CHAPTER 5 INVENTORY SURVEY AND PCM WORKSHOPS

5.1 Existing Irrigation Facilities

Many irrigation facilities are provided for the existing irrigation schemes in the Mainland. These include dams, intake structures, canal linings and related structures such as diversion structures, turnouts, checks, culverts, cross-drains, spillways, aqueducts, bridges, field outlets and washing steps and appear in the various projects at different levels of quality. Findings through site inspection are outlined as follows:

(1) Dams

In the 1970s, 21 small-scale dams were constructed mainly on seasonal rivers for irrigation and domestic use purposes, centered on the Tabora region. These are of the earthfill type and currently, all except seven small-scale dams suffer from serious sedimentation, the removal of which is essential for recovery of reservoir function. Dam construction is largely restricted by hydrological and topographic conditions, and suitable site can only be selected based after in-depth study. In addition to these dams, many smaller dams exist over the whole land, called Charco dam for use for irrigation, domestic and livestock purpose.

(2) Diversion Structures

There are several types of diversion structures comprising gunny bags piling type, wooden piling type, bamboo piling type, gabion type, stone masonry type, and concrete type. The former three types are seen in the traditional irrigation scheme and the remaining types in improved traditional scheme and modern irrigation scheme. The former types are simple and easily constructed by farmers themselves but need frequent repairs as they are often washed out by floods. The gabion type weir has recently been developed as a low-cost option, but even careful construction supervision does not provide protection against floods. Many gabion weirs have been damaged by flood mainly due to poor construction and frequent repairs impose big loads on farmers. The stone masonry and concrete type weirs are the most stable and firm of all designs, but except in some cases, poor exterior condition has been caused by unsuitable plan, design and construction. The stone masonry and concrete type weirs require higher construction cost, therefore appropriate technical approach is essential.

(3) Canals

Canal lining is observed in both improved traditional and modern irrigation schemes. The applied linings are of stone masonry, concrete panel and cast-in-situ concrete types. Canal linings bring about benefits such as less maintenance, low conveyance loss, less land acquisition area, and protection against water-borne disease. Many farmers prefer the canal lining but since canal lining is generally expensive, its application should be carefully determined from not only technical and economic viewpoints, but also socio-economic and environmental viewpoints.

(4) Canal Related Structures

Traditional irrigation schemes are generally provided with no or few simple structures such as concrete pipe for crossing purpose. On the other hand, improved traditional and modern irrigation schemes are provided with many structures for system operation. Those structures are mostly made of concrete or stone masonry. Generally, those structures, except in some exceptional cases, are not properly designed or constructed from a hydraulic or structure viewpoints. In some cases, the structure interferes with smooth canal flow or proper water distribution. Over-design is also found. Poor gates with extremely short spindles are seen from place to place. Farmers are faced with difficulty in management activity if these incorrectly constructed facilities are handed over. Practical design and construction supervision manuals, and training of how to use them effectively are urgently required.

5.2 Inventory Survey for Irrigation Schemes

5.2.1 Objective and Scope

The objective of inventory survey of irrigation schemes is to describe the present situation including any proposed irrigation schemes. Features to be described include location, history, irrigation and drainage, agriculture and land use, farmers' supporting system, farmers' organization, operation and maintenance, and environment.

An inventory survey was conducted for the Arusha, Kilimanjaro, Tanga, and Iringa Regions by the RBMSIIP in 1995, covering 739 irrigation schemes. In the NIMP, a similar inventory survey has been conducted for the existing and newly proposed irrigation schemes, focusing on the remaining regions of the Mainland although additional irrigation schemes in the above four regions have also been included, a total of 689 schemes. Thus, the total irrigation schemes to be analyzed have come to 1,428 covering an area of 854,300 ha as follows:

Inventorized Schemes

Data Source	Nos. of Schemes	Estimated Irrigation Area (ha)
Inventory survey by the NIMP	689	616,700
Inventory survey by the RBMSIIP	739	237,600
Total	1,428	854,300

Source: Inventory survey conducted by the NIMP and the RBMSIIP

The general features of those inventorized schemes are summarized hereinafter and the relevant details are compiled in Appendix A.

5.2.2 Definition of Irrigation Schemes

In the NIMP, four types of irrigation schemes are identified for grouping, following the study results on Regional Irrigation Development Strategy in 1992. These are traditional irrigation schemes, water harvesting schemes, modern irrigation schemes and improved traditional irrigation schemes. Those irrigation schemes are defined as follows:

Traditional Irrigation Schemes: schemes which have been initiated and operated by farmers themselves, with no intervention from external agencies. Those would include schemes based on traditional furrows for the production of fruit and vegetables in the highland areas, and simple water diversion schemes on the lowlands for paddies.

Water Harvesting Schemes: water harvesting schemes and flood recession schemes, on which sub-subsistence farmers have themselves introduced simple techniques to artificially control the availability of water to crops.

Modern Irrigation Schemes: the formally planned and designed fully developed smallholder schemes, on which full irrigation facilities have been provided by external agencies with or without some contribution from the beneficiaries, and on which there is usually a strong element of management provided by the government or other external agency.

Improved Traditional Irrigation Scheme: schemes which have been initiated and operated by semi-subsistence farmers themselves and on which there has subsequently been some intervention by an external agency in the form of construction of a new diversion structure.

5.2.3 Classification of Inventorized Irrigation Schemes

The inventorized irrigation schemes classified by the irrigation scheme types are as follows.

Inventorized Schemes by Type of Irrigation

Type of Irrigation	Nos. of Schemes	Existing Area (ha)	Estimated Irri. Area (ha)
Existing Schemes	1,189	191,900	670,400
Traditional Irrigation	982	122,600	518,700
Water Harvesting	42	7,900	27,600
Modern Irrigation	52	35,900	73,800
Improved Traditional Irrigation	113	25,500	50,300
Newly Proposed Schemes	239	-	183,900
Water Harvesting	163	-	123,100
Modern Irrigation	76	-	60,800
Total	**1,428**	**191,900**	**854,300**

Source: Inventory survey conducted by NIMP and RBMSIIP

Existing traditional irrigation schemes, in Arusha and Kilimanjaro, account for over 60% of the total area. Water harvesting schemes are mainly located in such regions as Dodoma, Mara, Mwanza, Shinyanga, Singida, and Tabora. Modern irrigation schemes are developed in Kilimanjaro, Morogoro and Mbeya.

Out of 1,428 schemes, 1,111 schemes have a potential area of less than 500 ha. The irrigation schemes are categorized by size of irrigation area as shown below.

Inventorized Schemes by Size of Potential Area Unit : Nos.

Type of Irrigation	Less than 500 ha	500 - 2,000 ha	More than 2,000 ha	Total
Traditional Irrigation	810	136	36	982
Water Harvesting	133	54	18	205
Modern Irrigation	86	25	17	128
Improved Traditional Irrigation	82	30	1	113
Total	1,111	245	72	1,428

Source: Inventory survey conducted by the NIMP and the RBMSIIP

Of the total schemes, 1,328 are smallholder irrigation schemes while 85 private schemes and 15 government-managed schemes, such as NAFCO, and SUDECO, have been identified. Some private scheme cultivates cash crops, namely, tea, coffee, cashew, sugarcane.

Inventorized Schemes by Management Type Unit : Nos.

Type of Irrigation	Smallholder	Private	Others	Total
Traditional Irrigation	924	52	6	982
Water Harvesting	204	1	0	205
Modern Irrigation	95	25	8	128
Improved Traditional Irrigation	105	7	1	113
Total	1,328	85	15	1,428

Source: Inventory survey conducted by the NIMP and the RBMSIIP

River water is the main water resource of irrigation schemes in the Mainland. Some 1,300 schemes depend on water source from rivers and streams. Pump irrigation schemes, which are mainly located in such regions as Kagera, Mara, and Mwanza, depend on water sources from groundwater and lakes such as Lake Victoria.

Inventorized Schemes by Type of Water Abstraction Unit : Nos.

Type of Irrigation	Gravity	Pump	Total
Traditional Irrigation	962	20	982
Water Harvesting	204	1	205
Modern Irrigation	74	54	128
Improved Traditional Irrigation	106	7	113
Total	1,346	82	1,428

Source: Inventory survey conducted by the NIMP and the RBMSIIP

The result of classification is presented in Tables 5.2.1 and 5.2.2.

5.2.4 Need of Rehabilitation and Improvement

The irrigation schemes required for construction/improvement and rehabilitation are as follows:

Required Work Type Unit : Nos.

Type of Irrigation	Construction/Improvement	Rehabilitation	Total Scheme
Dam	5	3	1,346
Diversion weir	478	395	
Pump	78	2	82
Irrigation Canals	340	895	1,428

Source: Inventory survey conducted by the NIMP and the RBMSIIP

Over 60% of gravity type irrigation scheme require construction, improvement, and rehabilitation of diversion weirs. Most of the diversion weirs made by local materials in traditional irrigation schemes will be replaced by permanent structures made of masonry or concrete. Irrigation canal shall be rehabilitated or improved by providing partial lining of the diversion structure. Most of the pump irrigation schemes are constrained by shortage of funding for the scheme operation and/or the breakdown of the pump equipment.

5.3 Problems Analysis on Specific Fields

5.3.1 Agriculture

Through the site inspection and review on the existing data and information, the problems and constraints facing agriculture are found and discussed in Sub-clauses 4.3.3 and 4.3.4, and are summarized as follows:

- Low crop yield and unstable production due to over-dependence of rainfed agriculture
- Insufficient investment in land improvement due to uncertainly and insecurity of land tenure
- Rudimentary farming system mostly depending on hand hoes
- High rates of soil degradation due to the reduced fallow period

5.3.2 *Irrigation Schemes*

The problem analysis has been conducted for the six selected irrigation schemes that had been constructed after the preparation of NIDP as explained in Clause 4.4. The results of problem analysis are summarized below:

- Inadequate farmers' participation
- Poor logical structure for project planning
- Insufficient capability of Irrigation Section on appropriate project planning
- No feedback system
- No practical guidelines and manuals on project implementation
- Poor capability of private sectors such as local consultant and contractors
- Poor supporting system to WUAs
- Low capability of local government staff in irrigation development

5.3.3 Institution and Organization

The major institutional and organizational problems and constraints to irrigation development, which are discussed in Sub-clauses 4.3.6 and 4.3.7, are as follows:

- Low autonomy of Irrigation Section
- Inadequate coordination capability of Irrigation Section
- Unclear demarcation of responsibilities for extension services between Irrigation Section and local governments
- Lack of institutional guarantee tenure
- Lack of institutional mechanism to mediate water conflicts
- No comprehensive mechanism among major participants at central level
- Lack of a legal mandate, technical skills and facilitate to enforce some roles
- Lack of expertise for strategic and financial planning and management
- Very limited resources for local level institutional building for community participation in development process
- A shortage of competent personnel and technical equipment to manage and control development process.

5.3.4 PCM Workshops

(1) Core Problems and Objectives Identified

Five PCM (Project Cycle Management) workshops inviting different participant groups were held in June 2002. The invited groups were (i) the Irrigation Section, MAFS, (ii) Zonal Irrigation Officers, (iii) LGAs (DALDO), and (iv) Irrigators' Groups.

At each workshop the core problem for irrigation development, which each participant group was facing, and its direct causes were discussed and identified. The core problems identified are as follows:

- Ineffective Performance of the Irrigation Section
- Poor Support to Irrigation Development by LGAs
- Water Scarcity on Farm Plots
- Poor Development of Irrigation Facilities

At least two hidden core problems were further identified from these separately identified problems. They are *insufficient ownership* and *insufficient capability in institution, technology and finance*.

The core problems and direct causes may have a causal relationship among them. The results are summarized into the two charts, the integrated problem tree and the integrated objective tree as shown in Figures 5.3.1 and 5.3.2. These charts are utilized to identify program and project approach of the NIMP.

(2) Classification of Problems and Constraints

In the PCM workshops, a number of problems and constraints to irrigation development and/or management were raised by the attendant stakeholders such as Irrigation Section, LGAs, and WUAs. These problems and constraints have been analyzed and direct and secondary causes have been clarified. In addition, these secondary causes have been classified into five categories: financial, technical, social, organizational/institutional, and environmental issues, as shown in Figures 5.3.3 to 5.3.6. The direct causes for each stakeholder with related issues are summarized below.

Summary of Problem Analysis on PCM Workshop

Stakeholders/ Core Problem	Direct Causes	Issues				
		Financial	Technical	Social	Organization/ Institution	Environment
MAFS Ineffective Performance of the Irrigation Section	Lack of reliable database	O	O			
	Poor coordination amongst programmes and projects within the section		O		O	
	Inappropriate institutional set up for irrigation development central-local				O	
	Inadequate policy guidelines in irrigation development				O	
	Inadequate irrigation development capacity		O			
	Low moral of staff		O		O	
LGAs Poor Support to Irrigation Farming by the Local Government	Inadequate adoption of irrigation development policies				O	
	Mismanagement of extension staff		O		O	
	Lack of knowledge on the importance of irrigation to local government leader		O		O	
	Inadequate resources and capacity in the Districts				O	
WUAs Water scarcity on farm plots	Vandalism and inadequate maintenance of irrigation infrastructure	O	O	O	O	
	Inadequate water utilization		O			
	Poor irrigation canals		O	O		
	Inadequate irrigation scheme development		O	O	O	
	Inadequate water distribution		O			

	Inadequate protection of water resources					○
<u>Farmers</u> Poor development of irrigation farming	Intakes constructions not durable	○	○			
	Poor irrigation infrastructure		○			
	Inadequate water utilization in farm		○			
	Low participation of farmers in self-help activities			○	○	
	Intakes are dilapidated	○	○			
	Unreliable availability of water at source					○

Source: PCM Workshop conducted by JICA Study Team

The analysis results on the PCM workshops, present agriculture and irrigation schemes mentioned above, are used for preparation of Subject-wise Improvement Programme which is discussed in Clause 8.3.

CHAPTER 6 POTENTIAL AREA FOR IRRIGATION DEVELOPMENT

6.1 General

In this chapter, the potential area for irrigation development is examined and clarified since it is a key factor for planning irrigation schemes. Generally, irrigation development potential is assessed from the water resources potential and land resources potential only. In this Study, socio-economic potential is also taken into consideration, because marketing conditions are very important for irrigation development and largely influence the selection of irrigation schemes. The possible extent of irrigation development is determined by preparing and overlaying the assessment maps for the respective potentials mentioned above. The estimated area using this assessment method is significantly larger than using potential area for irrigation development only, by as much as 1 million ha.

6.2 Water Resources Potential

6.2.1 Hydrological Environment

The country is hydrologically divided into nine drainage river basins. These are (i) Pangani River Basin, (ii) Ruvu/Wami River Basin, (iii) Rufiji River Basin, (iv) Ruvuma River and the Southern Coast Basin, (v) Lake Nyasa Basin, (vi) Internal Drainage Basin, (vii) Lake Rukwa Basin, (viii) Lake Tanganyika Basin, and (ix) Lake Victoria Basin. The river regime in the Mainland follows the general rainfall pattern. River discharge and water level of lakes start rising in November and December and generally reach their maximum in March and April with a recession period from May to October or November. Considering these hydrological circumstances, the hydrological year starts in October or November and ends in September or October.

6.2.2 Previous Studies on Assessment of Water Resources Potential

The MWLD has conducted the following three water resources potential assessments through different examinations in the Mainland:

Previously Conducted Assessments in Water Resources Potential

Name of Project	Completed Period	Remarks
Water Master Plan by Region	From 1970' to 1980'	This is the first comprehensive achievement in water resources potential assessment compiled for most of the regions. It keenly requires to be updated, considering recent accurate information and data.
Rapid Water Resources Assessment	In 1995	The assessment significantly gave an outline of water resources potential in the country as an entire country basis, and indicated new direction to deal with water resources every river basin. As titled "Rapid" in the project name, it was rapidly

		assessed.
River Basin Management Project *	From 1996 to 2002	RBM has two development objectives: (i) to strengthen the Government's capacity to manage water resources in the Pangani and Rufiji river basins and (ii) to improve irrigation efficiency of selected smallholder traditional irrigation schemes in those river basins. Water resources potential for the river basins have been studied under the former objective.

** : Related to this Project, "Project for Sustainable Management of the Usangu Wetland and its Catchment" was conducted during from September 1998 to March 2002, in which irrigation was focused and condemned from an environmental views in Usangu.*

6.2.3 Macroscopic Water Balance in the Country

Prior to assessment of water resources potential, it is necessary to identify a general feature of water balance in the entire Mainland.

Mean annual rainfall and mean annual run-off, which are major factors in the hydrologic cycle, were estimated utilizing existing hydro-metrological data observed at 143 stations. The amount of groundwater recharge and basin evapo-transpiration from river basin were also calculated on the basis of hydrological information as described in Appendix E. Hydrological water balance by river basin made up of hydrological factors obtained in such manner is tabulated below:

Hydrological Balance by River Basin

No.	Drainage River Baisins	Catchment Area (sq.km2)	Inflow	Outflow			Remarks
			Annual Mean Rainfall* (mm)	Annual Mean Runoff* (mm)	Evapo-transpiration from the Basin** (mm)	Groundwater Recharge*** (mm)	
I	Pangani River basin	56,300	1,001.9	31.5	966	4.0	into the Indian Ocean drainage system
II	Ruvu/Wami River Basin	72,930	765.1	51.7	710	3.0	into the Indian Ocean drainage system
III	Rufiji River Basin	177,420	988.3	185.9	799	3.0	into the Indian Ocean drainage system
IV	Ruvuma River and Southern Coast Basin	103,720	1,050.0	20.5	1,028	2.0	into the Indian Ocean drainage system
V	Lake Nyasa Basin	39,520	1,672.5	344.6	1,324	4.0	into the Lake Rukwa drainage system
VI	Internal Drainage Basin	153,800	619.0	36.6	577	5.0	into the Internal drainage system
VII	Lake Rukwa Basin	88,180	1,095.0	104.5	985	6.0	into the Lake Rukwa drainage system
VIII	Lake Tanganyika Basin	151,900	1,173.6	124.7	1,045	4.0	into the Atlantic Ocean drainage system
IX	Lake Victoria Basin	79,570	1,111.1	18.6	1,087	6.0	into the Mediterranean Sea drainage system
	Total	923,340	997.5	97.0	896	4.0	

* : *These were analyzed under this Study using data of 143 gauging stations.*
** : *These were estimated deducting (Runoff) and (Groundwater recharge) from (Rainfall).*
*** : *These were tentatively estimated consulting the groundwater potential map in "RAPID WATER RESOURCES ASSESSMENT, 1995".*

In the Mainland, various water uses have intervened into the hydrological cycle. Major water uses are drinking and domestic water supply, irrigation water supply, livestock water supply, and hydro-power generation. The amount of each water use could be approximately calculated by making reference to the report of Rapid

Water Resources Assessment. The result is shown in following table:

Estimated Present Water Uses

No.	Drainage River Balsins	Annual Mean Runoff (Million m³)	Groundwater Recharge (Million m³)	Present Water Use: Domestic water supply * (Upper: (population:1000) Lower: (Million m³))	Irrigation supply ** (Upper: (Area: ha) Lower: (Million m³))	Livestock supply *** (Upper: (heads; 1,000) Lower: (Million m³))	Hydropower (Upper: (MW) Lower: (Million c.m))
I	Pangani River basin	1,773.5	225.2	*3,507.7*	*46,347*	*2,675.9*	*75.0*
				57.6	1,205.1	14.8	(422.7)
II	Ruvu/Wami River Basin	3,770.5	218.8	*4,172.8*	*10,326*	*561.8*	*0.0*
				68.5	268.8	6.1	-
III	Rufiji River Basin	32,975.3	532.3	*4,551.1*	*35,027*	*1,534.5*	*280.0*
				74.8	1,183.9	22.8	-
IV	Ruvuma River and Southern Coast Basin	2,126.3	207.4	*2,208.1*	*6,263*	*595.8*	-
				36.3	187.9	1.8	-
V	Lake Nyasa Basin	13,618.6	158.1	*856.1*	*2,838*	*328.7*	-
				14.1	78.6	3.1	-
VI	Internal Drainage Basin	5,629.1	769.0	*4,455.4*	*29,239*	*4,776.8*	-
				73.2	876.1	63.3	-
VII	Lake Rukwa Basin	9,214.8	529.1	*1,674.3*	*12,417*	*498.0*	-
				27.5	319.3	9.6	-
VIII	Lake Tanganyika Basin	18,941.9	607.6	*4,692.7*	*7,416*	*3,011.3*	-
				77.1	185.4	46.1	-
IX	Lake Victoria Basin	1,480.0	477.4	*3,901.3*	*7,122*	*2,239.1*	-
				64.1	111.5	39.5	-
	Total			*30,019.5*	*156,995*	*16,221.9*	-
		89,529.9	3,724.9	493.1	4,416.6	207.2	-

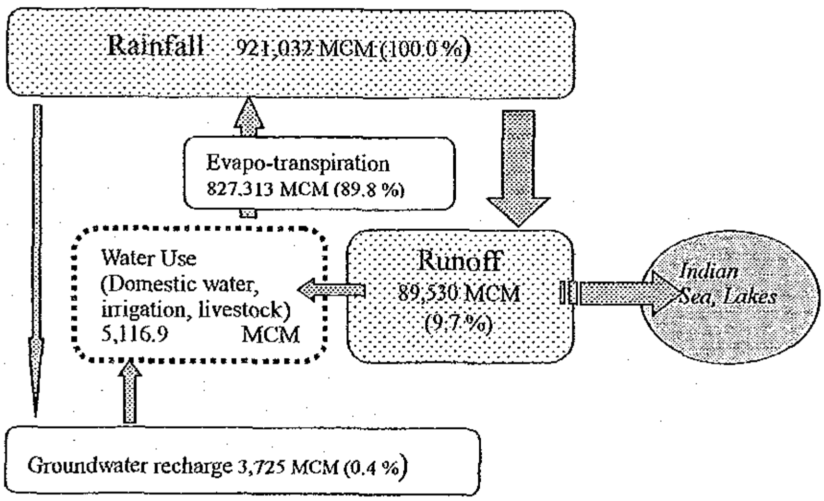
* : *Population of each basin was estimated recombining region-wise population in 1998 on the basis of geophisical factors.*

** : *These data in irrigation supply were estimated on the basis of the present irrigated areas which were referred in several sources.*

***: *Heads of livestock (cattle, goats and sheep) in each basin were estimated recombining the data in the District Integrated Agricultural Survey 1998/99 on the basis of geophysical factors. 30 lit/day and 5 lit/day of water requirement are applied for a cattle and a goat, respectively.*

The result of water balance analysis, indicated that and abundant amount of water source for present water use would be available. Water balance with present water use in the Mainland is schematically shown below:

General Water Balance in Entire Mainland



This figure indicates that the amount of water currently used requires only 0.6% of rainfall, although this does not include water used for rainfed cultivation.

However, fluctuation of water availability is a crucial factor since seasonal rivers are predominant in the Mainland. Most rivers have no flow in the dry season.

6.2.4 Method of Assessment of Water Resources Potential

(1) Specific Run-off

Specific run-off of every concerned hydro-meteorological station was calculated at annual mean level. Distribution of the obtained figures of specific run-off in the whole Mainland is shown in Figure 6.2.1. It is known that specific run-off becomes smaller as catchment area becomes larger. In this respect, the specific run-off was calculated using adjusted run-off data by deleting the effect of differences in magnitude of catchment area. The adjustment method is described in detail in Appendix E.

(2) Flow Regime

A flow duration curve shows a relationship between discharge of any given magnitude and the percentage of time that discharge is exceeded. In the Study, one-day flow duration curve was applied. It can be derived by assigning daily flows for the whole period of record to class intervals and counting the number of occurrences within each interval. The total number of occurrences above the lower limit of each class interval is then expressed as a percentage of the total number of days in the record.

Rivers classified into the Group A ($Q_1(95)>0$) are perennial and constant water abstraction from them would be achievable. Rivers into Group C($Q_1(65)=0$) are ephemeral rivers for which water use is short-lived within a year. Rivers into Group B($Q_1(65)>0$, $Q_1(95)=0$) are intermittent with an intermediate characteristic between the former two. The breakdown of river classification is that 68.5 %, 17.5 % and 14.0 % of rivers fall into Group A, B and C, respectively.

Regional distribution of flow regime was examined utilizing obtained flow duration curves in every concerned station. The flow duration curve for one-day discharge is expressed by $Q_1(n)$, where n is the percentage time exceeded in a year. Paying attention to the value of $Q_1(75)$ in the flow duration curves, the regional distribution was formed as shown in Figure 6.2.2, where the figure of 75 % means water flow available at the duration of at least three quarters of a year. The figure of regional distribution in the Mainland on flow regime, indicates that range of $Q_1(75)=0$ extends in marginal areas in Central Tanzania and southern parts. It confirms the fact that water harvesting is prominent in those areas.

(3) Groundwater Potential

Groundwater potential is closely related to hydro-geological characteristics, and correlates closely area by area. The amount of groundwater potential could be determined from the general hydro-geological structure in the Mainland. The general outline of groundwater potential for the Mainland was summarized as showing in Figure 6.2.3, utilizing previous result of investigation such as Rapid Water Resources Assessment Vol. I.

6.2.5 Identification of Water Resources Potential

In analyzing the results of assessment of water resources potential, three viewpoints, namely, "Quantitative potential of water in natural condition", "Allowable water quantity under the artificial control" and "Seasonal steadiness of water availability" were considered. Most significant viewpoint of water potential is the quantitative potential of water in natural condition. Besides availability of surface water, groundwater is also exploitable in the Mainland depending on the suitability of hydro-geological condition. However, quantitative share of groundwater within the whole hydrological cycle in the Mainland was identified at 0.4 % only. Therefore, for the purpose of understanding the general situation of water potential, a focus should be put on potentiality of surface water only.

Natural stream flow is not always abstracted freely. Attention should be paid for water right. "Allowable water quantity under the artificial control" means this water right. However, registration of water right has not been completed for all existing irrigation schemes so far. It should be therefore considered scheme by scheme, by means of confirming the individual water right.

Seasonal stability of water availability is another important factor of water potential for the convenience of perennial irrigation. This could be identified from the information of river regime characteristics obtained through the analysis of flow duration curves. The results for water potential analysis from the three viewpoints are summarized as follows.

Summary of Water Potential in Major Viewpoints

Viewpoints	Available Data	Identification of Water Potential	Status
Quantitative potential of water in natural	"Map of Specific Run-off" (see Figure 6.2.1)	Areas more than or equal 1.0 m^3/sec./500km^2 * could be identified as higher potential area.	To be considered largely
Allowable water quantity under artificial control	No information is available at the moment at the whole country basis.	It should be considered separately for scheme by scheme, by means of confirming individual water right.	To be referred if possible
Seasonal steadiness of water availability	"Map of Distribution of $Q_1(75)$ in Flow Duration Curves" (see Figure 6.2.2)	Areas having the value of $Q_1(75)$ more than or equal 10 % could be identified as higher potential area for perennial irrigation, otherwise identified as the area for water harvesting.	To be considered supplementary

*: *The "m^3/sec. per 500 km^2" is used as a unit for the data analysis as described in Appendix E.*

Generalizing the above examination, the "Specific Run-off" showing a quantitative potential of water in natural conditions could be regarded as providing wide-ranging water potential in the Mainland for the common purposes.

6.3 Land Resources Potential

6.3.1 Land Unit Classification

One hundred twenty eight land units were distinguished according to the position in the terrain and the proportions of the occurring soils. Each land unit was briefly described based on various viewpoints including slope and salinity. According to this description, land units were classified into three major classes, namely highly suitable, moderately suitable and marginal as land resources potential for irrigation development. Major criteria for the classification were based on slope, physical condition of the land, susceptibility to soil erosion and flood conditions.

Based on the above-mentioned classification, the land suitability map was processed from digitized land unit maps. This land suitability map was then utilized to produce the final land resources potential map to be explained in Sub-clause 6.3.4.

6.3.2 Soil Type Classification

Thirty major soil types were distinguished based on the dominant and associated soils distributed in the above-mentioned land units with different proportions. Characteristic of each major soil type is described in Soil Map of the World, FAO/UNESCO. According to this description, the major soil types were classified into three major classes, namely highly suitable, moderately suitable and marginal as land resources potential for irrigation development. Major criteria used were natural soil fertility levels, soil profile characteristics (such as hardpan), salinity levels, and drainage characteristics (well drained or poorly drained).

Based on the above-mentioned classification, the soil suitability map was processed from the digitized SADCC soil map. This soil suitability map was then utilized to produce the final land resources potential map to be explained in Sub-clause 6.3.4.

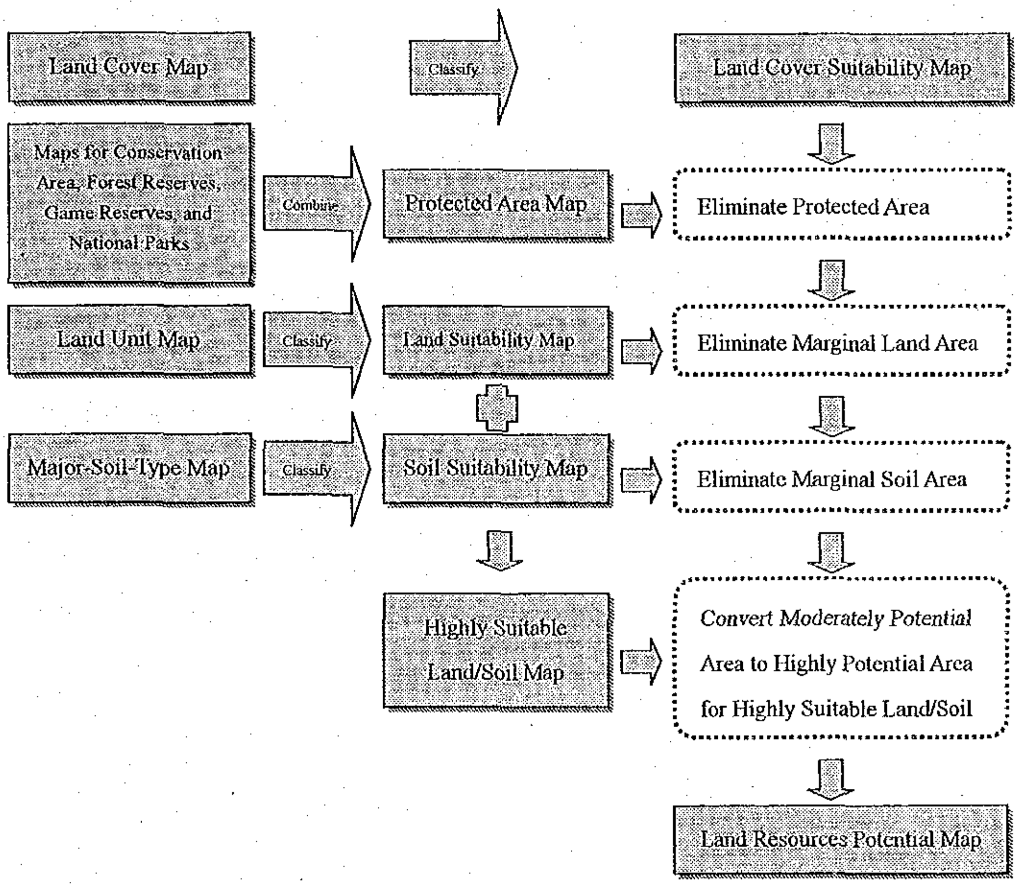
6.3.3 Land Cover Classification

Similar to land units and major soil types, the land cover suitability map was processed from the digitized national level land cover map. Since cultivated land has higher priority for irrigation development, cultivated land was classified as highly suitable area. The areas belonging to bushland and grassland were classified as moderately suitable area. Various forest types including natural forest, mangrove, plantation and woodland should be conserved. Other categories such as bare soil, salt crusts, rock outcrops, water surface and urban areas are marginal for irrigation development. This land cover suitability map was then utilized to produce the final land resources potential map for irrigation development to be explained in Sub-clause 6.3.4.

6.3.4 Identification of Land Resources Potential

Land resources potential map was prepared based on the above-mentioned maps such as land suitability, soil suitability, land cover suitability and protected area according to the data processing system as shown below.

Preparation Process of Land Resource Potential Map



The land cover suitability map was used as a base potential map for the current analysis. Since the protected areas including Forest Reserves, National Parks, Game Reserves and Conservation Areas are not permitted to be developed, all the protected areas were eliminated from the potential area. Marginal land such as mountainous ranges, steeply sloping land and saline areas were then eliminated from the potential area. Marginal soils such as saline soils were further eliminated from the potential area. Finally, the moderately potential areas were converted to highly potential areas provided that the land unit and soil type were both classified as highly suitable. The land resource potential map thus created is shown in Figure. 6.3.1.

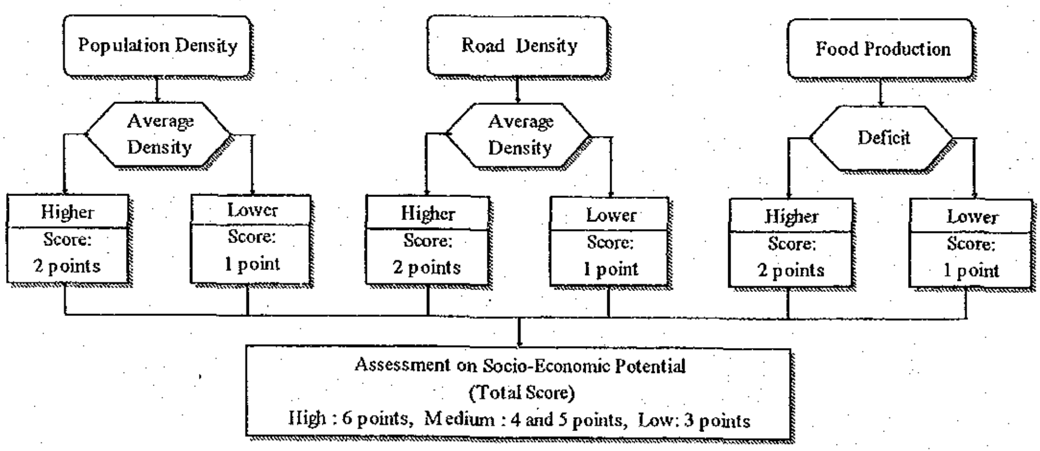
6.4 Socio-economic Potential

6.4.1 Assessment Methodology for Socio-economic Potential

Factors to be considered for assessment of socio-economic potential are (i) size of market, (ii) distance to market and its accessibility, and (iii) availability of agricultural labor. In this assessment, population density, road density and food deficit are employed as indicators expressing the said factors. Inventory survey results show that many irrigation schemes are located surrounding areas of paved roads (bitumen main roads: Dar es Salaam - Morogoro - Iringa – Mbeya, Dar es Salaam – Kilimanjaro – Arusha, Mwanza – Musoma, and Mwanza – Runere) so from the viewpoint of accessibility to markets, both sides 50 km from these roads are considered as an additional indicator.

As for population and road densities, all districts are classified into two areas, namely higher and lower density districts as compared with the average density in population and road of the Mainland. Food deficit was evaluated from the results of questionnaire survey and inspection by the Food Security Department, MAFS. The deficit scores 2 points and surplus one point. Finally, the socio-economic potential is expressed by total scores; high potential for 6 points, medium potential for 4 to 5 points, and low potential for 3 points as shown in the following figure:

Assessment Flow of Socio-Economic Potential



6.4.2 Population Density

Population density is estimated using the district area[1] and the estimated

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[1] *Socio-Economic Profiles for respective regions jointly prepared by the Planning Commission and Regional Commissioner's Office in 1998*

population for 2002[2]. In this Study, the districts newly established are used, and the population for them is calculated on the pro rata basis of area if data is not available. Table 6.4.1 presents the district area, population and road density. The average population density except Dar es Salaam Region is estimated at 36 persons/km^2, and then socio-economic potential by population density is assessed accordingly.

- Higher Potential (more than or equal to 36 persons/km^2) : 69 districts
- Lower Potential (less than 36 persons/km^2) : 30 districts

6.4.3 Road Density

The Socio-Economic Profiles also present the length of roads in the respective districts, such as trunk, regional, district and other small roads. The socio-economic potential by road density is assessed using the estimated average road length of 93 m/ km^2.

- Higher Potential (more than or equal to 93 m/km^2) : 70 districts
- Lower Potential (less than 93 m/km^2) : 29 districts

The results are shown in Table 6.4.1.

6.4.4 Food Deficit

The Food Security Department of MAFS executed the questionnaire survey on food situation for the statistically selected 35 households for respective districts in 2001. The survey results first determined the percentage of households in the sample who replied as "Deficit", and then more than or equal to 50% defined a food deficit area, which is compiled in A Statistical Analysis of 2000/01. In case of no reply, the food situation is judged by inspection by staff of the Food Security Department of MAFS.

- Higher Potential (more than or equal to 50%) : 31 districts
- Lower Potential (less than 50%) : 68 districts

The breakdown of deficit for respective regions is given in Table 6.4.1.

6.4.5 Identification of Socio-economic Potential

Based on the results of the study on population density, road density and cereal deficit, the socio-economic potential is assessed as shown in Table 6.4.1.

Out of 99 districts, 25 districts are categorized as a high potential area from socio-economic viewpoints, 58 districts as a medium potential area and 16

[2] *Tanzania Population Projections (2000 – 2025) prepared by the President's Office*

districts as a low potential area.

As mentioned above, the paved road gives positive effects to the socio-economic potential. The potential for the area within 50 km from the paved road were thus lastly upgraded. The final socio-economic potential thus determined is shown in Figure 6.4.1.

6.5 Identification of Irrigation Development Potential Area

Irrigation development potential area is demarcated based on the results of study on water resources, land resources and socio-economic potentials mentioned above. The demarcation is made by overlaying these three assessment maps, and then high, moderate and severe areas are roughly identified. The locations of high, medium and low potential areas in potential are shown in Figures 6.5.1.

According to this figure, the High Potential Area is largely split between four places. The first place is extended at Mara, Mwanza and Kagera regions. The second place is located at Arusha and Kilimanjaro regions. The third place is in Morogoro region. The fourth place lies at Mbeya and Iringa regions. The Medium Potential Area is mostly located around the high potential areas. The Low Potential Area is scattered over the whole country.

The study results show the total area of 94.8 million ha, consisting of 2.1 million ha for "High Potential Area", 4.8 million ha for "Medium Potential Area", 22.3 million ha of "Low Potential Area", 31.1 million ha for "Forest/Marginal Area", 7.3 million ha for "Water Body", and 27.1 million ha for "Protected Area". Table 6.5.1 presents the more detailed information on the above.

The irrigation development potential areas on the district basis are given in Appendix E.

6.6 Confirmation of Irrigation Schemes Inventorized by Identified Irrigation Development Potential Area

Irrigation schemes obtained through the inventory survey, for which accurate coordinates are available, are plotted on the irrigation development potential map shown in Figure 6.6.1. This figure confirms the general trend that most of the irrigation schemes plotted are located around the irrigation potential areas.

According to the irrigation potential map prepared, high potential area is estimated at 2.1 million ha in gross. The estimated existing irrigation area by inventory survey is 854,300 ha, which indicates that there would still be plenty of room for further irrigation development. It is therefore proposed that further irrigation development be undertaken, and that selection of irrigation schemes be made by referring to this irrigation potential map.