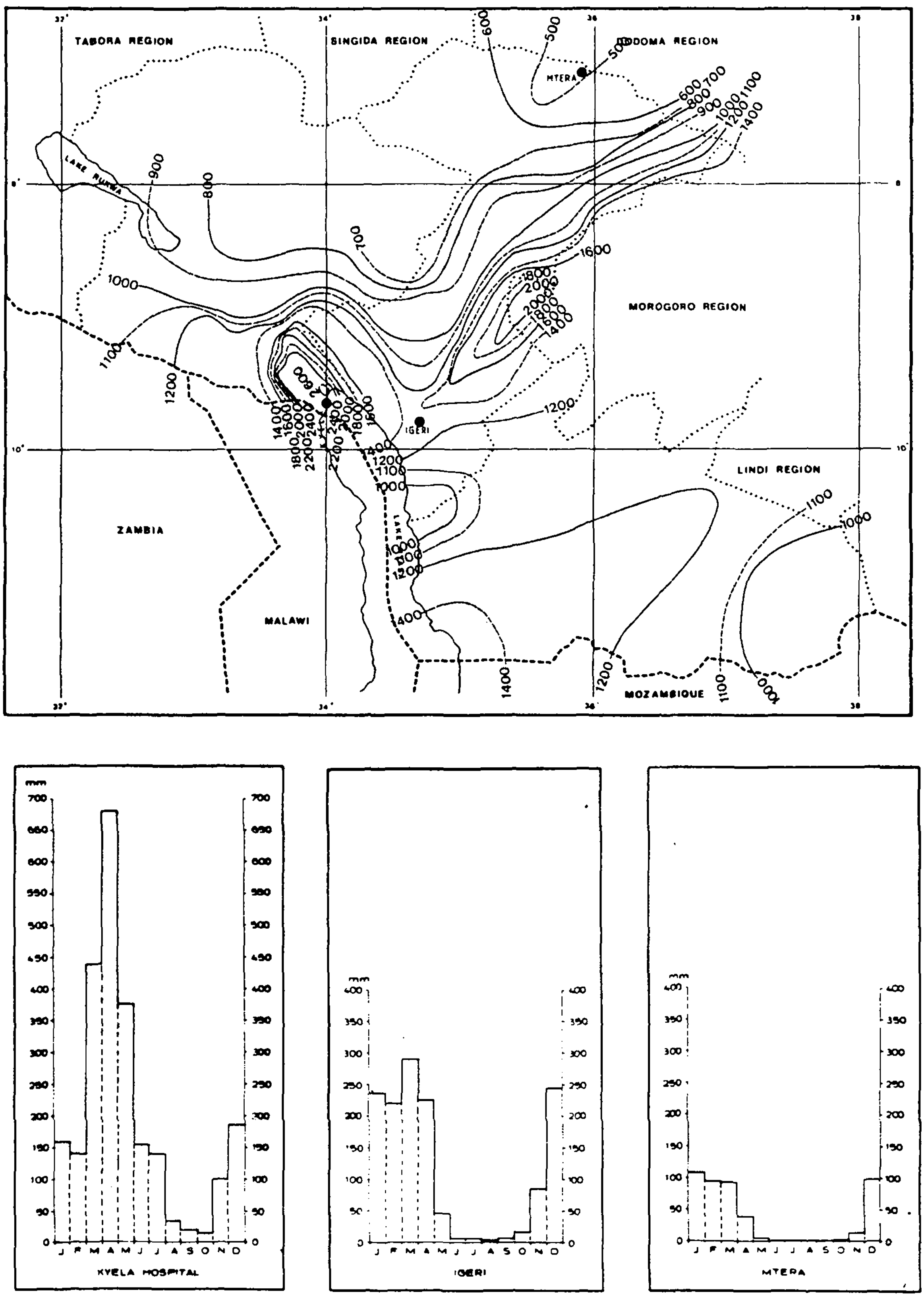


Figure 2.2 - Mean annual rainfall and mean monthly rainfall variation at selected locations.

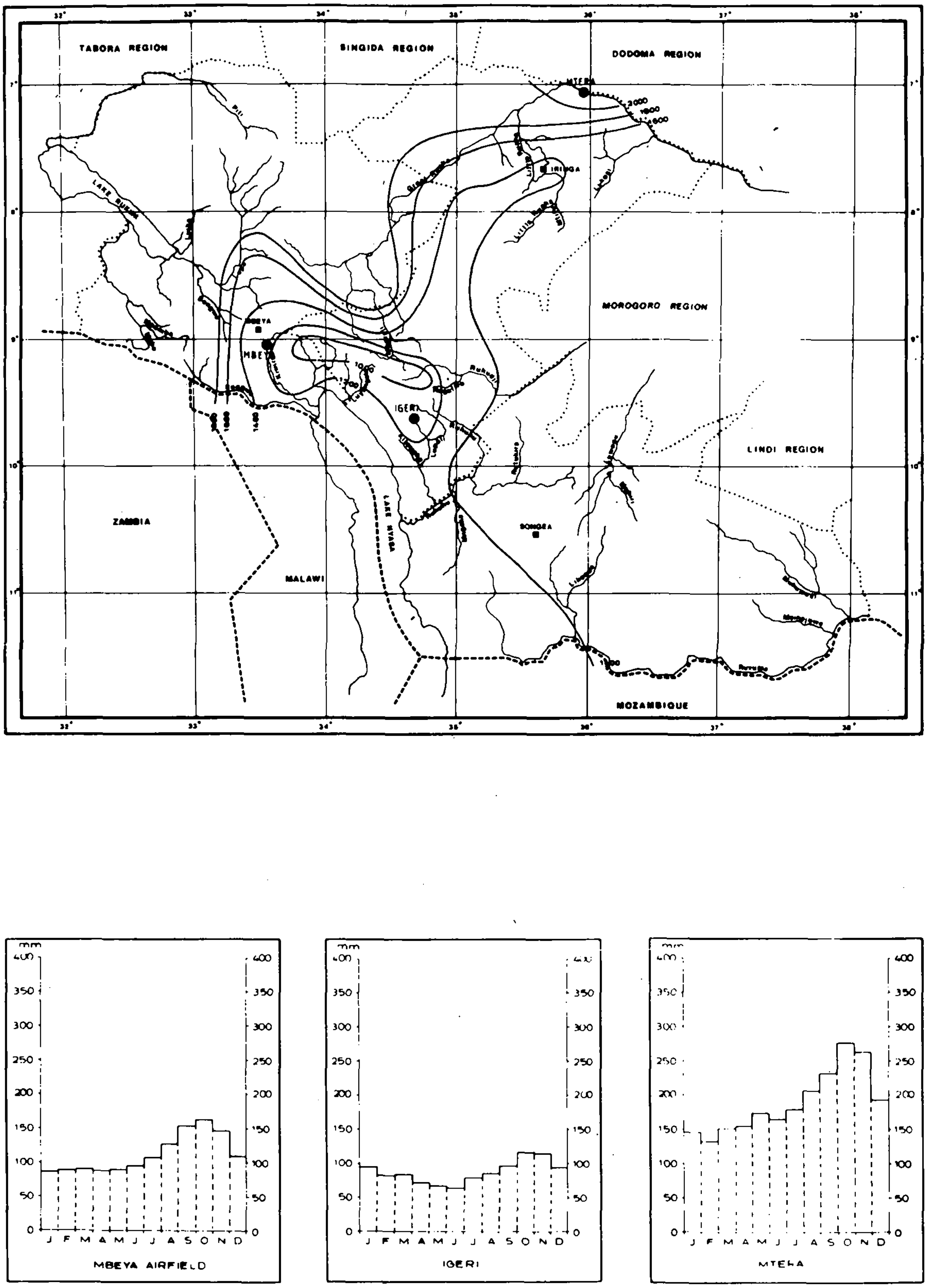
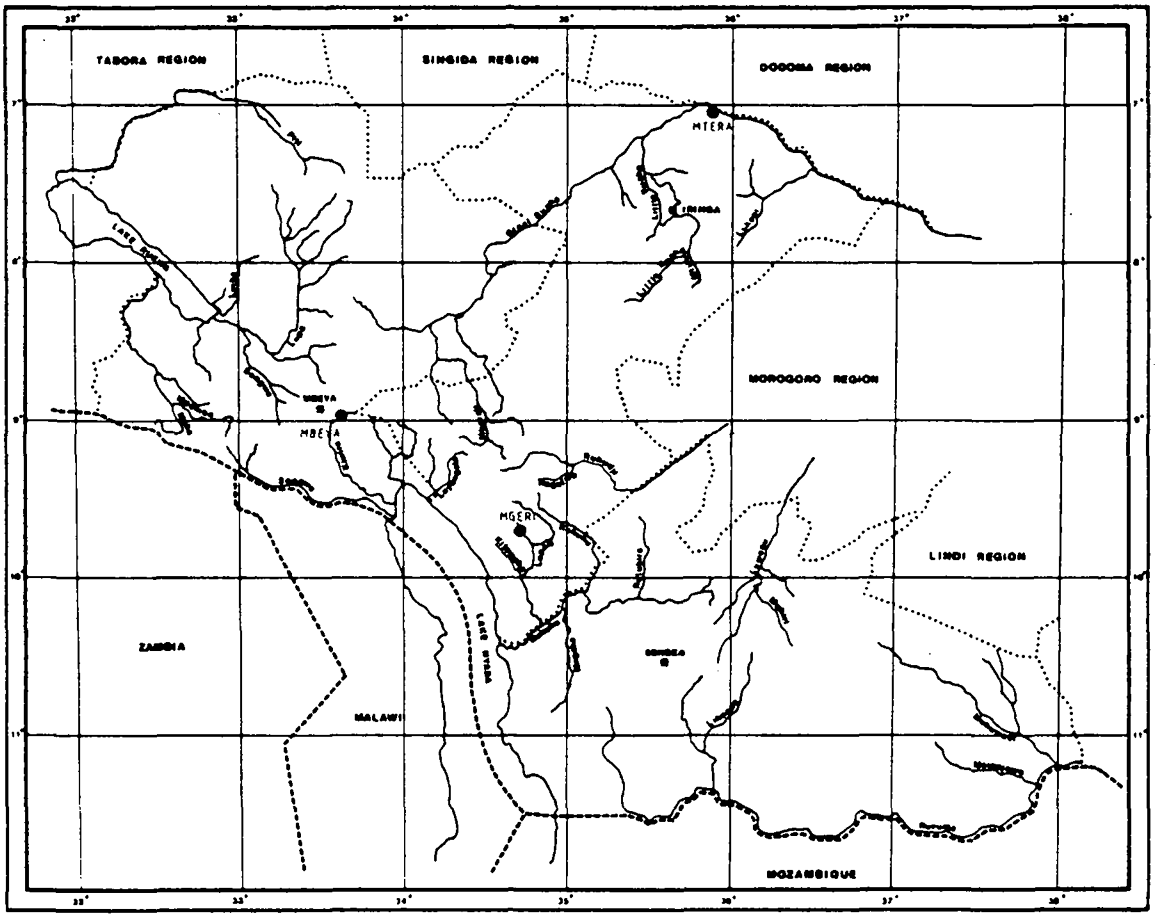


Figure 2.3 - Mean annual evapotranspiration, and mean monthly evapotranspiration at selected locations.



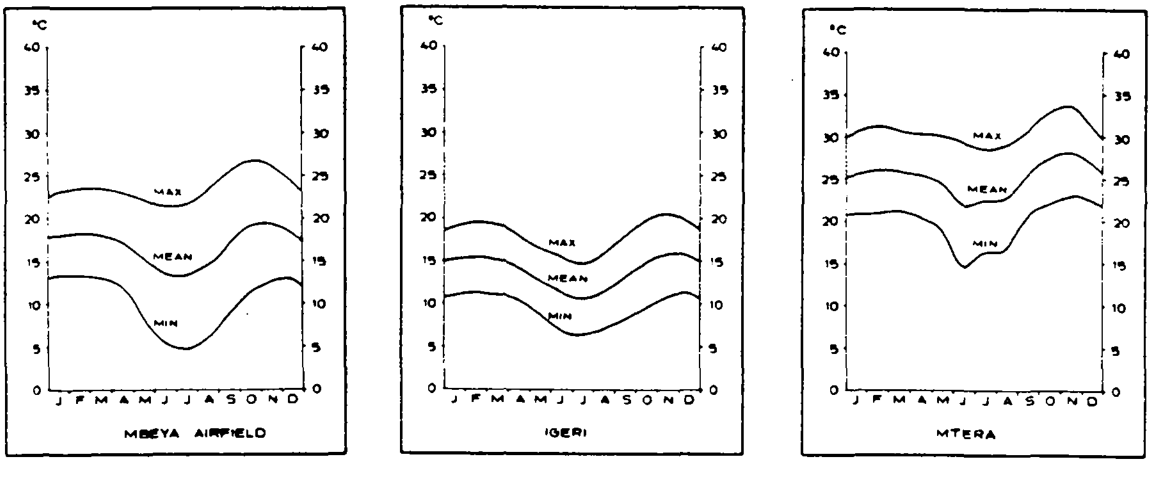


Figure 2.4 - Minimum, maximum and mean monthly temperature variation at selected locations.

The figures in Figure 2.3 represent potential evapotranspiration, i.e. the potential rate of combined evaporation and transpiration from a vegetated surface. This rate is some 20% lower than the corresponding evaporation from a free water surface, while the actual evapotranspiration from the area, because of water stress in the dry season, is in the range of only 40-60% of the potential rates shown in Figure 2.3; whereas the potential evapotranspiration varies only little from year to year, the spatial variability is considerable, ranging from more than 2,200 mm per year in the dry and warm northern Iringa Region, to less than 850 mm per year in the cool and wet highland in southern Mbeya and Iringa Regions.

Finally, Figure 2.4 indicates the variation of temperature at selected locations in the regions. Again the extreme variation is found between the northern parts of Mbeya and Iringa Regions, where mean annual temperatures exceed 25°C, and the southern mountainous parts of these regions, where mean annual temperatures at places are below 14°C. The temperature varies over the year from the cool June-July, where mean monthly temperatures in the mountains may approach 10°C to the warm October-November, where mean monthly temperatures in the northern areas approach 30°C. However, the typical variation over the year of mean monthly temperature for a given location is moderate, generally only 5-6°C. At the extremes mean daily temperatures range from less than 5°C in June-July in the mountainous areas, where frost occassionally may occur, to more than 35°C in October-November in the northern areas.

2.3 Surface drainage

Five major drainage basins divide Tanzania: The Lake Victoria basin, the Lake Tanganyika basin, the Northern internal basin, the Lake Rukwa internal basin and the Indian Ocean drainage basin. Iringa and Ruvuma Regions, and more than half of Mbeya Region, fall within the Indian Ocean drainage basin, while the remaining part of Mbeya Region drains to Lake Rukwa. Within these major drainage basins sub-divisions are made according to the catchments of major rivers and their principal tributaries. A drainage map indicating the major drainage systems of the Iringa, Ruvuma and Mbeya Regions is shown in Figure 2.5.

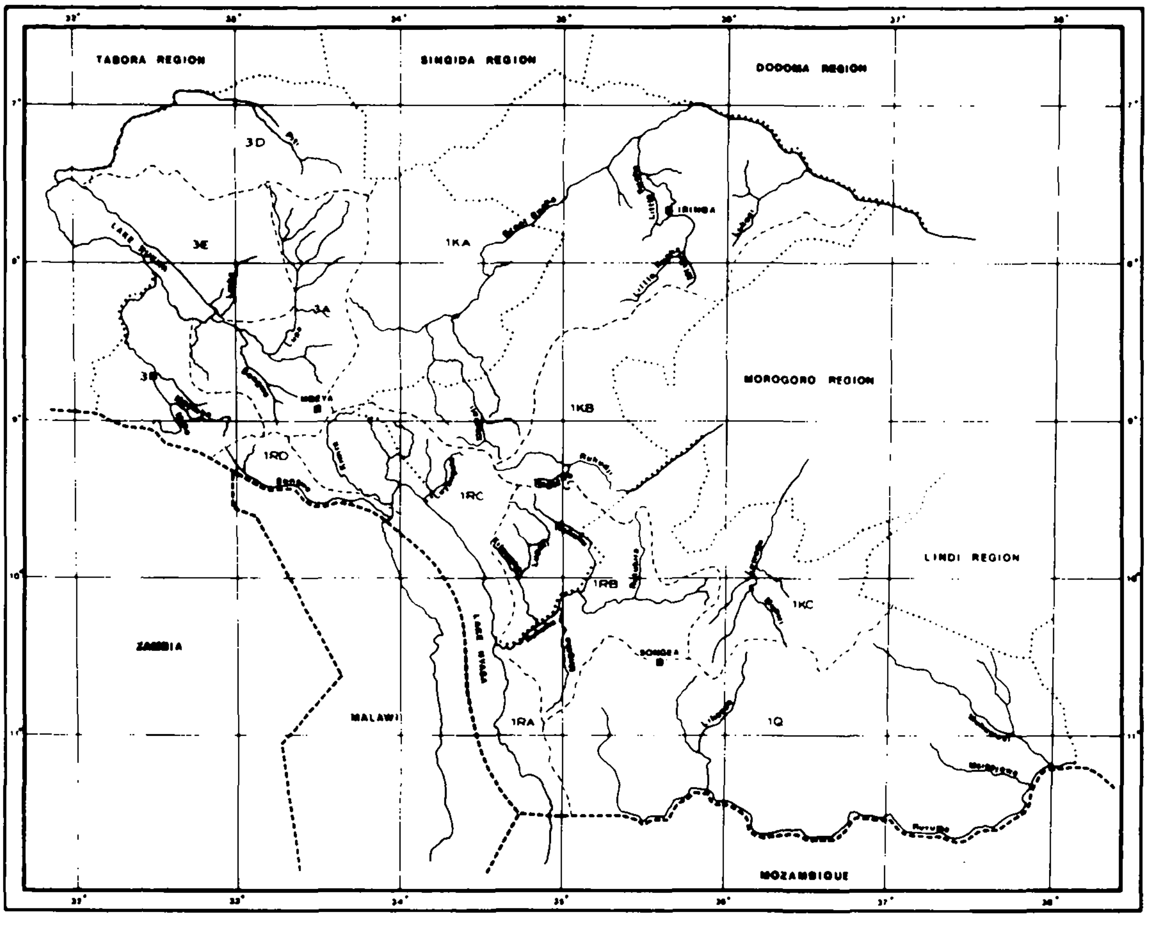


Figure 2.5 - Drainage map for Iringa, Ruvuma and Mbeya Regions.

In Iringa Region the central plateau largely divides the rivers into a northern drainage part and a southern drainage. The rivers draining north all merge into the Great Ruaha which in turn is part of the Rufiji system. The rivers draining south reach Ruhudji/Kilombero which again has a confluence with Rufuji river. The southernmost part of Iringa Region drains to Lake Nyasa, which through the Shire and Zambesi rivers is connected to the Indian Ocean.

The northern part of Mbeya Region drains towards Lake Rukwa, while the southern part drains towards Lake Nyasa. Finally, the eastern part of Mbeya is in the Rufiji system and drains to this through the Great Ruaha.

As for Ruvuma Region, the largest part drains to the Ruvuma river, while a small part drains to Lake Nyasa and another small part drains to the Rufiji through Luwegu river.

The surface runoff pattern in the regions corresponds rather closely to the general unimodal rainfall pattern. Streams start rising in November-December, experience a maximum flow in March-April, and have their recession period from May to October-November. In the warm and dry northern part of Iringa and Mbeya Regions, with annual rainfall below 500-800 mm, streams run dry every year, and the mean annual runoff is generally below 2 $l/s/km^2$. At the other end of the scale in the south-western highlands, where annual rainfall is in the range of 1,200-2,600 mm, streams and rivers are perennial, and mean annual runoff exceeds 10 $l/s/km^2$. In this area the Kiwira river, for example, has a mean annual runoff of 40 $l/s/km^2$ from the 1,660 km^2 catchment at Kyela.

Between these extremes, in areas like eastern Ruvuma Region, western Mbeya Region and Mufindi Region receiving 800-1,200 mm of rainfall annually, streams are perennial or intermittent (i.e. only occasionally dry), and mean annual runoff is in the range of 2-10 $l/s/km^2$. An example of a river in this regime is the Little Ruaha, which from its catchment of 759 km^2 at Makalala yields a mean annual runoff of 6 $l/s/km^2$.

The general spatial and temporal variation of runoff is illustrated in Figure 2.6.

2.4 Vegetation and land use

Although large areas of the regions are now cultivated the vast majority of the land is still covered by natural vegetation.

The most predominant natural vegetation in the three regions is the "Miombo" woodland, which is associated with rainfalls between 800 and 1,200 mm per year, and covers most soil groups with the exception of very alkaline and poorly drained soils.

Areas with less rainfall and semi-desert conditions, namely northern Iringa and Mbeya regions, support wooded grassland and bushlands of dense thickets. The most predominant trees in these areas are acacias and other thorny trees, which are sufficiently sturdy to withstand long periods of drought.

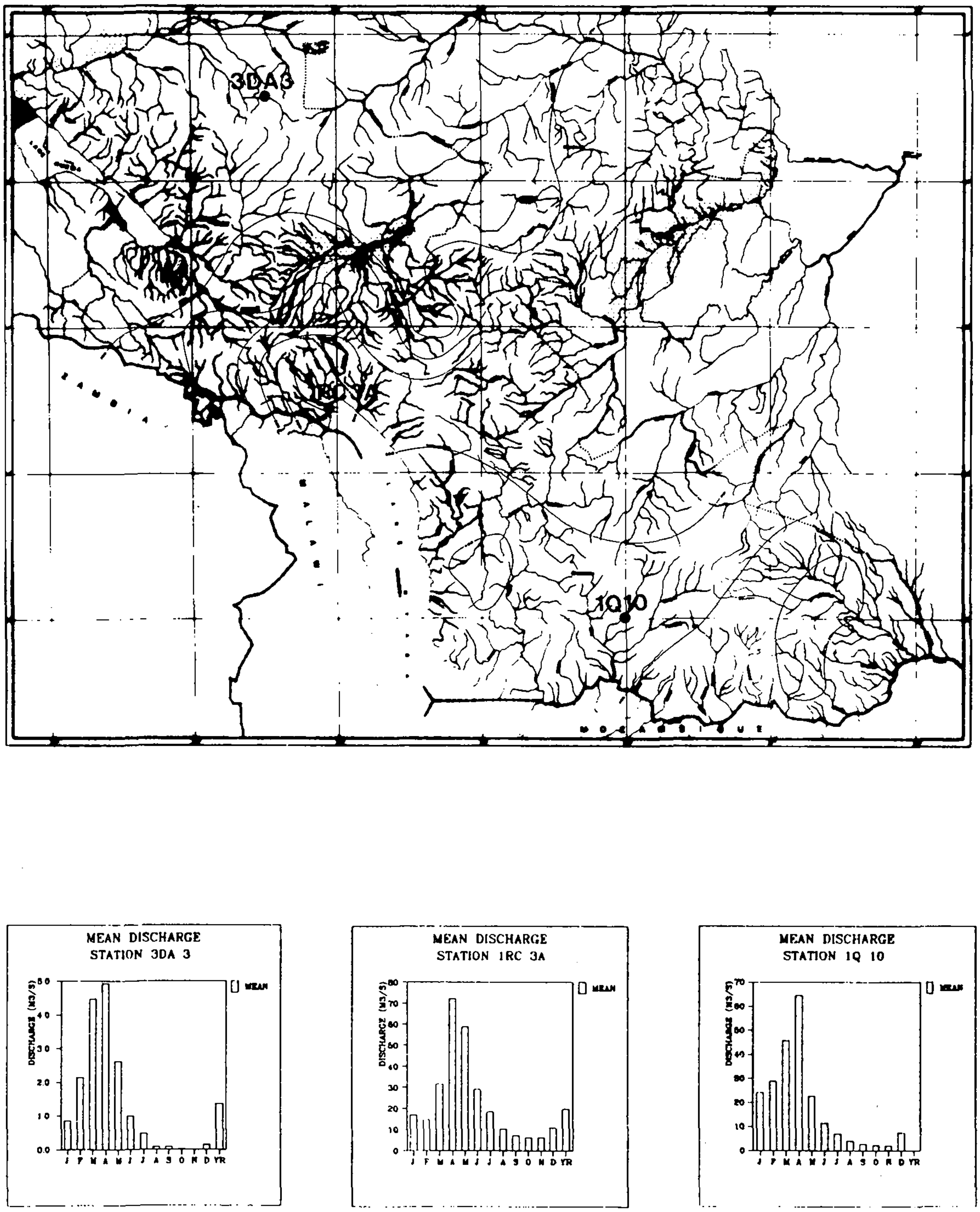


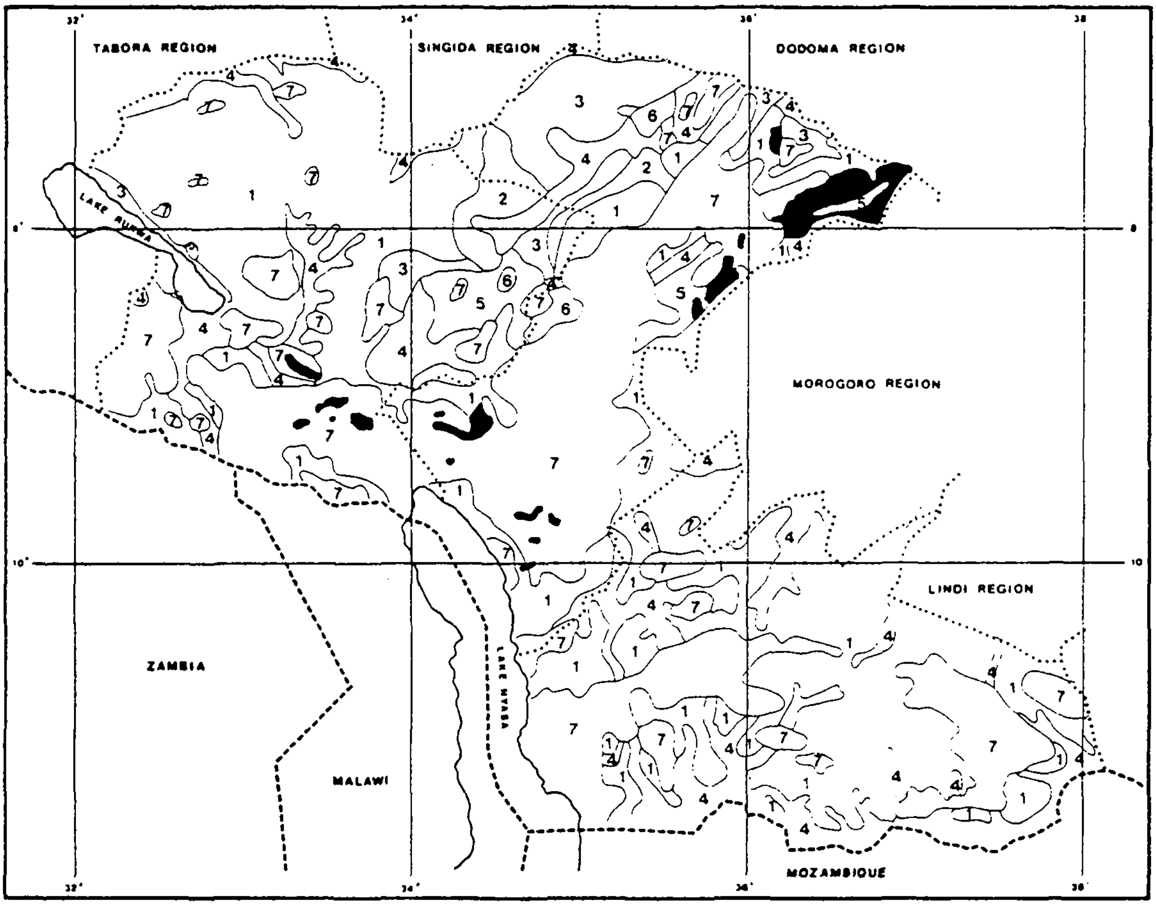
Figure 2.6 - Mean annual runoff, and mean monthly runoff at selected locations.

Areas with higher rainfall, like the Rungwe and Kyela Districts and the Dabaga area, support forests. In a few of these areas primeval rain-forest still exists, but in most places extensive deforestation has taken place for agricultural purposes.

Rainfall regime is a dominating factor, also with respect to land use and vegetational patterns. Distribution of the main cultivation areas is to a large extent determined by soil fertility and water availability, and it is characteristic that the agricultural areas in Mbeya, Iringa and Ruvuma Regions coincide with areas of high rainfall. Hence, in Iringa Region the cultivated area is found along the African Plateau from Iringa to the Njombe area in which the majority of the cultivation takes place. In Mbeya region cultivation is concentrated in the south-western high-lands, while in Ruvuma Region, the Mbinga-Songea area and to some extent also the Tunduru area account for the majority of the agricultural production.

In order of importance, the main crops grown in the three regions are: maize, wheat, beans, bananas and cassava in Iringa Region, maize, paddy rice, wheat, beans and bananas in Mbeya Region, and maize, cassava, wheat, beans and bananas in Ruvuma Region. Cash crops grown in the three regions are: tea, tobacco, pyrethrum and wattle in Iringa Region, coffee, tea, tobacco, pyrethrum, rice and citrus fruits in Mbeya Region, and coffee, tobacco and cashew nuts in Ruvuma Region. Cash crops are generally cultivated on plantations, whereas food crops are grown on smaller, individually held plots, often on a rotation basis with some land tracts lying fallow for a number of years to be cleared again when needed for further cultivation. (Slash and cut cultivation).

An outline, land use and vegetation map, based on Cook (1974) is shown as Figure 2.7.



■ FOREST
1 WOODLAND
2 WOODLAND / BUSHLANDS
3 BUSHLAND AND THICKET
4 WOODED GRASSLAND
5 GRASSLAND
6 PERMANENT SWAMP VEGETATION
7 CULTIVATION WITH SCATTERED SETTLEMENTS

Figure 2.7 - Land use and vegetation.

2.5 Soils

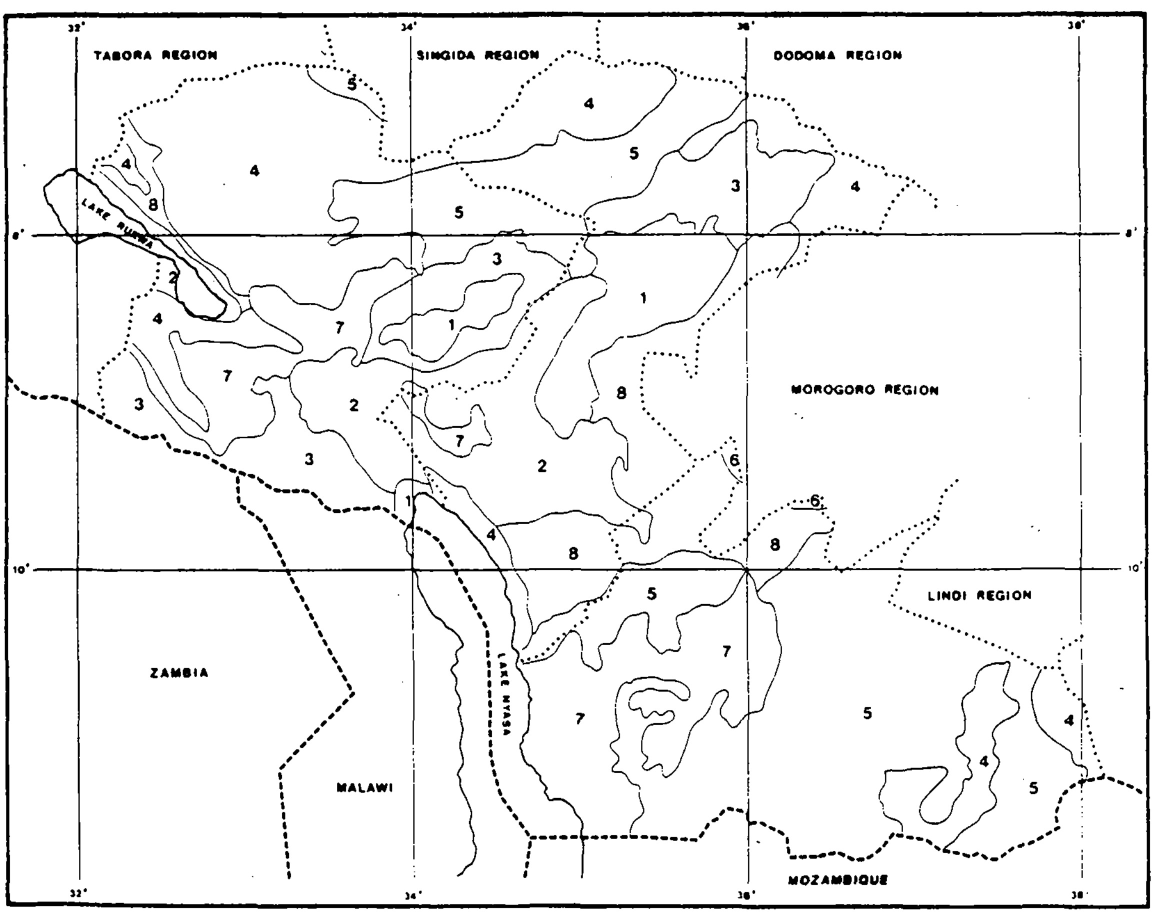
The soils of the three regions are generally well drained sands, clays, loams, and mixtures of these. Only three areas are characterised by imperfect or poor drainage. These areas are the lake deposits of the Rukwa Trough, the Usangu Flats, and the flood plains north of Lake Nyasa in Kyela District.

Eight different soil classes have been identified for Tanzania as a whole, of which all eight are found within the study area. This classification relates to the soil texture of the upper 30 cm of the profile, the most predominant classes in Tanzania are loamy sands and sandy loams. These are also the most common classes in the three regions, covering most of Ruvuma nearly half of Mbeya and some of Iringa Region in the Rift Valley.

The areas of highest elevation, the Mporotoes and the Kipengere Ranges with their well drained loamy soils, the Mbeya Range and hilly areas of western Ruvuma with a soil covering of clay loam with good drainage, constitute the best agricultural lands in the three regions.

Other soil classes such as sands, sandy clay loams, sandy clays and clays make up smaller portions of the regions.

A soil map, based on R.M. Baker (1970) is shown in Figure 2.8.



1 CLAY 2 SAND 3 LOAM 4 SANDY LOAM
5 LOAMY SAND 6 SANDY CLAY 7 CLAY LOAM 8 SANDY CLAY LOAM

Figure 2.8 - Distribution of soils in Iringa, Ruvuma and Mbeya Regions.

3. AGRICULTURAL CONDITIONS

3.1 General

As it appears from the previous chapter the physical conditions in Iringa, Ruvuma and Mbeya Regions indicate a vast agricultural potential for Tanzania. Virtually any crop cultivated by man can be produced somewhere in the regions, although crops such as cocoa, which demand a hot and very humid climate, are confined to Kyela District in Mbeya Region.

In most areas the natural rainfall will normally be sufficient to sustain one crop, and in areas with abundant rainfall such as Kyela and Rungwe Districts and the Mporoto Mountains, year-round cultivation is possible without irrigation. However, crop failure or semi-failure is a regularly recurring event as the amount of rain varies considerably from year to year, and consequently supplementary water in the form of irrigation, particularly towards the end of the dry season, holds promise of considerable increase in agricultural output. Not only does irrigation water sustain crops which otherwise could not be grown, it also contributes to increasing crop yields in general by ensuring optimal water availability. Furthermore, the uncertainty or risk of insufficient rain is a serious factor in making peasant producers reluctant to invest cash in agricultural input, and it is felt that supplementary irrigation would create a more secure base and thus encourage investment in fertilizers, insecticides, implements, etc., which contribute to increasing the agricultural output.

3.2 Crop characteristics

3.2.1 Growing seasons

The growing seasons are closely tied to the rains, and apart from the Rungwe District, that normally has only about three months with no rain, the crop season starts with the rains, and harvesting takes place in the beginning of the dry season.

Exceptions are pyrethrum and tea, that have a more continuous cropping pattern. Other perennial crops like coffee, cocoa and fruits obviously are not replanted annually, but the cropping pattern is still tied to the season.

An illustration of the growing seasons for rainfed crops is shown in

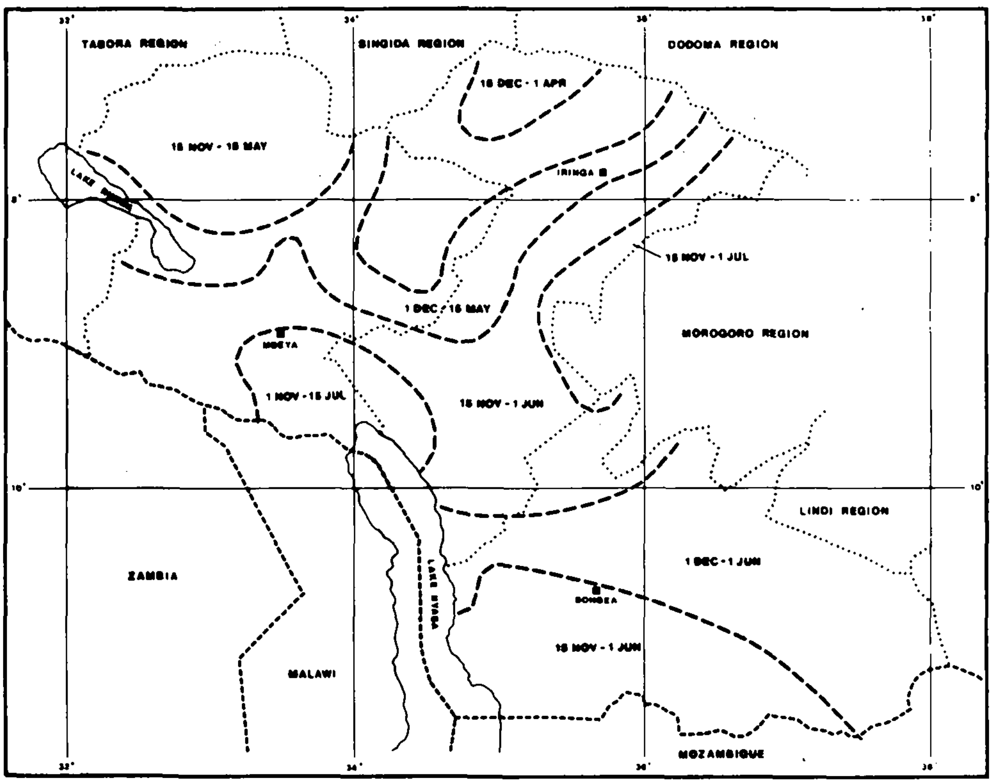


Figure 3.1 - Growing seasons for rainfed crops.

3.2.2 Crop yields

Crop yields vary considerably because of different climatic conditions, agricultural practices, etc. The extremes are found between traditional peasant cultivation in climatically or agriculturally marginal areas, to sophisticated irrigation farming with sufficient agricultural inputs. For illustrative purposes present yields and potential yields by use of fertilizer and irrigation of food crops are quoted below.

Crop	Present yield	Potential yield
Maize	0.6	5.6
Paddy	0.9-1.5	1.5-3.3
Wheat	1.1	2.2-3.0
Cassava	7.5-10.0	25.0
Potatoes	1.0	12.2
Beans	0.2-0.7	1.1

Table 3.1 - Present and potential yields (in tons/ha)

It will be seen that the potential for improvement under irrigation is great. When considering the above figures it must be borne in mind that no double cropping has been taken into account.

As an example of the increased production and return on labour that can be achieved on a rice plot with improved methods and irrigation, the following is quoted from Tanzania Food and Nutrition Centre, Data Report of April 1980:

	Tradition	Irrigation	Improved without fertilizer	Improved with fertilizer
Yield kg/ha	400	2,500	3,000	3,600
Producer price T.Shs/kg	1.20	1.20	1.20	1.20
Value T.Shs.	480	3,000	3,600	4,320

Table 3.2 - Example of rice yield improvement (1977/78 growing season)

The Irrigation Division of KILIMO, considers that when taking into account the possibility of supplementary irrigation during rains, and a second crop under complete irrigation regime, all properly fertilized and looked after crops can realistically expect an increase in yield per irrigated hectare of 200% to 250%.

3.2.3 Crop water requirements

Some aspects of crop water requirements are discussed in the evapotranspiration chapter in Volume 7 (Hydrology) of the present report. A brief summary including a map showing iso-lines of mean annual potential evapotranspiration, is given in Chapter 2 above.

Information on crop water requirements is important for irrigation planning, particularly in those parts of the regions where water availability is the limiting factor (as opposed to soil conditions, topography, infrastructure, etc., as further discussed below). As a rough guideline replacement of potential evapotranspiration can be aimed at, assuming a 50% total irrigation efficiency, which takes account of conveyance losses, farm losses, wrong timing, etc. Any surplus applied during stages of plant growth when water consumption is low, will then provide a useful leaching fraction, which will ensure that accumulated salts are removed. This of course presupposes that there is adequate drainage.

Assuming for the purposes of a rough indication of irrigation water requirements a 5 mm/day potential evapotranspiration (medium altitude areas), 50% irrigation efficiency, and 24 hour irrigation, a continuous flow of 1 m^3/s will cover an area of 860 ha in periods of no rainfall and full stage of growth. Obviously much larger areas can be covered in cases of only supplementary irrigation, as well as in well planned and operated schemes with high irrigation efficiency.

Rice is a special case. A total application per crop of approximately 1,800 mm is probably a good estimate.

3.3 Irrigation

3.3.1 Existing irrigation schemes

Apart from the 3,200 ha Mbarara scheme in Iringa Region, large scale irrigation is not presently practised in the three regions under review. However, there is a great number of individual micro-schemes of traditional rather primitive irrigation, not least in Iringa Region, where vegetables, particularly tomatoes and onions, are grown under irrigation, as well as some dry season maize.

Consistent and reliable estimates on the extent of existing irrigation in the regions are hard to find. According to a recent FAO/UNDP survey report on the National Village Irrigation Development Programme present and potential traditional small scale peasant irrigation can be summarised as follows:

Region	Area under Irrigation (ha)	Area under Cultivation (ha)	Available potential arable land (ha)
Iringa	828	309,300	464,200
Ruvuma	14,580	138,000	452,000
Mbeya	12,000	191,600	884,000

Table 3.3 - Present and potential small scale peasant irrigation

The figure from Iringa Region in this table was supplied by the region to the Irrigation Division of KILIMO. It is believed to be inaccurate, and does not tally with information later compiled by RIDEP - Iringa.

One scheme in Iringa Region is currently under rehabilitation (Kalenga, 200 ha), while three new schemes are in the planning phase (Luganga 1,000 ha, Lukozi 400 ha, Malolo 800 ha).

Brooke Bond Tea Company in Mufindi is irrigating close to 2,000 ha of tea during the long dry season. Chivanjee Tea Estate near Tukuyu has started to experiment with irrigation of tea and like in Mufindi have almost doubled yields by applying extra water during the dry months.

A number of water rights have been issued to expatriate farmers in Mbozi for irrigating coffee. Most of this water is probably not being efficiently used at present time. In Chunya District along the Saza and Lupa river flats there is some rice production under irrigation. This potential is not fully utilised but is under further investigation by the RADO and by the FAO team in Mbeya. In Kyela much rice is produced under natural flooding, but not much has been done to control and check the flood waters.

Rice is grown by peasants in NAFCO schemes in Usangu Flats in a combination of basin irrigation and uncontrolled flooding.

Generally existing irrigation schemes have been producing good crops, but water use has in many cases been inefficient and there have been problems particularly with the operation and maintenance of the small schemes.

For the planned large scale irrigation schemes competent and experienced management must be assumed to be provided under NAFCO or other organisations.

In the case of small and medium sized schemes, and even more for very small mini schemes, water management is likely to be more of a problem.

The Irrigation Division of KILIMO considers that management and control should be in the hands of village irrigation committees acting under advice from experienced irrigation extension officers employed by the regional agricultural offices, and that by-laws and guidelines should be worked out and agreed upon. This seems to be a good idea, but it is very important that extension officers of the right caliber be available for this support job. Ideally, they should be able to advise also on crop husbandry generally and not only in maintenance and execution of irrigation.

Problems and constraints associated with irrigation development are further discussed in Chapter 5 below.

3.3.2 Types of irrigation

The present system of irrigation as practised by peasant farmers does not conform to a set pattern or system of irrigation.

For some crops a system of furrow irrigation is attempted, and in some cases something like border irrigation has taken place. In most cases the system is more like wild flooding where water is led in on the contour and allowed to spill over the land between contours. Often this leads to erosion due to inadequate control.

The tea estates and some coffee estates have installed overhead sprinkler irrigation in the hills.

On the large-scale farms in the Usangu Flats run by NAFCO, basin irrigation is practised for the rice areas where adequate earth construction work and levelling have been effected.

In any future development of irrigation, either as village schemes or from a communal peasant-organised furrow, it would be advisable to have a proper survey done and an appropriate system suited to the locality adopted. In some areas border irrigation would be appropriate, in others and for certain crops a furrow system with syphon outlets would be more suitable. In very steep areas establishment of proper bench terraces is required.

3.3.3 Sources and availability of water

Generally, in large parts of the regions concerned, natural runoff is able to sustain a substantial irrigation development and only a small fraction of this resource is currently tapped for productive use. Hence the primary sources for irrigation are perennial streams and rivers, as well as springs feeding small village schemes.

Determination of the gross irrigation potential of the three regions is not possible on the basis of the present reconnaissance level review. Such a determination requires consideration not only of water and land resources, but also of the equally or even more important social and economic factors. Regional Integrated Development Programmes are being and will be prepared for the regions in which the irrigation potential should be evaluated.

However, a rough idea of the availability of water for irrigation can be obtained from the water resource studies conducted as part of the present water master planning effort. Hence, the mean annual runoff map in Chapter 2 above (Figure 2.6) illustrates that considerable runoff occurs, and only a very small fraction of this is required for rural water supply. In the critical period towards the end of the dry season, where agricultural production in most of the area will depend upon irrigation, water availability is best illustrated by the 10-year minimum runoff map in Figure 3.2 below. This map shows that even in very dry years surface water is available in large parts of the regions.

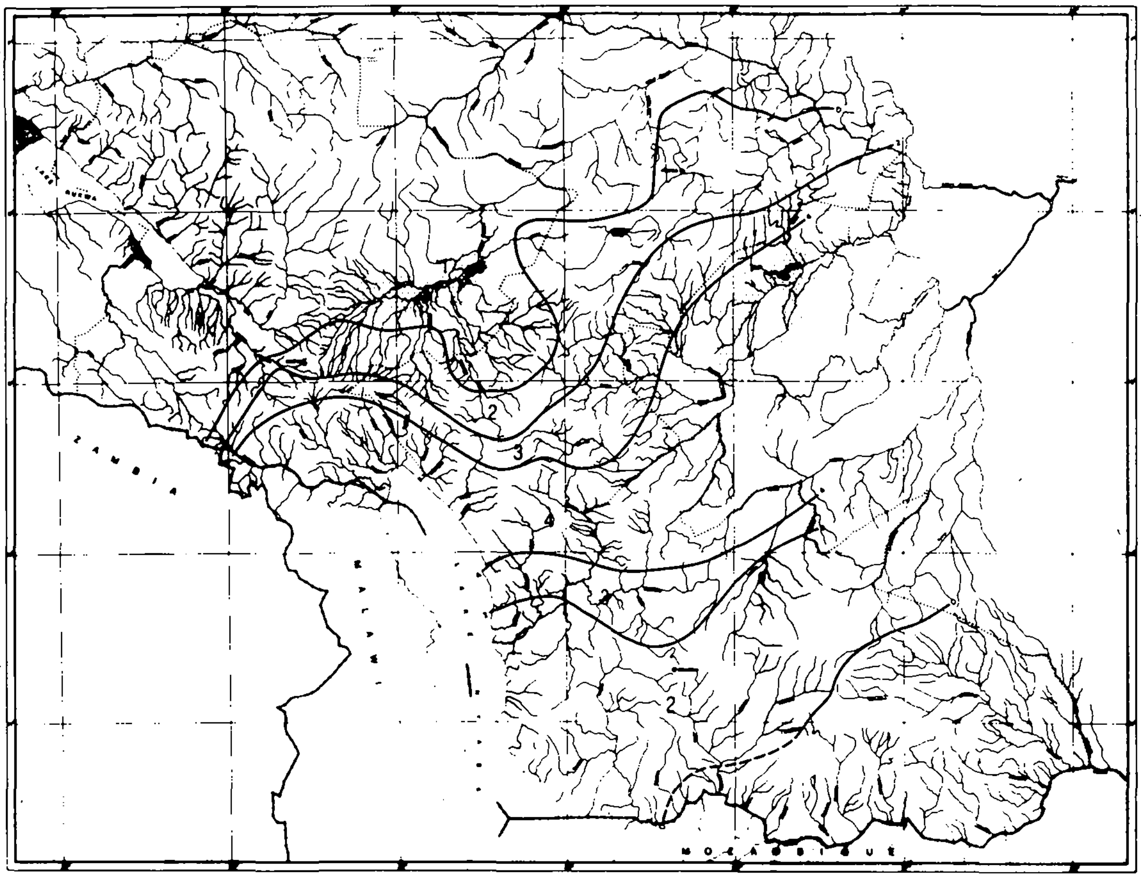
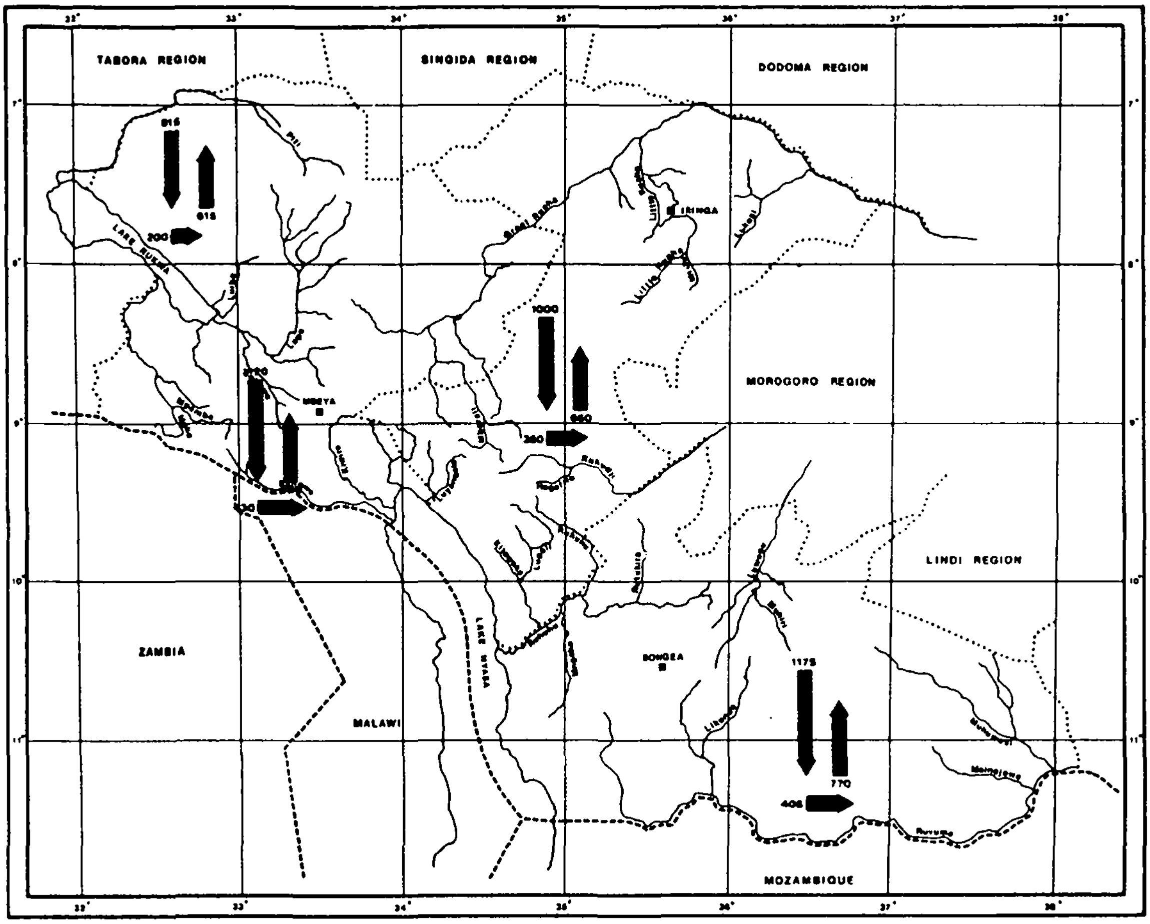


Figure 3.2 - 10-year minimum runoff. (1 = Dry, 2 = 80% of streams has a 10-year minimum. flow in the interval 0-2 $l/s/km^2$, 3 = in the interval 2-4 $l/s/km^2$, 4 = above 4 $l/s/km^2$).

Assuming 10-year minimum runoff conditions in the entire area, a conservative irrigation water requirement of 1 m^3/s per 860 ha irrigated area (cf. Sub-section 3.2.3 above), and withdrawal of only 80% of the flow for irrigation purposes, water is available for irrigation of more than 150,000 ha in the driest period. The assumptions behind this figure are rough, very conservative, and to a large extent oversimplified. The purpose of the estimate, however, is to illustrate that, from a regional point of view, water is not the primary limiting factor for irrigation development.

The runoff maps referred to above show the spatial distribution of surface water resources in the regions. In Figure 3.3 below seasonal water balance characteristics are illustrated (cf. Volume 7, Chapter 8 for details).



RAINFALL IN mm/YEAR

ACTUAL EVAPOTRANSPIRATION IN mm/YEAR

RUNOFF IN mm/YEAR

Figure 3.3 - Water balance elements.

In some areas there could be an untapped source of groundwater. Though this would be a comparatively expensive irrigation development, the potentiality would be worth mapping for future reference.

Another possible water source is Lake Nyasa by direct pumping from the lake. This would be a very saleable source but unfortunately suitable land adjacent to the lake is limited. The Kyela area would be served cheaper from the rivers.

Generally, the water quality in the area is good, and in particular the content of sodium carbonates and sodium bicarbonates is low, which reduces the risk of spoiling soil structure and thereby impeding internal drainage. Only in the Usangu Flats is there at present any real risk of this becoming a problem.

In the Lake Rukwa area there is some water with a higher salt content, but the sandy nature of the soil in the area probably alleviates any potential drainage problems for the time being. Nevertheless, it is necessary to be aware of the potential dangers, even if it is not an immediate risk.

3.3.4 Water rights

There has in the past been two schools of thought regarding the issue of water rights.

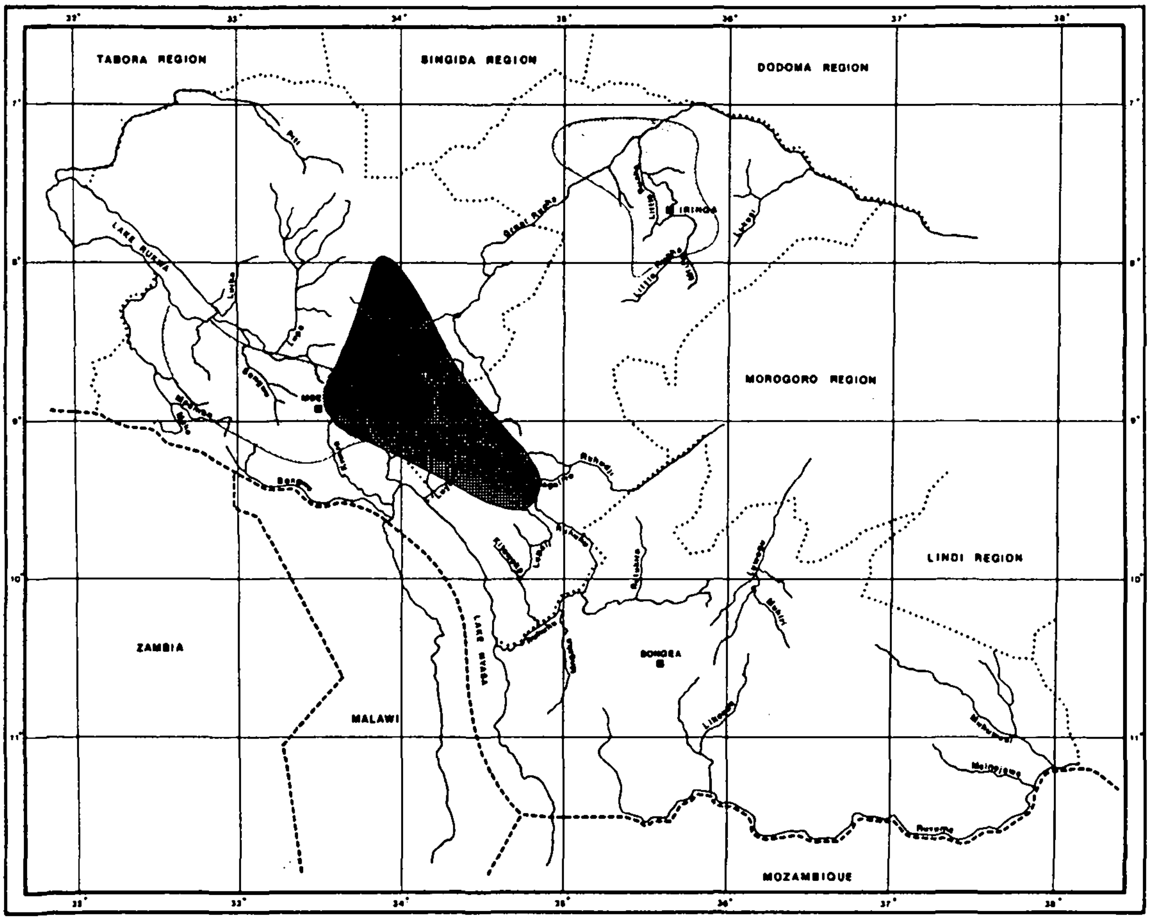
One was that an overall strategy for water use should be formulated, and that water rights should then be reserved for the most efficient and nationally most important user of water.

The other school maintained that as long as there was a user who could make productive use of existing water, he should be given permission to use it, provided adequate safeguards were observed to preserve river banks against erosion, etc., and provided it did not conflict with any other immediate user or interest. The philosophy was that a valuable asset like water should not be allowed to run waste if an immediate production could be obtained, just in order to provide for some hypothetical future development that might take decades to materialise.

The latter view has generally prevailed. When looking at the many water rights which have been issued to people who are no longer present in the country, one wonders if in many cases the water is at present being used for the purpose for which it was intended, or if it is being used at all.

If an investigation into irrigation potential is to be undertaken, then there may be a case for looking at all existing water rights in detail again. It would be wrong to revoke water rights for water that is being put to good and productive use, but there might be a case for modifying or even revoking others that are not being usefully exploited.

An investigation of water rights in the regions has shown that surface water resources are heavily appropriated in parts of southern Iringa and Mbeya Regions, as well as around Iringa Town. The result of this investigation is illustrated in Figure 3.4 which shows the variation of the degree of appropriation, defined as the appropriated fraction of the 10-year minimum runoff rate (cf. Volume 7, Chapter 8, for details).



A : TOTAL APPROPRIATION

Q_{min} : 10 YEAR MINIMUM FLOW

$A/Q_{min} \geq 1$

$A/Q_{min} = 0.5 - 1.0$

$A/Q_{min} = 0 - 0.5$

Figure 3.4 - Water Appropriations.

3.3.5 Drainage

In general when agricultural land is being irrigated, provision of adequate drainage is as important as the provision of water.

There are two main reasons for this. Firstly, hardly any agricultural crop, except rice and some root crops, are able to grow when the roots are standing in water. Roots need adequate oxygen to function and static groundwater is generally devoid of this. Roots of most plants will only penetrate as far into the soil as open air spaces are found, and will stop when the groundwater level is reached. This is the reason why crops will suffer earlier for lack of water in fields with very high groundwater levels in times of drought.

Secondly, if there is no drainage there will, under artificial irrigation, be an accumulation of salt in the ground. This is because all water used for irrigation contains some amount of salts, which cannot all be removed by crops. Therefore, over the years salts will accumulate in the soil and eventually reach a level when nothing will grow on the land. Numerous irrigation schemes have failed, and still do, for this reason.

In Tanzania the salt will, in most areas, be sodium carbonates or bicarbonates. High concentrations of such monovalent cations result in deflocculated soils with very high pH values, resulting in a soil structure that makes reclamation very difficult. So-called black alkali may appear on the surface.

Fortunately, most of the area in question in the regions under review have free draining soils on adequate slopes, so as to make accumulation of stagnant water unlikely in most cases.

3.4 Watershed management

In the regions under review there is an urgent and important, yet largely unrecognised need to ensure proper conservation of land and water resources. Erosion of unprotected soils on the slopes of the Southern Highlands is becoming a serious problem which demands attention.

Quoting from the RIDEP for Iringa 1976-81:

"Finally, it needs to be borne in mind that all investment in irrigation schemes are in jeopardy to the extent that uncontrolled land use upstream leads to accelerated soil erosion with, apart from the direct losses this involves, the twin dangers for downstream irrigation schemes of more rapid silting of engineering works and the emergence of greater fluctuation in stream flow, with problems of flooding and physical damage in the rains and the diminution or even the disappearance of stream flow in the dry season".

The early rain is often in the form of heavy showers of great intensity, and it occurs at a time when fields are generally devoid of vegetation having been prepared for planting in anticipation of the rain. This is the time when much serious erosion takes places, and much soil is carried away to the rivers. Severe signs of sheet erosion is often seen at that time of the year. Later when the crops have been established and new grass has covered the uncultivated land, erosion comes to an end for the season, and the sediment load in streams and rivers drop off significantly.

The cultivation pattern combined with lack of adequate soil conservation measures, and the problem of overstocking and overgrazing of uncultivated land, are main areas of concern in these regions. Fertility of cultivated land and productivity of grazing areas show marked signs of falling off. In a great many areas the original top soil has been eroded away and it is irretrievably lost. The subsoil can in most cases be brought into cultivation and made to produce, but eventually that may be lost as well, leaving only gravel and rock.

As indicated in the above quotation greater fluctuations in stream flow is a result of soil erosion. The reduced storage capacity of the soil cover leads to more rapid run-off, and hence increases severity of flooding, while less water seeps into the streams and rivers during the dry season. Although impossible to conclusively verify on the basis of the rather short stream flow records available, it is alleged that some previously perennial streams now dry up, and that the zero-flow periods in other seasonal streams have increased over the last decades.

4. PLANNED AND POTENTIAL IRRIGATION SCHEMES

4.1 Studies of irrigation potential

A number of studies of potential irrigation projects have been carried out in the three regions, and further investigations are on-going and underway. These studies include:

Iringa Region:

- Overseas Development Group University of East Anglia: A proposal for the five year plan 1976-81.
- Agrar und Hydrotechnik AG: Integrated Rural Development, including potential irrigation prospects in Iringa Region (ongoing activity).

Mbeya Region:

- Kirway and Kidunda, Uyole Agricultural Centre: Agro-Economist zoning of Mbeya Region as Basis for Farming Systems.
- Commonwealth Secretariat: Development Potential of the Usangu Plains of Tanzania, by Commonwalth Secretariat.
- Draft working paper by C. Opland: Draft, working paper for RIDEP office, Mbeya.
- Draft report: Mbeya Irrigation Reconnaissance Mission Report No. 42/78-15 of 23/8/78.
- Food and Agriculture Organisation of the United Nations (FAO):Currently working on Regional Integrated Development Programme in Mbeya Region. Working paper "Mbeya RIDEP project" is available.
- Uyole Agricultural Centre: Soil mapping in progress. Results for Mbeya region expected in June 1982.
- Kilimo: Paddy in Usangu Plains (1973).
- FAO: The Rufiji Multipurpose Development Report. Covers large parts of the regions.

4.2 Iringa Region

Iringa region is basically highland areas ranging from an altitude of 700 m in the Ruaha valley to about 2100 m in the higher areas. The area is generally well watered, having a unimodal rain pattern with generally sufficient rainfall for one good crop a year. There is a great number of perennial streams and a good potential for an agricultural production during the dry season under irrigation, not least in the form of mini or village irrigation schemes.

Iringa is a region with a vast diversity and large agricultural as well as livestock potential. Generally there is a great potential for most temperate agricultural crops and for tropical crops as diverse as rice in the lower river basin areas, to tea and pyrethrum in the hills, and timber for wood pulp in the Sao Hill area.

The current RIDEP activities by Agrar und Hydrotechnik (see Section 4.1 above) have advanced quite far in identifying potential irrigation possibilities as well as existing irrigation schemes in the area. As this team, as well as the English team who prepared the RIDEP for the 1976-81 period, have treated Iringa Region under one heading; it seems convenient to do the same for the purposes of this summarised review.

A map showing the location of main rivers and principal irrigation schemes (existing or planned) in the regions is included in Figure 4.1.

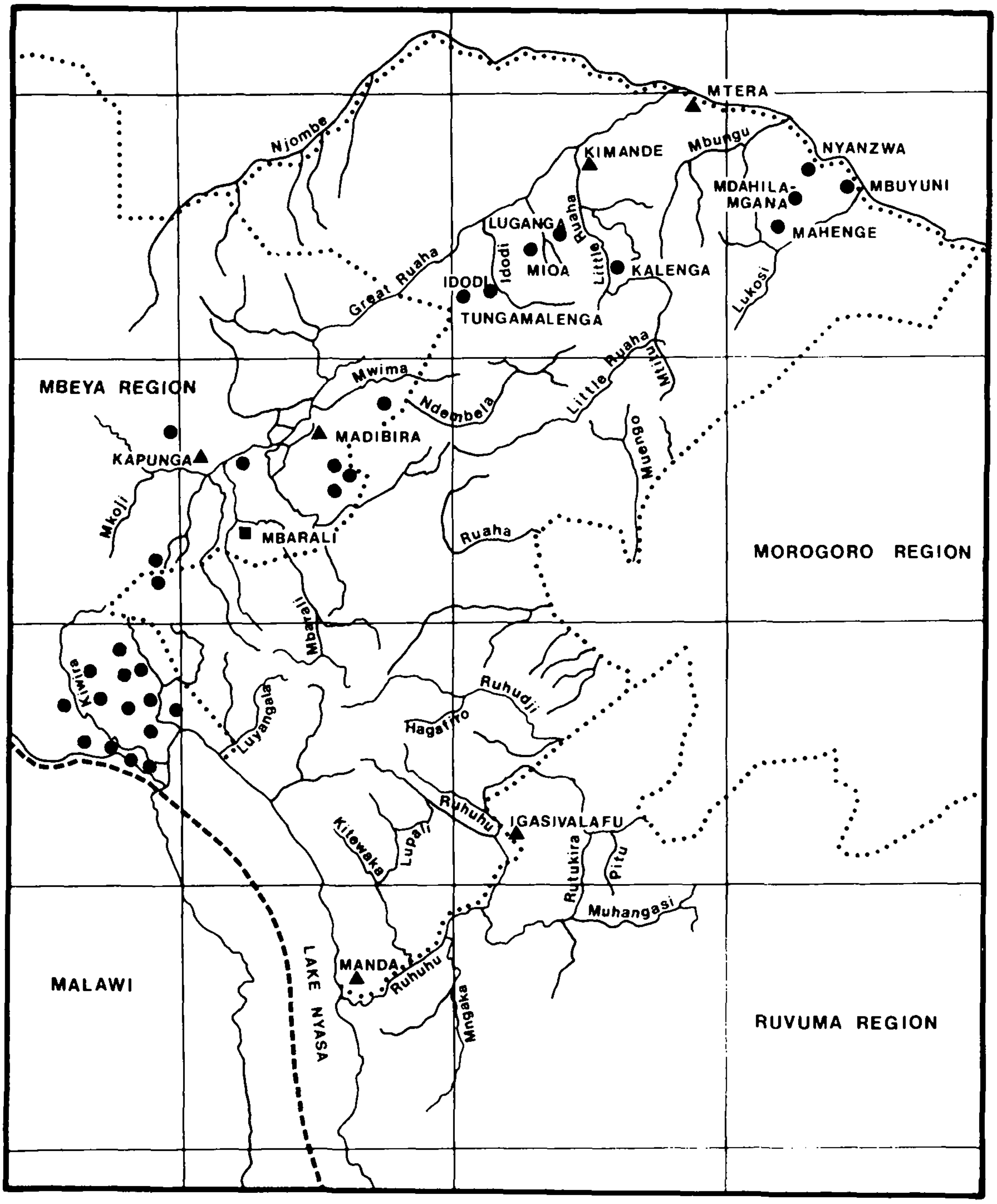
4.2.1 Large scale irrigation potential

Madibira rice project

This scheme is mentioned above in Sub-section 4.2.1 as it is located in the Usangu Flats. (5000 ha NAFCO rice scheme, plus 3000 ha small scale farming). A feasibility study for this scheme is under preparation, and it is understood that a temporary water right has been granted for a 13 m^3/s withdrawal from a proposed reservoir on the Ndembera river.

Kimande scheme

This is a 6000 ha rice irrigation scheme proposed in the 1976-81 RIDEP for Iringa. Little Ruaha is the proposed source of water, and the plans involve flood control as well as water storage. A reservoir at Makalala with a capacity of 60 mill. m^3 is envisaged.



⊙ SMALL SCALE SCHEMES

△ PLANNED BIG SCHEMES

■ EXISTING BIG SCHEMES

Figure 4.1 - Location of main rivers and principal irrigation schemes in the Iringa, Ruvuma and Mbeya Regions.

Mtera reservoir

It is estimated (RIDEP 1976-81) that as much as 40,000 ha annually will emerge from flooding when the reservoir water level drops during the dry season. 20,000 ha of this area would be in the Iringa Region and a third of that may be suitable for growing a short-term crop to be removed before the next flood is due. If some water could be spared for this, it will appear to be a cheap method of providing for additional irrigated agriculture. The water requirement will be comparatively low as the area will be saturated at planting time.

Pawaga-Kimande area

Near the confluence of the Little Ruaha and the Great Ruaha there is a potential irrigation area of possibly as much as 10,000 ha or more. There is some village settlement in the area, and some irrigation has taken place, but it appears that the full potential is far from being exploited. Agrar und Hydrotechnik AG are investigating the area and intend to come up with a detailed proposal for further work.

Mbuyuni project

At Mbuyuni in the northeast corner of the region it is reported that there is a potential of some 2-3,000 ha agriculture under irrigation. This is being investigated and presumably developed by a North Korean team.

Manda project

This project is on the Ruhuhu river in the Njombe district. The potential area amounts to 1,000 ha on the Iringa side of the river and 2,000 ha on the Ruvuma bank of the stream, making it a 3,000 ha development project. It should be a joint venture with Ruvuma Region.

Isigawafule project

This is a potential 5,000 ha irrigation development project, based on water supply from the Ruhuhu system.

4.2.2 Tea irrigation schemes

Mufindi Tea Estates (Brooke Bond) have in later years been irrigating tea by means of overhead sprinklers, and the crop of tea has almost doubled after introduction of this technique.

Overhead irrigation by means of a sprinkler system, and supplied by a pump, is a relatively sophisticated method of irrigation which requires a certain amount of skill to maintain in good working order. However, with a possibility of doubling yield of a valuable export crop, it would be well worth bearing the potential in mind for the Lupembe area as well.

At Lupembe there would be the additional possibility of reducing frost damage by sprinkling water on the crop when frost is imminent. Frost prevention does not necessarily require a heavy application of water.

4.2.3 Small and medium scale irrigation potential

The current RIDEP team in Iringa has compiled the following list of potential small and medium scale schemes in the region:-

	Present existing	Potential
Iringa District	1,790 ha	6,530 ha
Mufindi District	283 -	3,123 -
Njombe District	181 -	1,315 -
Makete District	not available	1,204 -
Rudewa District	115 -	235 -
		12,407 ha

Table 4.1 - Small to medium scale irrigation potential.

This does not include major schemes under NAFCO such as Madibira, the Kimande schemes, the Mtera reservoir and the Pawaga project as outlined above.

4.3 Ruvuma Region

Ruvuma Region suffers from poor communication and from being virtually cut off from the rest of the country for part of the year. This creates problems both for export of any surplus, and for bringing in farm inputs such as fertilizers, other chemicals, spares and other supplies.

In general, the region has good rainfall and high agricultural potential. It is hilly and undulating country with numerous streams and rivers, many of which are perennial.

Mbinga and Songea Districts are well populated in the higher areas, while in the lower areas vast resources remain untapped. These districts have fertile lands with a good production of agricultural products with maize being the mainstay of the economy in Songea, while Mbinga produces increasing crops of mild coffee for export. The main cash crop in Tunduru is cashew nuts, with a scope for cotton production. These cash crops can carry the high transport costs induced by the poor infrastructure in the region.

According to figures obtained from Irrigation Division of KILIMO there is a total of 14,580 ha being irrigated in the region. These are all traditional small scale irrigation schemes. Due to the topography there is not a big scope for large scale irrigation projects. It would appear that there is water available in most of the villages for mini-irrigation schemes of from 2 ha to 50 ha or even more. These could possibly be developed as village plots supplying vegetables and fruits in the dry season and thus provide a very useful addition to the diet, or else a surplus for sale. It would need surveying and planning in each case.

The region, and in particular Mbinga and Songea Districts, would appear to offer scope for systems of communal furrows for irrigation purposes, a bit like the system that is being practised in Kilimanjaro and Arusha. It would need a detailed survey and planning, and better water control systems would have to be constructed. Water should be allocated on a time basis under communal control.

Considering the topography of the region, there would appear to be several areas with an irrigation potential along the Ruvuma River and along the banks of most of its tributaries flowing south into the Ruvuma. This goes for Songea as well as for Tunduru Districts. However, these areas are very thinly populated and offer difficulties of access.

Finally, the only large scale scheme currently under consideration in Ruvuma Region is the Manda scheme on the lower reaches of Ruhuhu River. There is sufficient water in the Ruhuhu River, and suitable lands on both banks. The scheme, which has scope for developing 2,000 ha in Ruvuma and 1,000 ha in Iringa Region may be suitable for rice cultivation.

The pending soil classification map from Uyole will be valuable in pointing out further areas with a good crop potential from a fertility point of view. This work is likely to take some time to complete.

4.4 Mbeya Region

Mbeya Region presents a variety of agricultural zones, many of which have a very high either actual or potential agricultural production. It also has some of the most densely populated districts in the country, as well as areas where the density is very small.

The region is rich in water resources, but it is also a region where this water resource is threatened by mismanagement of the watersheds. This affects not only Mbeya Region, but may in the long run adversely affect the entire Rufiji River Basin.

4.4.1 Usangu Flats

Usangu Flats (or Usangu Plains) represents the largest and so far largely unexploited potential for irrigated agriculture and food production in the regions under review. A number of studies have been carried out which substantiate this potential (see Section 4.1 above), and major irrigation schemes in the area are already existing (Mbarara) or planned (e.g. Kapinga and Madibira, see below). Usangu Flats cover parts of Mbeya and Iringa Regions, and the area is part of the Rufiji River Basin.

The Mbeya RIDEP team considers Usangu Flats as divided into:

- A northern zone with little agricultural potential
- A grazing zone with an estimated cattle population of 500,000 heads.
- An irrigable cultivation zone which is of particular interest for this review, and finally,
- An intermediate zone with a possibility of cultivation if water can be provided. This zone is presently being overgrazed.

The Cultivation Zone includes an estimated 70,000 ha of land that could be irrigated. It is thought that this could be increased by as much as 20 to 25%, but with costly investments which at present may not be economically feasible.

It is reported that up to 20,000 ha is presently being cultivated and irrigated by peasant producers. In addition the large scale irrigation project at Mbarara covers 3,200 ha with planned expansion for a 2,700 ha large scale irrigation development, and another 2,000 ha is considered suitable for small scale irrigation from the Chimala and Great Ruaha rivers. In addition there are plans for 1,000 ha of small farming in the Kapunga area, based on water from the Chimala river. Finally, at Madibira (in Iringa Region, but still in Usangu Flats) there are plans for a 5,000 ha NAFCO rice farm under irrigation, and 3,000 ha of small scale farming based on water from a reservoir on the Ndembera river.

A farming technique of particular interest in the Usangu Flats is the so-called Large Scale Farming Method. The principle of this technique is to prepare the land deeply in the dry season by means of heavy machinery, and then dry plant and irrigate before the rain sets in in order to make the most of the growing season. Better yields and economic results are obtained by this method than is possible by traditional peasant production techniques. However, the method does require heavy machinery, well engineered irrigation works, and a possibility of accurate control of flooding if the high yielding rice varieties are to be employed. These varieties are very sensitive to excessive flooding, and a possibility of controlled draining of the fields for weeding, fertilizer application, etc. is desirable. For any substantial expansion of this method it will be necessary to construct dams and large reservoirs, as irrigation is required in times of very low river flow.

The traditional peasant practice is to wait with any cultivation until the first rain has softened the ground which is very hard when dry. Rice is then seeded when the rain sets in. The early rains are usually soon followed by natural flooding, as the rivers overflow when rains are heavy in the mountain catchments.

This traditional method is not at present very suitable for the newer high yielding short-straw variety which requires accurate water control. It does work well with the local long-straw and long-grain variety, which is also the most popular with the consumers in the area.

It is argued by the Commonwealth Secretarial Team and others that large scale farming as practiced by NAFCO, and the traditional method as practised by peasant producers complement each other quite well, because of their different cultivation practices. The reason for that is that the quantity of water available at the end of the long dry season is insufficient to allow the Large Scale Farming Method to be adopted on a very large scale. Most of the area will have to rely on run-of-the-river irrigation.

Suggestions for improvement of the peasant production in Usangu Flats will merit further attention, and investigation have been made by Mr. Leaky of the FAO RIDEP team in Mbeya (verbal communication). Mr. Leaky suggests that peasant production could be greatly expanded on the basis of natural floods with only minor and comparatively cheap correction of levels and construction of fairly simple river intakes. A system of minimum cultivation could be practised, when only a thin surface layer of soil is pulverised prior to the rain, and puddled with the early rains. By planting pregerminated seed (i.e. seed soaked for 48 hours) in these surface puddled fields, early germination will be assured, and the local or some other long-strawed variety will thus be able to keep up with the rising water. This way it should be possible to postpone costly civil engineering works, while at the same time expanding peasant production in the area to provide sufficient saleable surplus for some years to come.

Only when this method of expanding production has been fully exploited should large scale and capital intensive methods of expanding rice production in Usangu Flats be considered beyond what is already planned.

As indicated above further investigations are required before pursuing Mr. Leaky's suggestions. One major problem is the lack of a known method of cheaply preparing the soil for rice planting while it is still dry and hard. At one large scale farm run by NAFCO this is being done by heavy machinery, which means large investment in sophisticated machinery that uses expensive fuel and is difficult to maintain in working order under village conditions. Possibly, however, suitable ox-drawn implements could be devised.

As temperatures in the Usangu allow only one rice crop per annum, fields could be cleaned up by allowing cattle in on the harvested fields to eat the rice straw. In the Usangu there is a considerable cattle population which is largely untapped for commercial purposes. The cattle is mainly kept for prestige and traditional purposes. There ought to be a possibility of developing this food source in connection with expansion of rice production. There may be a possibility that the Wasukuma, who are herders as well as cultivators and who have already moved into the area, might form a good nucleus for a system of mixed farming based on cattle and rice as cash crops, utilising their oxen for cultivation.

4.4.2 Kyela District

Kyela District is another area where there is a great potential for increased paddy production and for creating a large marketable surplus.

The problems in Kyela are of a different nature than the problem in Usangu. The total area of the district is some 870 km^2 only, and it is one of the most densely populated areas in the country. The district is a broad flood plain at an altitude of between 450 m and 600 m only, characterised by very heavy rainfall (2500 mm mean annual rainfall). Owing to the high rainfall one rice crop can be grown without irrigation.

The Kyela area is fed by four big rivers draining into Lake Nyasa namely Lufirio, Mbaka, Kiwira and Songwe. These rivers carry much silt during the early rains, and they have built up their beds so that the land falls away from the rivers, causing the land between the rivers to be flooded. One reason for the apparently increasing severity of the floods in the Kyela area is the denudation of watershed and forest areas. Too many hills are deprived of trees and vegetation, and too many steep slopes are cultivated with scant or no regards for soil conservation measures. The flooding problem is further aggravated by the cyclic rise in the water level of Lake Nyasa.

Only one crop per year is produced, although the climate and water avail-ablity would make two crops possible. For the crop that is produced the problem is to avoid excessive flooding rather than getting water on to the rice fields. Floods make the communication difficult, and often spoil the crops.

Hence the main problem in the area is to modify or prevent floods, and several suggestions have been made to this effect. One solution proposed by Dutch consultants is to build levees along the river banks in order to contain floods and prevent inundation of the land.

Another solution, suggested by Mr. Leaky, is to establish diversion channels through the lower-lying areas which would be capable of carrying the excess flow during periods of flood, retaining a normal flow in the present river beds. If water could be brought under control this way it would be perfectly feasible to produce a second crop by irrigation, using the normal flow in the rivers for irrigation during the dry season. The diversion channels would then act as drains for the paddy fields. The idea would be worth investigating and a study ought to be made of the possibilities.

While many types of tropical food crops are grown in Kyela District, and there is a production of cocoa and quite a bit of fruit, the main cash crop is rice grown in the rainy season. However, yields are very low, and much could be gained by improvement of agricultural practices, including better cultivation methods and weed control. Some levelling would likely have to be done to improve efficiency of irrigation in dry seasons.

There is seemingly a potential possibility of quadrupling the rice production in the area, as well as improving the output and performances of many other crops.

4.4.3 Rungwe District

This district generally has an adequate rainfall, and there would seem to be little scope for large scale irrigation. The temperature is too low for rice production, but there is excellent scope for most subtropical and temperate food crops. There is much tea and a good deal of coffee produced in the area.

There are numerous small and big rivers in the district and water shortage as such does not exist. During the dry season there is scope for mini irrigation schemes for production of vegetables, etc. This is already being practiced to a limited extent, but, a survey of the possibilities of constructing properly engineered mini-schemes should be indicated.

4.4.4 Mbozi District and Lake Rukwa Area

Mbozi District is a high plateau of altitudes of 1500 m to 2500 m above sea level.

The main food crops are maize, beans and vegetables, and the main cash crop is coffee. Some of the world's best quality coffee has been produced in Mbozi, and the district is an expansion area for coffee production.

Water supply both for domestic and for irrigation purposes is a problem, but whereever water can be made available in the dry season there is scope for irrigation. Some eight small irrigation schemes of 150 ha to 200 ha per scheme are in existence today. Coffee crops could be improved, and excellent perennial vegetables and food crops could be produced if water were available for irrigation. A detailed examination of the potential is called for, and is probably at present included in the FAO-supported RIDEP programme which - among other things - includes an investigation of the production potential in the area. Also the ground water potential should be examined.

There could be a ready market in Zambia's copper belt for any surplus that the district could produce, if the Tazara Railway would be sufficiently speedy and reliable to take the products through regularly.

There is a number of water rights issued in the district, but it is doubtful that proper and efficient use of available water in fact does take place at the present time.

In the Lake Rukwa area there is, according to RADO Mbeya, a potential for an approximately 8000 ha rice scheme with adequate water of an acceptable quality. At some distance from the lake the area is reputed to be free draining, and there should be no danger of salinization of the soil.

The main problem in the area relates to support facilities and infrastructure. This area should be investigated and surveyed, either with a view to a communal development scheme, or with a view to creating a large scale farm in an area where such an operation may be more appropriate for overcoming the inconveniences of remoteness.

4.4.5 Mbeya and Chunya Districts

In Mbeya District there are numerous micro irrigation schemes, where primitive intakes have been built with a view to producing dry season vegetables, or for providing supplementary water for coffee, etc.

There is much wastage of water, and there would be a real case for examining the situation in depth, and for having intakes and prospective irrigation areas properly surveyed, designed and implemented or rehabilitated. This, together with a planned protection of river banks and catchment areas, could help greatly to boost production, and at the same time preserve and improve a valuable asset for prosperity.

The altitude of the Chunya District is generally between 800 m and 1800 m, and the rainfall over the area is rather low (600 to 800 mm per year).

There is at present no shortage of agricultural land. The main food crops are maize, sorghum, sweet potatoes and cassava, and some groundnuts and finger millets. There is a potential for cotton production and for tobacco.

There ought to be some scope for small scale and mini irrigation schemes. Even if water would be short in the later part of the dry season a considerable boost could be given to some valuable crops such as vegetables and fruits by supplementary irrigation. These would be valuable addition to the diet and make it more balanced.

5. CONSTRAINTS TO AGRICULTURAL DEVELOPMENT

Irrigation development in the three regions under review is not generally constrained by inadequate natural resources or adverse natural conditions. Vast land and water resources in the regions remain untapped. The constraints to agricultural production in general, and to irrigated agriculture in particular in these regions are rather associated with inadequate infrastructure, market conditions, agricultural support and general incentives for increased output.

Main constraints, common to all the regions concerned, are indicated below:-

(a) Poor infrastructure.
All the regions are remote from the main markets. If peasants produced a substantial saleable surplus it would be a major effort to get it to the market. Access roads and transport possibilities are needed.

The poor infrastructure in the regions is probably the single most important constraint to agricultural development.

(b) Inadequate markets and prices.
No organised and secure markets are available to a lot of villages. Local stores capable of receiving and temporarily storing the products would be of great help, particularly for vegetables and fruits which these regions could produce in abundance.

Price to producers of agricultural products are probably too low, particularly in relation to costs of yield improving inputs such as fertilizers, weed control, irrigation, etc.

(c) Inadequate agricultural support.
Unavailability or delayed availability of agricultural input, such as fertilizer, pest and weed control chemicals, improved seeds, etc.

Unavailability or shortage of mechanical cultivation aids, agricultural machinery and treck oxen or tractors.

Ineffective, inadequate or complete lack of meaningful and supportive extension service, that has the confidence of the peasant producers.

Lack of technical support and advice for constructing irrigation works, and water and soil conservation works.

Lack of repair facilities and spares for even simple agricultural machinery.

(d) Inadequate health and education facilities.
Particularly in the lower flood irrigated areas there is a high incidence of infection with a number of debilitating parasites. Bilharzia and malaria are the most common in these areas, but there is a host of others that is also present at the higher elevations.

People unfit are not likely to be surplus producers or innovators of newer and improved agricultural practices. This apart from the problem of human suffering need to be ameliorated.

Education facilities are poor in many areas. This has a bearing on the future, but also on the present, as many enterprising parents tend to move closer to good schools and training institutions.

(e) Lack of incentives.
Little of what is desired in addition to food can be obtained for surplus money either locally or even at district headquaters. Even daily necessities such as soap, paraffin, and clothes are hard to get, not to mention items such as radios, bicycles, cotton prints, iron sheets, lamps, etc. There is little incentive for a peasant to produce a surplus when the extra earning buys nothing of what he really wants.

Generally there is too little or no incentive for young energetic people to stay in the villages, where life appears far less attractive than in urban areas. Complaints are heard that some villages are populated by older people and young children only. Older people are not generally the most receptive to new ways and improved methods that to them are still untried and unproven.

6. SUMMARY AND CONCLUSIONS

There is a vast potential for increased agricultural production in the regions under review.

With a unimodal rainfall pattern, but with a great number of mostly perennial streams, there is a potential in most areas for a second crop during the dry season, as well as improvement of the wet season crop by water control and supplementary irrigation.

A reconnaissance level review of irrigation in the three regions has been undertaken as part of the present water master planning study, indicating present agricultural conditions, irrigation potential and constraints to agricultural development. The review has been carried out region by region on the basis of available information and discussions with knowledgeable people. Existing and planned irrigation schemes have been identified, and potential irrigation development in each of the three regions discussed; but no effort has been made to estimate a gross irrigable area. Not only does the present level of information make any such estimate extremely uncertain, and hence of questionable value, but the figure itself would have only academic interest.

Land and water resources are important elements in the evaluation of the feasibility of irrigation development, but social, economic and other factors are equally or even more important, and the irrigation potential must consequently be evaluated as part of the Regional Integrated Development Programmes now underway in Iringa and Mbeya Regions, later to come in Ruvuma Region. In any case it can be conclusively stated that in large parts of the regions concerned water will not in a foreseeable future become a limiting factor for irrigation development.

The principal conclusions resulting from the present review are outlined below:-

(a) Medium to large-scale irrigation development.

With the acute shortage of food in the country, and the urgent need for a rapid increase in food production, it is correct to press ahead with large-scale irrigation schemes with a highly mechanised agricultural system for which feasibility studies have either been completed or are underway. Reference in this regard is made to the expansion of Mbarara, the Kapunga and Madibira projects, the Pawaga studies and the possibilities of making use of the Mtera reservoir area.

These schemes will in part be run by NAFCO, or in the case of medium schemes, by villagers under the guidance of Regional Agricultural Development Offices. Suggestions for the strengthening of these units have been prepared by the Irrigation Division of KILIMO.

Iringa Region in 1978 formulated plans of irrigation up to a total of some 8,000 ha in a series of small and medium size irrigation schemes by 1984. This is presently being further pursued and examined in detail by Agrar und Hydrotechnic A.G. under the irrigation section of the Regional Integrated Development work in Iringa Region.

Usangu and Kyela in Mbeya Region are special cases with particular problems of a different nature. These problems have been studied in some detail by Mr. Leaky of FAO.

Potential development areas for irrigation on a larger scale in the Chunya District from rivers draining into Lake Rukwa have been identified by RADO in Mbeya.

(b) Small-scale irrigation development.

It is likely that given technical assistance and adequate incentives and motivation, the peasant producers could provide a very substantial surplus for sale, of both food and cash crops.

Apart from the above rather large undertakings a considerable potential for small and mini-schemes in the villages appears to exist. A more regular supply of vegetables and fruits in the dry season may well have a very favourable impact on the general health of the population. Possibly this could be planned to go hand in hand with implementation of plans for supplying villagers domestic water.

(c) Watershed management.

Unless a very serious effort is made to protect the catchment areas, and stop the denudation of hills and mountains, it could well be that by the time irrigation works have been completed, there will be little water left for irrigation in the dry season. Indeed in many areas even domestic water supplies may be threatened, particularly where dependent upon surface water. Soil erosion also contributes to increasing the severity of floods which in some areas complicate wet season cultivation.

Urgent action is needed to protect an existing valuable asset.

(d) Agricultural extension services.

Successful irrigation farming requires a higher level of skill than does traditional rainfed farming if the potential of irrigation works is to be fully realised. Also it would be possible and desirable to produce a greater variety of crops than is normally done at present.

The present level of agricultural extension services is too inadequate to fully realise the potential benefits of irrigation development.

(e) Credit facilities and markets.

It is unlikely that a peasant producer will readily invest in fertilizer etc. for a crop that itself will bring no cash income. In many cases he would not have the cash to do so in any case. If peasant production is greatly to increase, rural credit facilities will have to be extended to be within reach of the small peasant producer.

Cash income is required to repay loans, and this is possible only if organised and secure markets are available within reach for the peasant producers. Development of such markets is a precondition for increased agricultural output from the villages.

(f) Agricultural mechanisation.
Most peasant cultivation is done by hand hoe. This puts a severe limit on what it is possible for a man and his family to cope with.

Iringa Region has instituted a programme for training oxen, and there are plans underway for obtaining suitable implements for use with oxen. This is a good development and worthy of support.

Indiscriminate mechanical cultivation, however, very often leads to increased and accelerated soil erosion. If mechanical cultivation is started anywhere except on very flat land it should go hand in hand with soil conservation measures.

(g) Health aspects.
When extending irrigation agriculture there is normally the associated hazard of water-borne parasites. The most important ones in this connection are bilharzia and malaria.

Both diseases can be very debilitating, and for a successful expansion of present agriculture under irrigation it would be necessary to bring these diseases under control.

(h) Provision of adequate incentives.
It is not to be expected that peasant producers will increase their production much above subsistence level unless adequate incentives are provided. It must be felt that the greater effort and input are worthwhile. This means that not only must there be adequate financial returns, but desirable goods and facilities must be fairly easily obtainable for the extra cash available.

7. RECOMMENDATIONS

The present review of irrigation conditions and possiblities in Iringa, Ruvuma and Mbeya Regions has indicated a large number of strategic elements of a successful irrigation development in the area. Detailed and comprehensive recommendations for such a development will undoubtedly result from the Regional Integrated Development Programmes. However, based on the present review, particularly the constraints to agricultural development listed in Chapter 5 above, the following specific recommendations are stressed:-

- As pointed out above poor infrastructure is probably the single most important constraint to agricultural development in the regions. Access roads, and transport possibilities in particular, need to be improved in order for peasants to be able to get their products to the market.
- Higher mountain areas should be protected against devastating erosion by tree planting on the steepest slopes, and a soil and water conservation programme in the lower areas. It would be necessary to continue this with a programme of planting trees for fire-wood in the villages, so as to have an alternate source of fuel for cooking.
- Agricultural extension services need improvement. Personnel should be found for this task who would also be skilled in the installation, operation and maintenance of irrigation works. It is necessary that the extension officer has the confidence of the people he is to serve, and that he has sufficient time to get to grips with the problems in the field. Special courses for training extension officers should be considered.
- The ideas of Mr. Leaky of FAO on irrigation development in Usangu and Kyela should be examined in more detail.
- A more detailed study of the potential for small and mini village irrigation schemes should be undertaken.
- Soil fertility and suitability for irrigation should be investigated, initially by preparation of detailed soil maps for the three regions (i.e. ongoing soil mapping by Uyole Agricultural Centre), secondly by more detailed soil investigations in promising areas.
- Credit facilities should be extended to the small peasant producer,

possibly by the creation of small credit unions with memberships of say up to 20 farmers. It should then be a rule that all members were responsible for any single defaulter's debt. It was indicated to the Consultant that if small peasant credit societies of this nature were set up, then the National Bank of Commerce might be willing to consider an enhanced rate of interest on their deposits in order to encourage this kind of business.

- Mechanised cultivation practices should be carefully controlled. If the Irrigation Division of KILIMO goes ahead with creation of a mobile irrigation construction unit, it would be well to join it with a soil conservation unit and to insist that no irrigation construction work be undertaken without appropriate soil conservation measures.
- The incidence of bilharzia and malaria must be reduced by controlling the vectors, i.e. the bilharzia-bearing snail Bionphilaria opp., and the malaria-bearing Anopheles mosquitos. Extensive work has been done by Tropical Pesticide Research Institute and by Tanganyika Planting Company (TPC), Ltd. on snail and mosquito control on the 8,000 ha irrigated sugar estate near Moshi. The results have been very good, and their methods would be worth studying with a view to extending particularly the snail control to other parts of the country. In Kyela and Usangu, with water that is not alkaline, the introduction of the biological control as successfully practiced by TPC in some of their non-alkaline drains may hold some promise.

APPENDIX 1.1

APPENDIX 1.1

IRRIGATION TERMS AND DEFINITIONS

ACTUAL EVAPOTRANSPIRATION: The rate of evapotranspiration, which actually takes place. The value is primarily determined by the supply of water to the root zone and soil surface. (mm per day).

BORDER IRRIGATION: Method of irrigation which requires that the irrigation area is divided into strips separated by low levees or borders, which guide the sheet of water as it moves down the slope. The land between two borders is called a border strip. Generally, these strips vary from 3 m to 30 m in width, and from 100 m to 800 m in length.

BASIN IRRIGATION: (Check flooding). A method of irrigation by which the desired amount of water is filled into plots bordered by levees, where it is allowed to stand until it infiltrates/evaporates. Basin sizes may vary from 1 m^2 to as much as 7.5 hectares.

CHECK STRUCTURES: Structures placed across field ditches to control the water level.

CONSUMPTIVE USE: The rate of water transfer from a vegetated area into the atmosphere by the combined processes of transpiration and evaporation from soil and interception storage. Essentially the same concept as evapotranspiration, when this is used to indicate the water consumption by crop stands. Consumptive use is mostly used in agricultural disciplines in conjunction with crop production, whereas the concept of evapotranspiration normally is used in hydrology as designation for the water loss from catchments. (mm per day).

CROP WATER REQUIREMENTS: The depth of water required to satisfy the water loss through evapotranspiration of a crop under ideal conditions. (mm per day).

EVAPORATION: The rate of water transfer from free-water surfaces to the atmosphere. (mm per day).

TRICKLE (DRIP) IRRIGATION: A method of irrigation whereby water is supplied to the crop through perforated pipes along the ground at the base of a row of crops.

CONVEYANCE EFFICIENCY: Ratio between the amount of water received at the irrigation fields and that diverted from the source to the irrigation system (Q_F/Q_S for surface water in Figure 1).

CROP YIELD: Harvested crop per unit area (kg/ha).

DEEP PERCOLATION: Rate of downward movement of soil water from the bottom of root zone. (mm per day).

DIVERSION STRUCTURES: Structures which divide the flow of water such as weirs, gates and inlet structures.

EVAPOTRANSPIRATION: The rate water transfers from an area into the atmosphere by the combined process of transpiration and evaporation from soil, plant and water surfaces.

FARM LOSS: Amount of water lostfrom the field through deep seepage and surface runoff (G+R in Figure 1).

FIELD APPLICATION EFFICIENCY: Ratio between the amount of water directly available to the crop and that received at the field inlet (E_S/Q_F for surface water in Figure 1).

FIELD CAPACITY: Moisture content of the soil profile after free gravitational drainage during two to five days of an initially saturated soil profile.

FLOOD IRRIGATION (WILD FLOODING): A method of irrigation whereby the water is flowing freely down natural slopes without much control. Interceptor ditches are usually placed at intervals down the slopes to collect surplus water.

FURROW IRRIGATION: A method of irrigation whereby the water is conveyed in narrow ditches between rows of plants. Water may be diverted by openings in the bank of the supply ditches or by small siphons.

GROWING SEASON: Period between planting or sowing and harvest.

IRRIGATION REQUIREMENT: The amount of water in excess of rainfall to meet crop water requirements, leaching requirements and various losses. (mm per day).

IRRIGATION EFFICIENCY: General term applied in irrigation practices, usually defined as the product of the conveyance efficiency and the field application efficiency.

LEACHING: Removal of accumulated salts by applying excess water (to allow water draining through the root zone).

PERMANENT WILTING POINT: Moisture content of the soil at which plants no longer are able to extract sufficient water for growth.

POTENTIAL EVAPOTRANSPIRATION: Total water loss to the atmosphere from an extensive surface of short green crop, actively growing, completely shading the ground and well supplied with water. (mm per day).

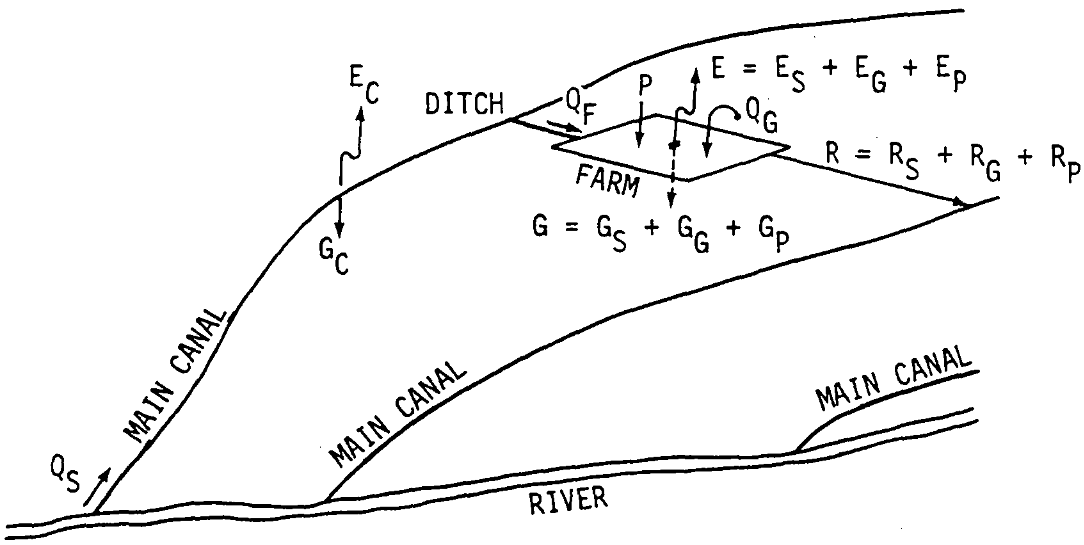
REFERENCE CROP EVAPOTRANSPIRATION: The rate of evapotranspiration from an extensive surface of a reference crop, which is actively growing, complete shading the ground and not short of water. Various reference crops have been suggested, e.g. an 8 to 15 cm tall green grass cover (FAO). (mm per day).

SIPHON: Short, often curved, tube for conveyance of water.

SIPHON STRUCTURES: Siphon spillways for regulation of water level within a reservoir; or inverted siphons for conveying water under roads or other obstructions.

SOIL EVAPORATION: Rate of water transfer from the soil surface to the atmosphere. (mm per day).

TRANSPIRATION: Rate of water transfer from the plant to the atmosphere. (mm per day).



Q_S - RIVER WATER DIVERSION

Q_F - RIVER WATER TO FARM

Q_G - GROUNDWATER PUMPAGE

E_C - CONVEYANCE EVAPORATION LOSS

G_C - CONVEYANCE SEEPAGE LOSS

P - PRECIPITATION

E - CROP CONSUMPTIVE USE
- E_S - FROM SURFACE WATER
- E_G - FROM GROUNDWATER
- E_P - FROM PRECIPITATION

G - DEEP PERCOLATION TO AQUIFER
- G_S - FROM SURFACE WATER
- G_G - FROM GROUNDWATER
- G_P - FROM PRECIPITATION

R - SURFACE RETURN FLOW
- R_S - FROM SURFACE WATER
- R_G - FROM GROUNDWATER
- R_P - FROM PRECIPITATION

HYDROPOWER

1. INTRODUCTION

1.1 General background

The Tanzanian policy seeks to diversify the economy by developing the industrial sector, thus reducing the reliance on agricultural exports for the generation of foreign exchange. The current trend is towards basic industries like cement, pulp and paper and textiles, although several other types of industries are planned as well.

The industrial developments will require large amounts of energy and the power generation is thus crucial to the national development plan.

Present policies on domestic use includes plans to bring electricity to a larger part of the urban population and to emphasise rural electrification as a means towards the cementation of the village structure.

On a national basis the maximum demand (1979) was 140 x 10^6 Watt (140 MW) while approximately 800 x 10^9 Watt x hrs (800 GWh) was generated. This corresponds to less than 50 kilowatt x hrs (50 kWh) per capita. However, less than 5% of the population has access to electricity.

Although the main objective of the Water Master Plans is to study the availability of water and the supply to the villages, also other utilisation of the water resources shall be taken into account. Among the possibilities for allocations for other utilisation are irrigation and hydropower. Thus, the hydropower potential of Iringa, Ruvuma and Mbeya Regions are outlined in the following chapters.

1.2 Approach

To a large extent the study has been based on the Western Tanzania Project Report (1976). This report lists identified potential sites in the regions and through the present study, efforts have been made to either verify or revise these findings. Additional sites have been identified through information collected in the field during the Water Master Plan study and from studies of airphotos and topographic maps.

The efforts in assessing the regions' hydropower potential have been concentrated on developments which immediately seemed technically and economically feasible. These assumptions are, however, made without extensive field investigations and in most cases utilising streamflow records covering an insufficient period of time. For these reasons the results of this study must be regarded as preliminary only, but may prove an adequate guide to where future efforts should be concentrated. As hydropower potentials deemed unfeasible are not included, the gross hydropower potential of the regions has not been assessed, this barely being of any but academic interest.

1.3 General power supply situation

The Iringa, Ruvuma and Mbeya Regions are presently served by isolated systems. These comprise diesel driven generating units in the main population centres and some minor hydroelectric installations.

The power demand has in some places reached or surpassed the capacity limits of the generating units, and installation of additional units is planned in Mbeya and Njombe.

In parallel with these plans construction of extensions of the national grid is undertaken. Of particular interest is the extension from Kidatu to Mbeya via Iringa and Mufindi (cf. Figure 1.1).

The power supply from the diesel-powered generating units is in many cases unreliable. Frequent power breaks occur and this combined with inadequate capacity render the conditions in for instance Mbeya quite unsatisfactory for the consumer. Load-shedding is taking place. The distribution from the isolated units is at 11 kilo Volt (kV) lines while only when long distances are involved 33 kV lines have been constructed.

The load variations for the isolated units normally show a two peak distribution, the largest peak occurring between 1900 to 2200 hrs, while a smaller, secondary peak is experienced at noon.

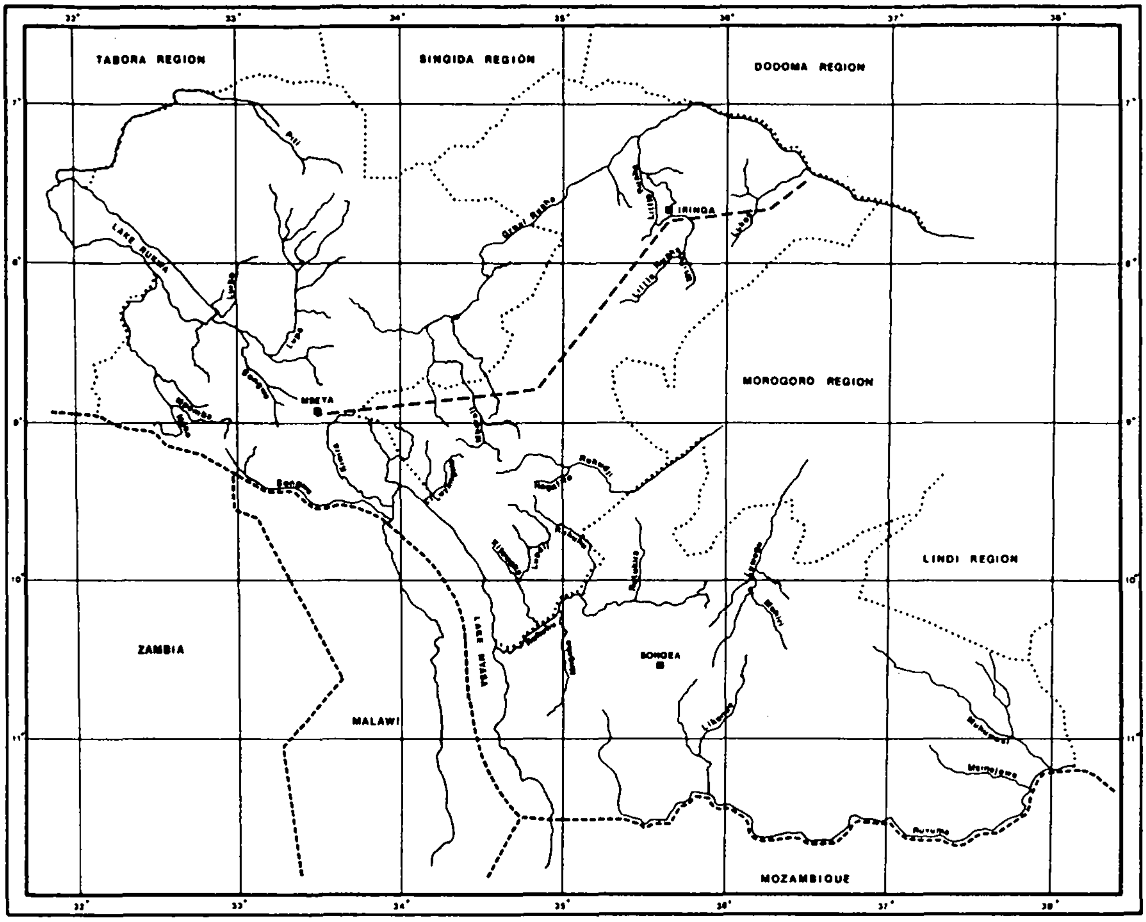


Figure 1.1 - Transmission line under construction.

1.4 Institutional aspects

The responsibility for all planning with respect to energy consumption in Tanzania lies with MAJI, Ministry of Water and Energy. However, the responsibility for all public generation, transmission and distribution of electric energy is executed through TANESCO, the national electric power utility. With respect to electric energy also studies of new sources for future use is to a large extent administered by this fully government-owned corporation.

2. HYDROPOWER DEVELOPMENT

2.1 General

The generation of hydropower exploits the difference in hydraulic head between two points of a river. By construction of impounding dams at appropriate locations the head difference and thus the potential of a power plant can be increased.

Figure 2.1 defines some main parameters of a hydropower system.

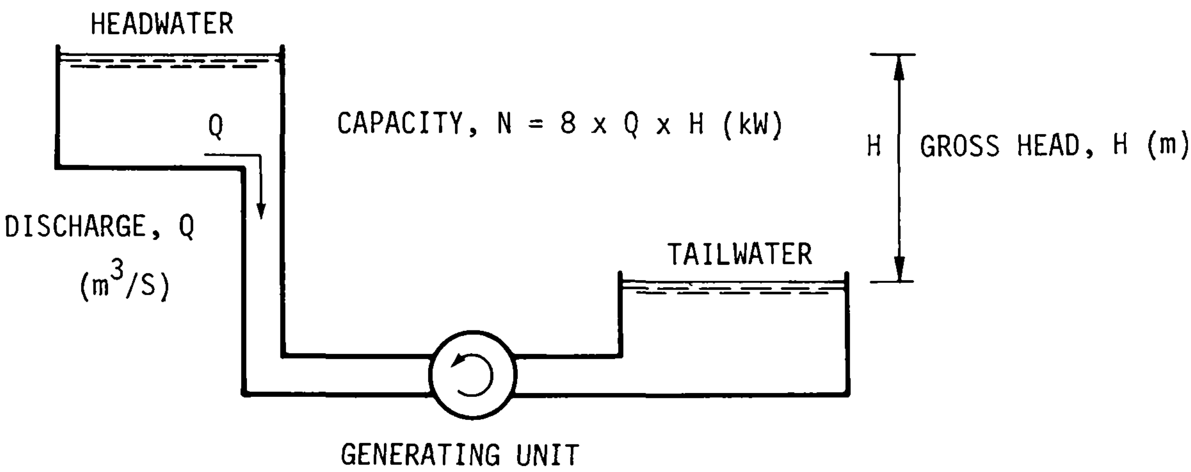


Figure 2.1 - Main parameter definition sketch.

The capacity of a hydro-electric power plant is determined by the discharge multiplied by the available head. The correct formula is:-

$$N = g \times Q \times H_e \times C_e$$

where

g = 9.81 m/s^2

H_e = net head (m) i.e. gross head minus head-losses

C_e = efficiency ratio of the generating unit.

Roughly, head-losses and efficiency ratio taken into account, the capacity is 8 x Q x H as indicated on the definition sketch. Apparently, the discharge and the head have equal importance with respect to output. However, taking into account generation costs which affect the economic feasibility, the head is more valuable than the discharge. High heads bring the waterway dimensions down relative to the output capacity, and also increase the rotating speed of the generating unit, both bringing the installation cost per kilowatt down.

The initial cost of a hydropower project is generally higher than that of a comparable thermal plant. The initial cost of the hydropower project includes the cost of the dam, diversion works, conduits, the generating plant itself, access roads, etc. Often a hydro-electric project is located at a relatively inaccessible location which adds to the initial cost because of the expense of hauling materials and equipment and because of long transmission lines to carry the energy to the market. In addition to the cost of transmission facilities there is loss of energy during transmission.

Thermal plants are usually located near their load centres, eliminating the need for long transmission lines. The site requirements for a thermal plant include the availability of an adequate supply of fuel and plenty of water for cooling the condensers. Hence, thermal plants are usually located on a sea coast or near a lake or a river.

The cost of operating a thermal plant is much higher than for a hydro-electric plant, mainly because of fuel costs. A thermal plant is also more difficult to operate and maintain, and the cost of maintenance and repairs is substantial.

Once found technically and economically feasible, the hydropower production costs are known more or less for the useful life of the project. The price of thermal power is conversely very dependent on fluctuating fuel prices, which in the Tanzanian context means a constant increase in the foreign currency bill.

Hydropower developments mean utilisation of a renewable source of energy, while conventional thermal power developments will exhaust the available resource. As the river flows vary considerably throughout the year and can be regulated only through establishment of reservoirs, an electricity supply based on hydropower only may not be feasible, or say possible. However, even a combination of the two sources of electric energy could mean a substantial reduction of oil imports.

There are different categories of hydro-electric power production schemes. They rank from run-of-the-river schemes, where the output varies with the variation in river flow, to the reservoir scheme with storage capacity large enough to regulate (control) the flow at all times. The degree of regulation affects the availability of the power, and hence the value of it. The highest value has the power that is available at all times, i.e. the firm power. Normally, one can accept a certain deficit at times and the term "firm power" is often used for power with an availability ranging from 90 to 100 per cent. In this study the terms used have the following definition:-

- Firm power: Power available 90% of the time.
- Firm energy: The corresponding annual energy output.
- Installed capacity: Maximum possible output.
- Load factor: The mean/maximum power demand ratio.

2.2 Medium to large-scale potentials

The normal procedure in identifying potential sites for hydropower development will be through a study based on topographic maps and airphotos. River stretches with concentrated falls or large gradients (at least 1%) can be found and the corresponding catchment areas measured. Matched with hydrological information about the runoff a rough idea of the energy potential can be worked out. Also the possibilities of establishing storage capacity will have to be evaluated and the approximate dimensions worked out. In addition, remoteness and accessibility have to be evaluated. For further refinement the various factors will have to be verified in the field, or if no topographic maps exist, the field work is the only way of identifying potential sites. In case of the latter, no evaluation can possibly be made without streamflow records on the site for a fairly long period of time.

The various factors, runoff, storage potential, river gradient, remoteness and accessibility - all affect the feasibility. The present study does not include a detailed evaluation of the feasibility of the various potential sites, but, based on experience from similar studies, the sites obviously not feasible for any of the above reasons, have been written off in order not to over-estimate the hydropower potential.

2.3 Small-scale hydropower developments

Minor, remote settlements with a certain demand for electric energy presently supplied by a small diesel generating unit, or without any supply, would definitely gain from development of small hydro-electric units. However, small demands calling only for a few kW installed capacity would require a source of hydropower a short distance away only. If not possible the transmission costs could easily kill the feasibility. In addition, development should be possible without extensive civil works like large dams. On the other hand, even though small hydropower units become relatively expensive per kW installed capacity, the present cost of diesel generated electric energy at remote locations allow a fairly high installation cost before a break-even point is reached.

As the Iringa, Ruvuma and Mbeya regions, like many other regions in Tanzania, do have a potential for small-scale hydropower developments the study of these potentials should be part of the programme for rural electrification. Especially for the remote settlements, where one cannot expect to be tied up with the grid system in a foreseeable future, a separate study of the potential for micro-hydropower schemes may prove beneficial.

2.4 Impact of hydropower development

Run-of-the-river schemes have litte, or no impact, on the streamflow regime of the rivers. The exception is of course the stretch between the intake end outlet, where the flow drops to zero during periods when it is not exceeding the power plant's maximum discharge capacity. Storage schemes will regulate the flow, i.e. the flow is increased during the dry season and reduced during the rainy season. Reduction of flood peaks after the reservoir is filled up cannot generally be controlled by the reservoir. If flooding represents a problem in the lower reaches of the river basin, storage schemes may have an additional benefit derived from the flood control, when reserving part of the storage capacity for this purpose. Through regulation of the flow, storage schemes may have a multi-purpose effect for instance in combination with downstream irrigation potentials. During a detailed study of potential sites, sediment transport will have to be given close consideration with respect to reservoir silting, which can reduce the useful life of the scheme. Also, the possible environmental impact must be taken into account upon assessment of the feasibility of a particular scheme, especially when dealing with large reservoirs and major diversions from one basin to another.

3. HYDROPOWER POTENTIAL ASSESSMENT

3.1 General

The hydropower potentials of Iringa, Ruvuma and Mbeya Regions have been assessed on an outline basis. Potentials, where development is deemed uneconomical, are not included. The feasibility of the schemes included in the total hydropower potential of the regions still remain to be established, and through a detailed feasibility study some of the identified sites may prove not economic.

3.2 Data base

3.2.1 Hydrology

There is an extensive network of streamflow gauging stations in the Iringa, Ruvuma and Mbeya Regions. Unfortunately, the time series on many occasions are either too short or incomplete. The runoff magnitudes and characteristics are based on all existing data, and to give an idea of the extent of the data base a statistics summary is shown below. For further information on the hydrology Volume 7 is referred to.

Iringa Region

Number of gauging stations:	19
Years of record range:	5-25
Average number of years on record:	19
Complete years of record range:	1-21
Average number of complete years:	13

For use in an outline hydropower study the records represent a relatively good basis for estimating the mean flows. With respect to firm flows the number of years on record represent a less sufficient basis for estimates. However, except for some run-of-the-river schemes the hydropower potential evaluations are less dependent upon dry season flows as the topographic conditions for creation of reservoirs in the region may be characterised as good.

Ruvuma Region

Number of gauging stations:	14
Years of record range:	2-16
Average number of years on record:	7
Complete years of record range:	0-7
Average number of complete years:	2

Even for rough estimates the time series represent a poor basis. The evaluations resulting from these records could therefore be considered tentative only.

A future updating of the hydropower potential assessment in the Ruvuma Region is strongly recommended.

Mbeya Region

Number of gauging stations:	41
Years of record range:	4-26
Average number of years on record:	14
Complete years of record range:	0-20
Average number of complete years:	7

The gauging stations are not evenly distributed throughout the region. The southern part of the region has the best coverage and also represents the most interesting part with respect to hydropower. Still, the time series are relatively short, but represent a fairly good basis for the rough estimates needed for the study. Large areas, the remote northern parts of the region and also the western part, suffer from insufficient hydrological data. Hence, estimates of river discharges cannot be carried out with sufficient accuracy.

3.2.2 Maps

The study is mainly based on the new topographic maps, series Y 742, scale 1:50,000. The availability of these maps is good in the southern and southwestern parts of the Iringa Region and in the south-eastern part of the Mbeya Region. Luckily the bulk of these regions' hydropower potential is found here. The availability of new maps in the Ruvuma Region is good. The vast majority of the Mbeya Region and the northern half of the Iringa Region suffer a lack of sufficient mapping.

Also the maps, series Y 303, scale 1:250,000 have been used, but except for rough estimates of catchment sizes for the very largest basins, these maps have little or no significance for site identification.

3.2.3 Reconnaissance basis

Some reconnaissance work has been done during other studies over the years. Most significant to the present study have been the Western Tanzania Project Report (1976), Acres (1981) and Halcrow-ULG (1981) reports.

3.3 Assessment of potential

As indicated earlier, potential sites have been identified primarily through a study of topographic maps and airphotos. Assessment of the energy potentials of the sites have in turn been evaluated through runoff estimates based on available streamflow records and through heads and waterway lengths determined from maps.

Regulation of flow through storage highly affects the energy potential. Regulated flow/necessary storage relationship curves do not exist as these normally require fairly long time series of streamflow records. A rough, conservative curve based on experience has been drawn for regulated firm flow (cf. Figure 3.1) and used for the purpose of this study.

For estimates of dry season flows with 90% availability (firm flow), duration curves from the existing streamflow records were used. An example of a duration curve is shown in Figure 3.2.

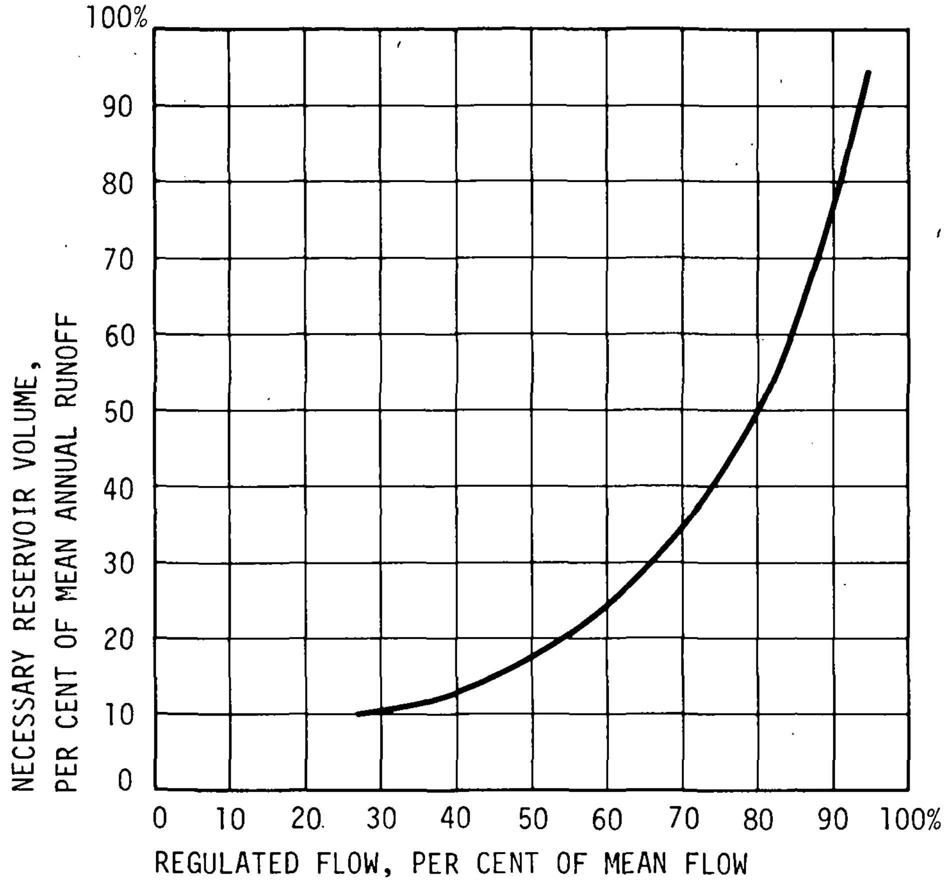


Figure 3.1 - Regulated flow

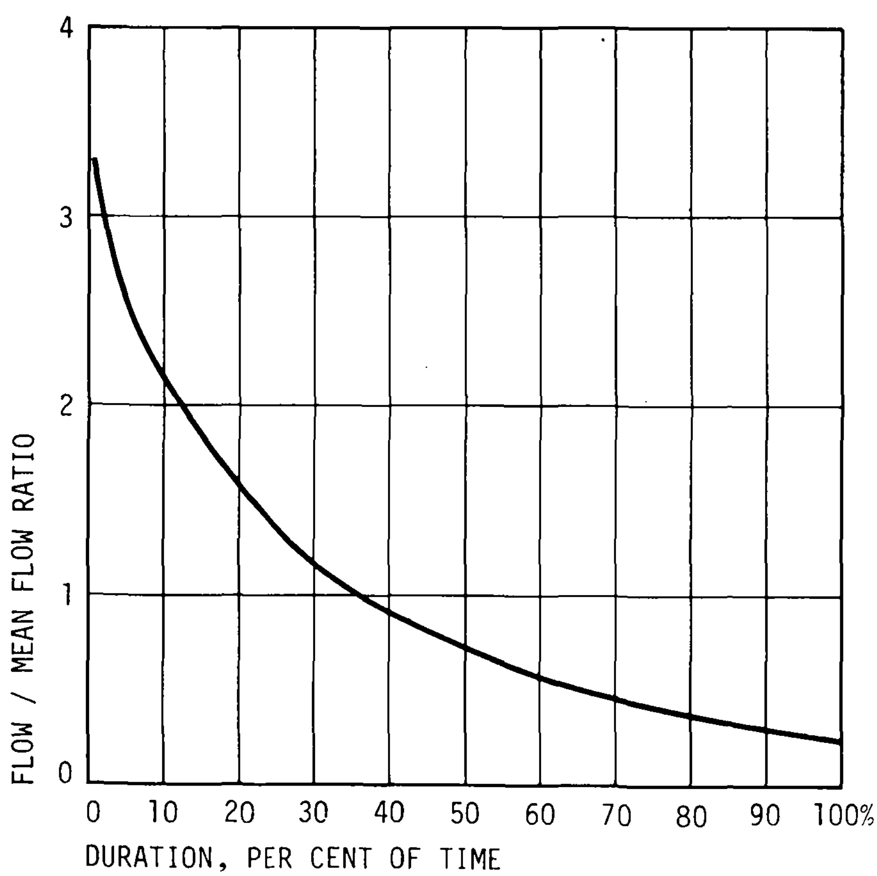


Figure 3.2 - Flow-duration curve

Dam heights, i.e. storage capacities, have been chosen mainly on a physical feature basis from available maps and not from an evaluation of the optimum dam height. This matter is requiring a thorough analysis based on detailed investigations and belong to a much later stage of hydropower studies.

Once the reservoir volume is chosen, the firm flow is found from the curve (cf. Figure 3.1). From a net head evaluation the firm power capacity is found, and hence the annual firm energy capacity.

Installed capacity takes into account a grid load factor of 0.7, which means the firm power capacity has to be increased by approximately 43% to arrive at the installed capacity. No attempt has been made to study the economies of additional installations for utilisation of the energy found in the mean flow - firm flow difference. Especially for run-of-the-river schemes this energy potential normally exceeds the firm energy potential and could very well be utilised in case of grid connection to a greater market.

3.4 Cost estimates

Capital cost estimates given in this study are made purely on an outline basis. With no geological or soil investigations and no detailed mapping, the intention is only to present a means of ranking the schemes with respect to further studies. The cost estimates are based on updated international prices for similar works. Included are civil works, electro-mechanical equipment and hydraulic steel works. Switchyard and transmission costs are not included. The idea of presenting the total capital cost per scheme is only to emphasise that the estimates are very rough, i.e. the uncertainty involved in the unit prices resulting from lack of site investigations. For instance, the unit price for a fill-dam may be 160 T.Shs. per m^3 (all included) with a 50% uncertainty involved, based on availability of core material, hauling distances, seismicity, i.e. embankment slope, foundation, seepage control, etc. The way of pricing the various works and equipment at this stage of a hydropower study, cannot be based on unit pricing similar to normal engineering estimates, but on an overall cost basis, i.e. price per m^3 total volume for fill-dams or concrete structures, per metre tunnel, etc. (including rock support, lining, etc.). Also, following the outline basis of the study estimates of cash flow can hardly be evaluated.

4. HYDROPOWER POTENTIAL

4.1 Present power supply

4.1.1 Existing diesel and hydro-electric installations

Table 4.1 lists the larger power installations in the three regions, their type and available capacity.

Name/location	Type	Available capacity kW	Owner
Iringa Region			
Tosamaganga	hydro	1,220	TANESCO
Iringa Urban	diesel	700	TANESCO
Wemba/Njombe *	hydro	100	Benedict.Fathers
Bulongwa	hydro	180	Bulongwa Hospital
Ruvuma Region			
Songea Urban	diesel	530	TANESCO
Songea	hydro	45	Magareza Project
Peramiho	hydro	30	Benedict. Fathers
Peramiho	hydro	3	Benedict. Fathers
Hanga **	hydro	-	St. Marus
Mbeya Region			
Mbalizi	hydro	270	TANESCO
Mbeya Urban	diesel	2,080	TANESCO
Tukuyu	diesel	1,050	TANESCO
Isoko/Tukuyu	hydro	10	Moravian Mission
Isoko/Tukuyu	hydro	7	Moravian Mission
Rungwe	hydro	21	Moravian Mission
Tunduma	diesel	225	TANESCO
Utengule	hydro	-	Swiss Plantation
Mbarali	hydro	160	State farm

Table 4.1 - Existing power installations
* under procurement
** under installation

Apart from the above mentioned larger installations there will definitely be a large number of minor diesel-electric generating units spread over the regions operated by missions, farms or government posts, like police stations, etc.

4.1.2 Main transmission grid

The national grid, the so-called coastal grid, interconnects the Kilimanjaro, Tanga, Dar es Salaam, Morogoro and Kidatu areas via 132-220 kW transmission lines. The main generating facilities are the 200,000 kW Kidatu hydro-electric scheme. The hydro-electric schemes on the Pangani River, 48,000 kW in total, and the thermal power plants at Ubungu, Dar es Salaam, 61,600 kW in total. This grid is being extended from Kidatu westwards via Iringa and Mufindi to Mbeya with a 220-130 kV line. The first part is under construction, this being very important to potential hydropower developments in the Iringa and Mbeya Regions.

4.2 Iringa Region

The hydropower potential of the Iringa Region is found mainly in the mountainous areas around Njombe, draining both westwards to Lake Nyasa and eastwards to the Kilombero Valley. Also, along the escarpment further east on the Iringa/Morogoro border line well-defined potential sites for hydropower developments are found. Both areas receive above average rainfall, and the scarps and plateaus represent desirable conditions for hydropower developments with respect to head and storage potentials. The streams in these areas are perennial. As, to a great extent, topographic maps exist for these areas, it has been possible to identify a number of specific sites and to estimate their potential. Some potential for hydropower is also found in the Great Ruaha River Basin, but except for a few potential developments on the Little Ruaha river and the known potential in connection with the Mtera Reservoir very little can be done owing to lack of topographic information. There is, however, no doubt that even more sites will be identified once topographic maps of the entire region become available.

4.2.1 Identified sites. Power and energy potential.

The identified sites, resulting from this study, are listed in Table 4.2. Location code, i.e. map sheet and grid references for the sites, is given in Table 4.3. Reference is made to the location map, Figure 4.1.

The schemes listed in Table 4.2 represent the following energy potential:-

- Firm power capacity 675 MW
- Firm energy capability 5,785 GWh/year
- Installed capacity (at 0.7 load factor) 975 MW

The feasibility of the schemes will have to be established through further studies.

Rough capital cost estimates are given in Table 4.4.

4.2.2 Other studies

According to information obtained from TANESCO aid agencies from various countries are presently conducting studies on specific small hydro-electric projects in the region, or may start doing so in the near future. Some of the schemes mentioned in this report may therefore be revised shortly, and some more added. However, these schemes are not likely to have any significant impact on the region´s total hydropower potential.

In the Iringa Region Denmark is presently sponsoring the study of the Ruhudji River Falls in Njombe, while the Federal Republic of Germany is sponsoring a study on the Hagafiro River east of Njombe.

Main river Tributary and site elevation (m)	Area km^2	Mean $l/s/km^2$	Flow m^3/s	Head m	Dam height m	Stor. cap. 10^6 m^3	Firm flow m^3/s	Firm cap. MW	Firm energy GWh/year	Install. cap. MW	Remarks
Great Ruaha											
Mtera								24	210	60	Source: 1)
Little Ruaha											
Tosamaganga	3,100	6.5	20.0	50	-	-	6.0	2.5	21.5	3.5	2)
Manyandomonda	3,200	6.5	20.0	35	-	-	6.0	1.7	15	2.5	
Ibosa	3,200	6.5	20.0	150	-	-	6.0	7.5	65	10.5	
Nginayo Hill	3,500	6.5	22.8	165	-	-	6.8	9.5	80	13.0	
Ndembera											
Maluluma Falls	-	-	-	50	-	208	-	-	15.8	2.0	Source: 3)
Kilombero											
Ruhudji											
Njombe	360	14.0	5.0	45	-	-	1.5	0.55	4.5	1	
1,430	2,035	15.0	30.5	100	50	340	21.5	17.5	150	25	
1,330	2,280	15.0	34.2	760	50	-	22.5	144.0	1,225	200	Daily pondage
575	2,425	15.0	36.4	210	45	-	23.0	40.0	340	50	" "
Mpanga 655	1,910	14.0	26.7	380	110	380	21.4	65.0	550	90	
Ruaha											
North Branch											
1,065				-	80	400					Diversion
South Branch											
980	3,750	20.0	75.0	140	100	900	56.0	62	530	90	N. Branch included
Ruhuhu											
Upper Ruhuhu											
Lupali 1,460				-	40	30					Diversion
Ngongwe 1,360				-	35	-					"
Ruhuhu 1,260	1,250	15	18.7	200	80	160	11.7	18	160	25	Diversion incl.
Lukumburu 1,160	570	15	8.6	160	40	120	6.4	8	70	12	
Ruhuhu 925	2,300	15	34.5	280	55	505	27.0	60	510	85	Diversion incl. storage added in cf. Ruvuma Region
Nkiwe											
Nkiwe 1,990	555	20	11.1	100	70	230	9.5	7.5	60	10	
1,900	620	20	12.4	420	60	280	11.0	36.5	310	50	Storage added
1,500	735	20	14.7	320	40	310	12.5	32.0	280	45	" "
Malisa 1,490	315	20	6.3	360	70	50	3.8	11	95	15	
1,200	370	20	7.4	-	20	-	-	-	-	-	Diversion
Nkiwe 1,200	1,200	20	24.2	745	20	360	19.3	119	1,020	170	Malisa diversion incl.
Rumbila											
Layangala 660	1,400	20	28.0	200	20	-	5.6	9.0	75	13	
Rumakali											cf. Mbeya Region
Total region								675	5,785	975	

Table 4.2 - Iringa Region - Identified hydro-electric projects. Technical key figures.

Main River/Site Elevation (m)	Ref. No.	Map Sheet No.	Grid Reference
Great Ruaha (A)			
Mtera (A)	101		
Little Ruaha			
Tosamaganga (A)	102	215 - 3	YG 863 - 323
Manyandomonda (A)	103	215 - 1	YG 852 - 444
Ibosa Hill (A)	104	215 - 1	YG 825 - 555
Nginayo Hill (A)	105	215 - 1	YG 767 - 617
Ndembera, Maluluma (A)	106		
Ruhudji			
Njombe (B)	107	261 - 4	XE 936 - 690
1,430	108	262 - 4	YE 494 - 554
1,330	109	275 - 2	YE 531 - 487
575	110	275 - 2	YE 667 - 471
Mpanga (B)			
655	111	249 - 3	YF 911 - 201
Ruaha (B)			
1,065 (diversion)	112 - 1	248 - 4	YF 598 - 120
980	112 - 2	262 - 2	YF 600 - 022
Ruhuhu			
Lupali (B) 1,460 (diversion)	113 - 1	274 - 4	YE 107 - 174
Ngongwe (B) 1,360 (diversion)	113 - 2	275 - 1	YE 213 - 275
Ruhuhu (B) 1,260	113 - 3	274 - 2	YE 179 - 324
Lukumburu (B) 1,160	114	275 - 3	YE 328 - 194
Ruhuhu (B)			
925	115	275 - 3	YE 387 - 010
Nkiwe (B) 1,990	116	273 - 2	XE 600 - 480
1,900	117	273 - 2	XE 558 - 418
1,500	118	273 - 2	XE 559 - 333
1,200	120 - 2	273 - 2	XE 509 - 299
Malisa (B) 1,490	119	273 - 2	XE 568 - 231
1,200	120 - 1	273 - 2	XE 531 - 230
Rumbila (B) 660	121	273 - 2	XE 288 - 436

Table 4.3 - Iringa Region. Identified hydro-electric projects. Location code and duration curve reference. (A) refers to 1KA2A, (B) refers to 1KB19.

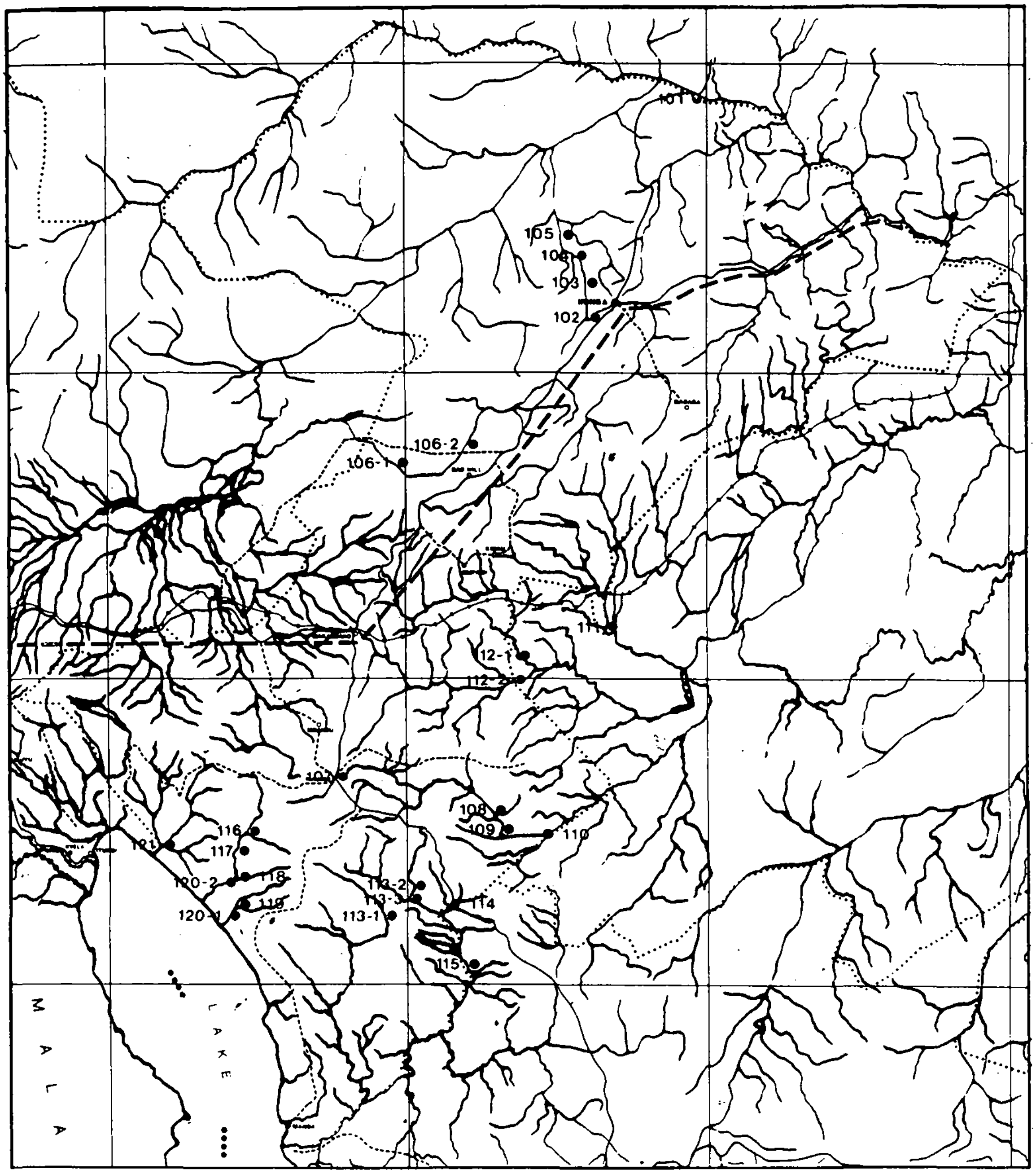


Figure 4.1 - Iringa Region - Identified hydropower project sites.
Reference numbers refer to Table 4.3.

Main River/Site/	Elevation (m)	Firm capacity MW	Firm energy GWh	Installed capacity MW	Capital cost million T.Shs.
Great Ruaha					
Mtera *		24	210	60	1,264
Little Ruaha					
Tosamaganga		2.5	20	3.5	64
Manyandomonda		1.7	15	2.5	40
Ibosa Hill		7.5	65	10.5	160
Nginayo Hill		9.5	80	13.0	88
Ndembera, Maluluma Falls **				2.0	29
Ruhudji					
Njombe		0.55	4.5	1	24
	1,430	17.5	150	25	680
	1,330	144	1,225	200	1,000
	575	40	340	50	520
Mpanga	655	65	550	90	2,120
Ruaha (to Kilombero Valley)	980	62	530	90	2,200
Upper Ruhuhu					
Ruhuhu	1,260	18	160	25	1,600
Lukumburu	1,160	8	70	12	400
Ruhuhu	925	60	510	85	1,240
Nkiwe					
	1,990	7.5	60	10	720
	1,900	36.5	310	50	704
	1,500	32	280	45	520
Malisa	1,490	11	95	15	680
Nkiwe	1,200	119	1,020	170	696
Rumbila/ Luyangala	660	9.0	75	13	216

Table 4.4 - Iringa Region. Identified Hydro-electric Projects. Rough capital cost estimates.

* Source: Tanzania Power Sector, Acres International, Febr. 1981. Report figure + 10%.

** Source: NAFCO. Report figure February 1981, 29.2 million T.Shs. Reservoir costs not included as this is part of the Rice Scheme.

4.3 Ruvuma Region

The only river basin of any significance to the hydropower potential in the Ruvuma region is the Ruhuhu River. This basin is partly located in the Iringa region and potential hydropower developments on the upper Ruhuhu fall within this region.

The lower reaches of the Ruhuhu River form the border line between the Iringa and Ruvuma regions. As this part of the basin geographically is closer to the central parts of the Ruvuma region, developments here are listed under this region.

In addition, conditions for hydropower developments are present on the scarps along Lake Nyasa, but the catchments are mainly small. The rest of the region has undulating terrain and streams that tend to dry up between rainy seasons. It is therefore not likely that one will find feasible developments here. Using the 1:50,00 maps with 20 m contour lines no developments on the Ruvuma River with tributaries appear to be feasible. Exceptions are on the upper reaches of the Lumeme River along the Mbamba Bay-Mbinga road.

4.3.1 Identified sites. Power and energy potential.

Sites identified during the study or by others are listed in Table 4.5. Location code, i.e. map sheet and grid references, are given in Table 4.6. Reference is made to the location map, Figure 4.2.

Main river / Tributary and site	site elevation	Area km^2	Mean $l/s/km^2$	Flow m^3/s	Head m	Dam height m	Stor. cap. 10^6 m^3	Firm flow m^3/s	Firm cap. MW	Firm energy GWh/year	Install. cap. MW	Remarks
Ruhuhu												
Upper Ruhuhu												cf. Iringa Region
Njegeya (Lilondi)	965	185	15	2.8	210	30	25	1.8	2.8	25	4	
Ruhuhu	570	10,500	15	158	120	125	5,800	142	120	1,040	170	
Mhangasi (Kitiwaka)	670	2,700	15	40.5	140	70	350	26	33	285	50	
Ruhuhu	495	13,500	15	194	85	90	5,800	188	128	1,100	180	Daily pondeage
Ruhuhu	520	-	15	-	190	170	7,900	194	297	2,540	425	Alternative Scheme
Ruvuma												
Lumeme	1,340	100	12.5	1.25	340	30	20	0.95	2.5	22	3.7	To Ng'ongi River
Ng'ongi												
Ng,ongi	900	190	12.5	2.38	245	5	20	1.3	2.6	22	3.7	Lumeme diversion incl.
Total region									290	2,495	410	

Table 4.5 - Ruvuma Region. Identified hydro-electric projects. Technical key figures.

Main River/Site	Elevation (m)	Ref. No.	Map Sheet No.	Grid Reference
Ruhuhu				
Njegeye	995	201	275 - 4	XD 941 - 441
Ruhuhu	570	202	285 - 4	YD 065 - 525
Mhangasi	670	203	285 - 4	YD 011 - 553
Ruhuhu	495	204	285 - 4	XD 941 - 441
Ruvuma				
Lumeme	1,340	206	309 - 2	YC 132 - 667
Ng'ongi				
Ng'ongi	900	207	309 - 2	YC 090 - 586

Table 4.6 - Ruvuma Region. Identified hydro-electric projects. Location code. All estimates are based on duration curve from 1RB2.

The schemes listed in Table 4.5 represent the following total energy potential:-

- Firm power capacity 290 MW
- Firm energy capability 2,495 GWh
- Installed capacity (at 0.7 load factor) 410 MW

The feasibility of the schemes will have to be established through further studies.

Rough capital cost estimates are given in Table 4.7.

Main River/Site Elevation (m)		Capacity MW	Firm Energy GWh	Installed Capacity MW	Capital Costs Million T.Shs.
Ruhuhu					
Njegeya	965	2.8	25	4	104
Ruhuhu	570	120.0	1,040	170	2,800
Mhangasi	670	33.0	285	50	1,360
Ruhuhu	495	128.0	1,100	180	1,320
Ruhuhu	520	295.0	2,540	425	4.800
Ruvuma					
Lumeme	1,340	2.5	22	3.7	240
Ng´ongi	900	2.6	22	3.7	80

Table 4.7 - Ruvuma Region. Identified hydro-electric projects. Rough capital cost estimates.

4.3.2 Other studies

According to information obtained from TANESCO aid agencies from various countries are presently conducting studies on specific small-scale hydro-electric projects in the region or may start doing so in the near future. The list of schemes may therefore be revised once the results from these studies become available. However, these schemes are not likely to have any impact on the regions´ total hydropower potential.

In the Ruvuma region, Sweden is presently sponsoring studies in the Songea and Tunduru areas, while the Federal Republic of Germany is sponsoring a study on the Luaita River near Mbinga.

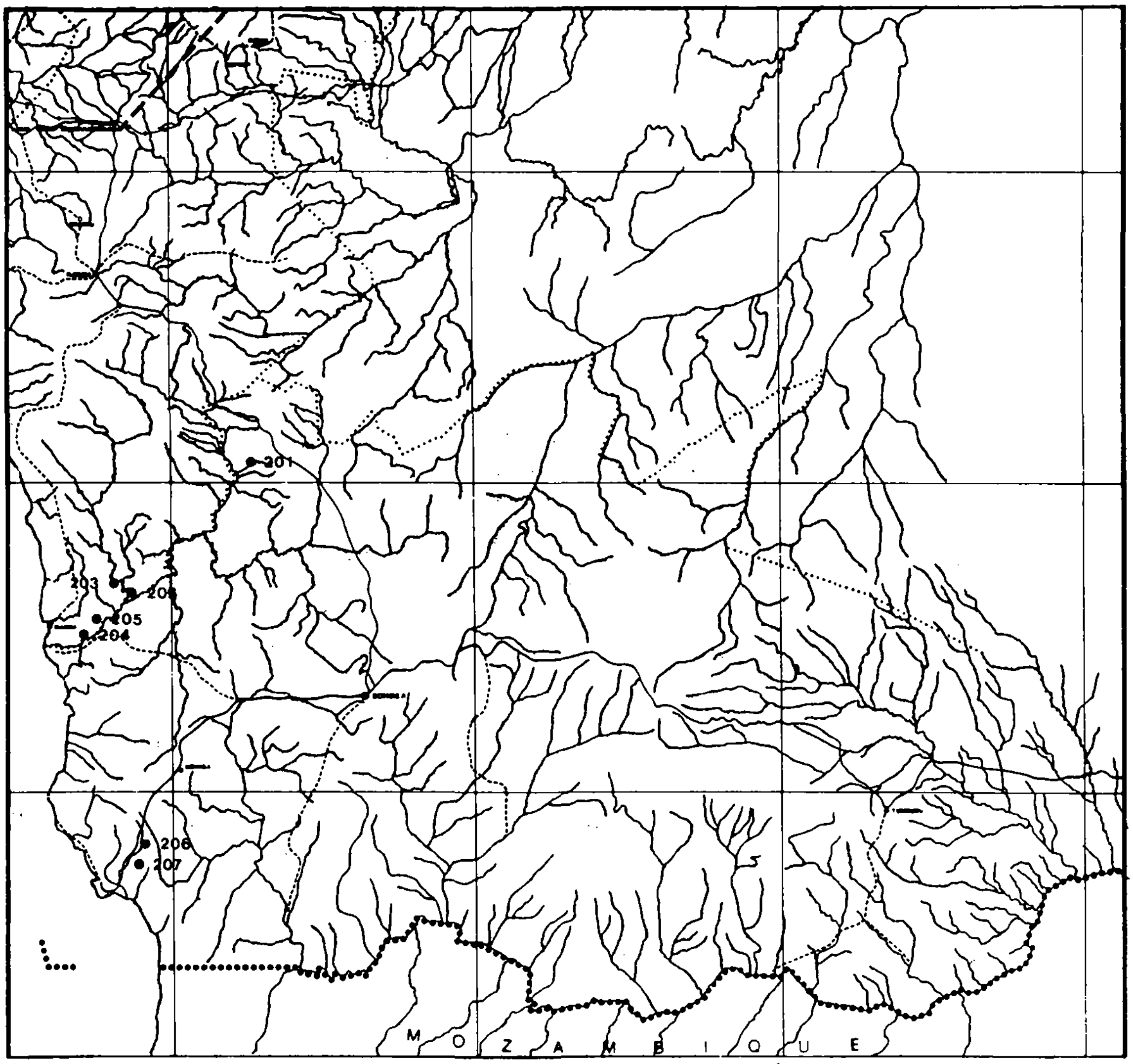


Figure 4.2 - Ruvuma Region - Identified hydropower projct sites.
Reference numbers refer to Table 4.6.

4.4 Mbeya Region

The hydropower potential in the Mbeya region is found in the mountainous areas south and south-east of Mbeya town. These areas receive above average rainfall and along the scarps surrounding the northern end of Lake Nyasa, the topography is in favour of hydropower developments. For the larger part of the Mbeya region or approximately all areas north of 8° 30′ degrees South the annual rainfall is less than 1000 mm which, combined with a very pronounced dry season results in few perennial streams. As topographic maps with contour lines are non-existent for these areas potential reservoirs cannot be identified. The feasibility of hydropower developments here therefore is very uncertain, hence the schemes covered by the Western Tanzania Project, Report No. 2 on the Mtembwa, Songwe (to Lake Rukwa), Lupa, Lukwate, Wuku and Yeye Rivers are disregarded for the purpose of this study. It is recommended, however, that these basins be looked into later, when maps and further hydrological information becomes available.

The Songwe River, draining areas on both sides of the Tanzania - Malawi border to Lake Nyasa, has large reservoir possibilities in the Bupigu area half way between Tunduma and the lake. Although hydrological conditions here are favourable to hydropower developments, lack of mapping precludes evaluations of the feasibility. Potential sites are therefore not included in this study, but should be kept in mind for future studies.

4.4.1 Identified sites. Power and energy potential.

The identified sites resulting from this study are listed in Table 4.8. Location code, i.e. map sheet and grid references, are given in Table 4.9. Reference is made to the location map, Figure 4.3.

Main river Tributary and site elevation	Area km^2	Mean $l/s/km^2$	Flow m^3/s	Head m	Dam height m	Stor. cap. 10^6 m^3	Firm flow m^3/s	Firm cap. MW	Firm energy GWh/year	Install. cap. MW	Remarks
Great Ruaha											
Mbarali 1,295	1,500	10	15	60	20	-	4.0	2.0	17	2.8	Daily pondage
Dhimala 1,340	190	20	3.8	150	-	-	0.75	0.9	8	1.3	
Lufirio											
Rumakali 2,190	275	25	6.9	200	40	160	6.2	10	85	15	
Nyituli 2,010	110	25	2.7	-	40	-	-	-	-	-	Diversion
Rumakali 2,005	525	25	13.1	1,440	35	310	11.8	140	1,250	200	Diversion incl.
Mbaka											
Mbaka 700	185	35	6.5	55	-	-	1.6	0.7	6.0	1.0	
600	300	35	10.5	40	-	-	2.6	0.85	7.0	1.2	
Kiwira											
Kiwira, Nat. bridge	655	32	21	60	-	-	8.75	4.5	38	6.5	Source
Alternative 1, down stream	825	35	28.9	300	-	-	10.7	26	220	36	"
Total region								185	1,630	265	

Source: Western Tanzania Project, April 1976 - revised.

Table 4.8 - Mbeya Region. Identified hydro-electric projects. Technical key figures.

Main River/Site	Elevation (m)	Ref. No.	Map Sheet No.	Grid Reference
Great Ruaha				
Mbarali (A)	1,295	301	246 - 4	XF 570 - 175
Chimala (A)	1,340	302	246 - 3	XF 116 - 170
Lufirio				
Rumakali (B)	2,190	303	260 - 1	XE 174 - 793
Nyituli (B)	2,010	304	259 - 4	XE 081 - 765
Rumakali (B)	2,005	304	260 - 3	XE 113 - 690
Mbaka				
Mbaka (B)	700	305	259 - 4	XE 862 - 674
	600	306	259 - 4	XE 880 - 624
Kiwira				
Kiwira, Nat. bridge (B)		307		
downstream (B)		308		

Table 4.9 - Mbeya Region. Identified hydro-electric projects. Location code and duration curve reference. (A) refers to 1KA7A, (B) refers to 1RC8A.

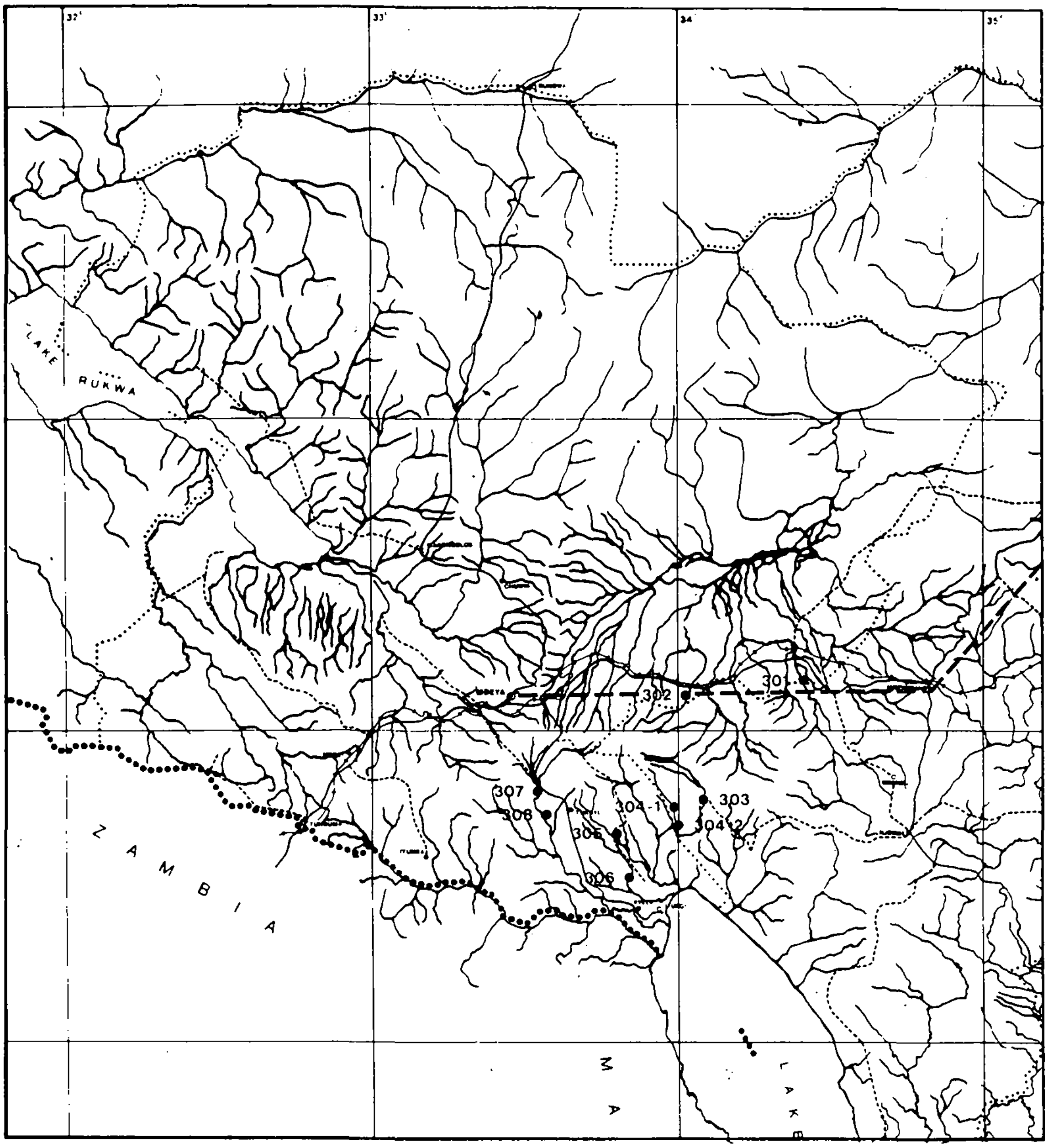


Figure 4.3 - Mbeya Region - Identified hydropower project sites.
Reference numbers refer to Table 4.9.

The schemes listed in Table 4.8 represent the following total power and energy potential:-

Firm power capacity	185 MW
Firm energy capability	1,630 GWh
Installed capacity (at 0.7 load factor)	265 MW

The feasibility of the schemes will have to be established through further studies.

Rough capital cost estimates are given in Table 4.10.

Main River/Site	Elevation (m)	Firm Capacity MW	Firm Energy GWh	Installed Capacity MW	Capital Costs mill. T.Shs
Great Ruaha					
Mbarali	1,295	2.0	17	2.8	120
Chimala	1,340	0.9	8	1.3	48
Lufirio					
Rumakali	2,190	10	85	15	704
	2,005	140	1,250	200	1,400
Mbaka	700	0.7	6.0	1.0	16
	600	0.85	7.0	1.2	24

Table 4.10 - Mbeya Region. Identified hydro-electric projects.
Rough capital cost estimates.

4.4.2 Other studies

There is at present no other known hydropower studies being conducted in the Mbeya region. However, according to information obtained from TANESCO a more detailed study of a possible development on the Kiwira River may soon go ahead sponsored by the Korean Aid Agency.

5. SUMMARY AND CONCLUSIONS

5.1 General

The hydropower potentials of the Iringa, Ruvuma and Mbeya regions have been assessed.

The most interesting parts of the regions with respect to hydropower are the mountainous areas in the southern parts of the Iringa and Mbeya regions with rivers draining to Lake Nyasa and the eastern part of the Iringa region with rivers draining to the Kilombero Valley and eventually into the Rufiji River. In addition, interesting potential hydropower sites may be found in the lower reaches of the Ruhuhu River on the borderline between the Iringa and Ruvuma regions. Most areas of interest are covered with new topographical maps at scale 1:50,000. There are, however, still large areas both in the Iringa and Mbeya regions with insufficient topographical mapping. Hence, there is no doubt that more potential sites for hydropower developments may be evaluated once the maps become available. Therefore, it is necessary that the hydropower potential be updated when more maps become available and preferably through a separate study.

The hydropower potentials are summarised in Table 5.1.

To arrive at an idea about the scale of the hydropower potential identified it could be mentioned that the total 1979 maximum demand was about 140 MW. Projections of this demand in conjunction with grid extensions to cover most demand centres in Tanzania could take this figure to, say 700 MW in the year 2005. The hydropower potential (if found feasible) in Iringa region alone could cater for this demand. It is thus clear that extremely large potentials are present, and if just one of the larger identified potential locations is deemed feasible power demand in a foreseeable future can be satisfied from hydro-electricity.

There is additional hydropower potentials in the regions that could be developed through small-scale projects. However, the potential energy of these schemes is without any significance to the regions' total hydropower potential and also the identification of such schemes requires extensive field work. However, considering the prices of fuel, the foreign currency shortage and the difficulties involved in maintaining thermal plants it is expected that small-scale hydropower plants will play an increasingly important role in the power supply for the rural areas. Also on an international scale more and more effort is directed towards development of appropriate hydraulic machinery for use in mini-hydropower plants.

River/Name	Sites	Firm Capacity MW	Firm Energy GWh	Installed Capacity MW
Iringa				
Ruhudji	4	202	1,720	276
Mpanga	1	65	550	90
Ruaha	1	62	530	90
Ruhuhu				
Upper Ruhuhu	3	86	740	122
Nkiwe	4	195	1,670	275
Others	8	66	575	120
Total	21	676	5,785	973
Ruvuma				
Ruhuhu				
Lower Ruhuhu	3	280	2,425	400
Others	3	8	70	11
Total	6	288	2,495	411
Mbeya				
Rumakali	2	150	1,335	215
Kiwira	2	30	260	42
Others	4	4.5	40	6.5
Total	8	185	1,635	265

Table 5.1 - Hydropower potential summary. Iringa, Ruvuma and Mbeya Regions.

The Tanzanian policy - to industrialise in order to increase exports and hence generate foreign currency will undoubtedly mean a steady increase in the demand for electric energy. Import of oil for thermal electricity generation at the same time means a great pressure on the economy because of the increasing prices. Hence, the development of indigenous resources, of which hydropower is plentiful, must be expected to play an important role in the future Tanzanian economy.

With the planned transmission line extension from Kidatu at the eastern corner of the Iringa region right through this region to Mbeya partly under construction already, transmission distances from potential schemes in this area are cut to within 150 km. This would make further studies of potential hydropower developments rather meaningful. One important benefit, among other things, would then be the combination of local supply and "export" of surplus capacity, i.e. development of locally too large schemes may be justified resulting in benefit from the economies of scale.

The Iringa and Mbeya regions both have potential sites for hydropower developments that deserve closer study as they may easily play an important role in the future economy of Tanzania with respect to rural as well as national developments. The feasibility of the potential sites described in this study will have to be established in more detail through further hydrological, geological and other studies. The rough cost estimates given should be used in ranking the schemes for further investigations only. It seems appropriate to concentrate on the less remote schemes with respect to the planned transmission line and high head schemes before low head schemes.

6. RECOMMENDATIONS

6.1 General

The present outline study of hydropower potentials has yielded a great number of possible locations for development of hydro-electric power generation. The potentials are seemingly very large in comparison to present and future demands.

The study gives rise to the following recommendations:-

- The promising results of this study should be followed up by a closer study of selected potential sites.
- Selection of sites for further studies should be based on proximity to the National Power Grid and schemes with high head possibilities should have priority in the selection over those with low head.
- Unmapped areas, or rather areas where no topographic details are known, should be mapped.

References

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