No. 2

The United Republic of Tanzania

THE FEASIBILITY STUDY ON LOWER HAI AND LOWER ROMBO AGRICULTURAL DEVELOPMENT PROJECT

Volume I

MAIN REPORT

THE FEASIBILITY STUDY ON LOWER HAI AND LOWER ROMBO AGRICULTURAL DEVELOPMENT PROJECT VOLUME I MAIN REPORT

The United Republic of Tanzania

THE FEASIBILITY STUDY ON LOWER HAI AND LOWER ROMBO AGRICULTURAL DEVELOPMENT PROJECT

Volume 1

MAIN REPORT

November 1990

Japan International Cooperation Agency (JICA)

THE FEASIBILITY STUDY

ON

LOWER HAI AND LOWER ROMBO AGRICULTURAL DEVELOPMENT PROJECT

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PREFACE

In response to a request from the Government of the United Republic of Tanzania, the Japanese Government decided to conduct a Feasibility Study for the Lower Hai and Lower Rombo Agricultural Development Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Tanzania a survey team headed by Mr. Shinichi Yano, Nippon Koei Co, Ltd., three times from October, 1988 to August, 1990.

The team held discussions with the concerned officials of the Government of Tanzania, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

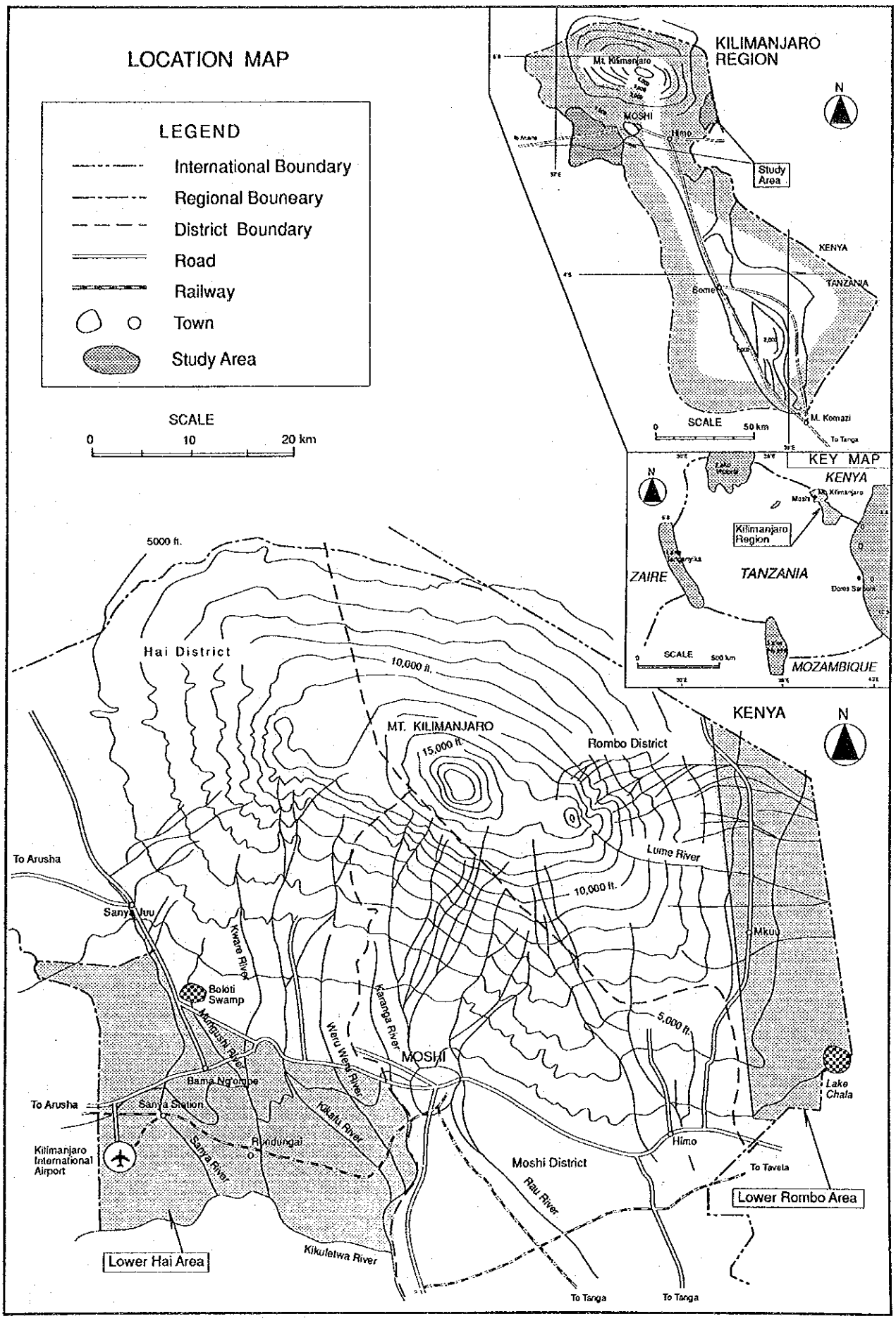
I hope that this report will contribute to the promotion of the Project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the United Republic of Tanzania for their close cooperation extended to the team.

November, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency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SUMMARY AND RECOMMENDATION

INTRODUCTION

1. This Report on the Feasibility Study on the Lower Hai and Lower Rombo Agricultural Development Project has been prepared in accordance with the "Scope of Work" agreed upon between Regional Development Director (RDD), Kilimanjaro Region of the United Republic of Tanzania and Japan International Cooperation Agency (JICA) on February 27, 1988. In particular this report presents the feasibility study for the development of the Sanya river basin selected as a development priority area (the Project area) among the various areas studied in both Lower Hai and Lower Rombo areas.

2. The Government of Tanzania requested the Government of Japan to provide technical assistance for a feasibility study on agricultural development project for the Lower Hai and Lower Rombo areas in March, 1985. In response to the request, the Government of Japan sent a contact mission in April, 1987 and a preliminary survey team in February, 1988 and decided to provide technical services for the feasibility study on the Lower Hai and Lower Rombo Agricultural Development Project. The Scope of Work for the Study and the Minutes of Meeting were agreed upon and signed on February 27, 1988 between RDD and JICA. They are attached in Attachment 1.

3. The objectives of the Study were (1) to assess the availability of groundwater and surface water resources for agricultural development, (2) to identify areas having

a potential of agricultural development from the view of water resources and land resources, (3) to select development priority area(s) among the identified areas, (4) to formulate agricultural development plan(s) for the development priority area(s), and to verify the technical and economic feasibility of the agricultural development in the development priority area(s).

4. The Study was carried out by JICA in three Phases in cooperation with the Government of Tanzania over the period from October 1988 to September 1990 in accordance with the Scope of Works.

AGRICULTURAL AND ECONOMIC BACKGROUND

5. The economy of Tanzania has grown steadily during the last decade and the Gross Domestic Product (GDP) at 1976 constant prices attained around Tsh. 27,039 million in 1988. The GDP grew at an annual rate of 1.9% during 1978 to 1988. Per capita GDP was estimated at Tsh. 1,201. The country's trade balance had a net deficit of US$ 813.0 million in 1988. Agriculture is still the largest sector in the Tanzanian economy. It provides about 45% of GNP, about 70% of export earnings and over 80% of total employment.

6. Kilimanjaro Region covers an area of 13,209 km^2 which corresponds to 1.4% of the total area of Tanzania. The population was 1,108,699 in 1988, which was 4.8% of the national population. The annual growth rate was 2.1% in last decade. Administratively, Kilimanjaro Region is divided into five (5) districts: Moshi, Hai, Rombo, Mwanga and Same. The gross regional

domestic product (GRDP) in Kilimanjaro Region attained Tsh. 9,992 million in 1988 at current prices, and was 3.67% of Tanzania mainland's GDP.

7. Agriculture in Kilimanjaro Region has played an important role in both the national and regional economy. The region is one of the main producers of cash crops, especially coffee. More than 90% of the population is estimated to engage in agriculture either directly or indirectly. In 1988, net cultivated lands were estimated about 2,800 km^2 which corresponds to 43.5% of the total arable lands. Kilimanjaro Region however continues to suffer from food deficiency because of low productivity and instability of food crops due to shortage of water resources, insufficient irrigation facilities and a rapid growth in population. In order to overcome the food deficiency, the agricultural sector has been allocated the highest amount of Tsh. 10 billion or 83% of the total funds in the Second Five Year Regional Development Plan (1988/89 - 1992/93).

THE STUDY AREA

8. The Study area consists of two areas; the Lower Hai area of about 600 km^2 and the Lower Rombo area of about 300 km^2. The Lower Hai area is located in Hai District on the southern foot of Mt. Kilimanjaro at an altitude of 750 m to 1,050 m. The area is undulating in most of the area. The climate is largely divided into two; the dry season from June to September and the rainy season from October to May. The mean annual rainfall is about 900 mm in the northern part and about 500 mm in southern part. Mean temperature is 20 to 22°C.

Relative humidity ranges from about 50% to 75%. There are five major rivers flowing from Mt. Kilimanjaro southwards: the Karanga, Weru Weru, Kikafu, Kware and Sanya Rivers. One river, the Kikuletwa flows from west to east along the southern border of the Study area. The area geologically consists of Precambrian basement rock, post-Neogene volcanic deposits, river deposits, lahar, outwash and alluvium. The lahar, outwash and old river deposits are considered to be principal aquifers in the Sanya Plain.

9. Population in the Lower Hai area is estimated to be around 42,000 and the population density is 70 person per km^2. The agricultural land accounts for 35% of the Study area. The main cropping season is March to July and the predominant crop is maize which is planted with rains in March/April and harvested in July/August. It is usually intercropped with either beans or other crops. Dry season cropping from September to February is limited because of shortage of water. There are small-scale the irrigation systems along major rivers. The total commanding area of the irrigation systems is roughly estimated at 5,800 ha. Most of irrigation systems have no or few structures such as intake gates, checks, turnouts, division boxes and measuring devices and no on-farm irrigation facilities are available. No systematic irrigation operations are actually being made at present.

10. The Lower Rombo area is located on the eastern foot of Mt. Kilimanjaro along the Kenyan border at an altitude of 1,000 m to 1,500 m. The area is hilly to flat topography. The rainy season is from November to May. The seasonal rainfall pattern has two peaks from

November to December and from March to May. The mean annual rainfall is 700 mm in the lower area to 1,500 mm in the upper area. In November and December, the temperature seems to be slightly lower than that in Lower Hai area. There are many small streams flowing through the east skirt of Mt. Kilimanjaro from west to east. The Lume river is the only perennial river. Streams other than the Lume river are seasonal in which water can be found only in the peak rainy season. The geology of Lower Rombo consists of Precambrian basement rock, post-Neogene volcanic deposit, talus deposit, pulverized deposit, fan deposit, terrace deposit, alluvium and riverbed deposit. There is deep groundwater in the post-Neogene volcanic deposit. The groundwater level is deep and the head required for pumping up such groundwater is more than 100 to 200 m. It is accordingly not suitable for the groundwater development from the economic view point. There is no good aquifer in the shallow zone consisting of fan deposit, terrace deposit, etc.

11. The population in the Lower Rombo area is estimated around 37,000 and population density is 123 person per km^2. About two thirds of the Lower Rombo area is extensively utilized for agriculture. The major cropping season is October to June. Double-cropping is conducted especially in the upper part of the Lower Rombo area. The main crops are maize, beans, cowpeas, and finger millet. There is only one existing irrigation system commanding about 300 ha served by the Lume river.

SELECTION OF THE PROJECT AREA

12. The available groundwater resources and surface water resources for agricultural development were examined in both the Lower Hai and Lower Rombo areas and it was found that no or little water resources were available for agricultural development in the Lower Rombo area. The following areas in the Lower Hai area were identified as a development potential area from the viewpoints of land resources as well as water resources:

Identified Area	Water Source
Sanya river basin Sanya plain (1,050 ha) Boloti area (290 ha) Mungushi area (210 ha)	Sanya river and Boloti swamp
Sanya plain downstream half (610 ha)	Groundwater
Mtakuja area (300 ha)	Kikuletwa river or groundwater
Kimashuku area (1,600 ha)	Weru Weru river

13. Among the identified areas the Sanya river basin area was selected as the Project area after the formulation of preliminary development plans of each of the identified areas.

THE PROJECT AREA

14. The project area covers about 3,170 ha gross. The Boloti and Mungushi areas are located to the north of the Moshi-Arusha highway. The Sanya plain extends southwards and is about 5 km south of Boma Ng'ombe. Administratively, the project area belongs in the Hai

district (Masama south and north wards; Nkawansira, Mungushi and Sanya Station villages).

15. The peak rainy season is the April. The annual rainfall is about 600 mm in the Sanya plain or about 750 mm in the Mungushi and Boloti areas. Out of the annual rainfall, about 60% and about 50% precipitate from March to May in Sanya plain and Boloti and Mungushi areas, respectively. The surface water sources will be the Sanya river including the Fuka river and the Lawati river, which are tributaries of the Sanya river, and the Boloti swamp. The surface water resources are estimated at 35 MCM on average and 21 MCM in drought year 1983/84. Out of annual runoff, about 65% flows during three months from April to June. As for the groundwater resources, some prospective aquiferous structures mainly consisting of old river deposits were found in the Sanya river downstream. Groundwater of 30 to 70 lit/sec/well and about 50 lit/sec/well on an average is expected to be obtainable.

16. The Sanya plain has flat topography sloping constantly at 0.5% to 0.7% in the north-west to south east direction. The soils are medium texture and the soil depth is deep along the Sanya river. While the Boloti and Mungushi areas are undulating. The ground surface slope ranges from 1% to 5%. The soils contain many stones and the soil depth is shallow. The land, 1,380 ha or 43% of the total area classified as arable (Class I to III) for irrigation farming is located in Sanya plain. The lands in Boloti and Mungushi areas (570 ha) and 1,050 ha of the lands in Sanya plain, however, are classified as restricted arable due mainly to shallow soil depth, stoniness and sodicity.

17. The population and available labour force are estimated on the basis of the demographic data of related villages and farmers' lists obtained from the traditional furrow leaders in the project area as follows:

	Boloti	Mungushi	Sanya Plain
Number of Households	159	253	384
Population	873	1,543	2,035
Available Labour Force	393	728	999

18. Maize and beans are the predominant crops. Most of the crops are planted at the start of the rainy season in March/April depending on rainfall. Planting of crops during the dry season is very limited and only where irrigation water is available. The cropping intensity ranges from 60% to 89% for the cultivation area.

19. Land preparation in Boloti and Mungushi areas is mainly by use of oxen. On the other hand, use of tractors for land preparation is common in the Sanya Plain. The farmers use their own seeds or purchase them from other farmers for planting due to low availability of certified seed. Direct seeding is common for maize. For beans, broadcasting is generally practiced in the Mungushi area and the Sanya plain, while direct seeding is generally done in the Boloti area. Fertilizers are used for maize and vegetables in the Boloti and Mungushi area, but not common for other crops. In Sanya Plain, most of farmers don't use fertilizers.

20. The present yields of crops remain very low as shown below:

Crop	Yield (ton/ha)
Maize	0.8 - 1.5
Beans	0.1 - 0.5
Sunflower	0.4
Vegetables (Tomato)	8.5
Banana	3.9

21. Present crop production from the Project is are estimated from net cultivated lands, cropping intensity and the above crop yields. Total production of maize, beans, sunflower, vegetables, and banana averaged during last decade 922, 127, 15, 85, and 98 tons respectively.

22. All land in the Project area is held by villagers under the traditional cultivation right known as Shamba tenure system. The average holding sizes in Boloti, Mungushi and Sanya Plain are estimated at 1.1 ha, 0.8 ha and 1.9 ha, respectively. About 90% of the farmers in the Boloti and Mungushi areas hold land less than 2.0 ha and occupy about 70% of the total areas. About 70% of the farmers in the Sanya Plain have land less than 2.0 ha of land.

23. The farm gate prices of the crops are shown below:

Crop	Price (Tsh./kg)
Maize	21.9
Beans	48.9
Tomato	35.0
Sunflower	51.0
Banana	7.4

24. The present extension works put emphasis on the introduction of recommended farming practices but do not function effectively due to lack of staff and insufficient facilities, particularly transportation. However, the "National Agricultural and Livestock Extension Rehabilitation Project" has been in operation since 1987 and conditions are expected to be gradually improved. About 400 tractors are in good and/or serviceable condition in Hai district and are properly operated under the Regional Farm Mechanization Programme through KNCU Hai branch office, the rural cooperative society, Hai district office and private sectors. Three (3) rural cooperative societies are operating in the project area. All the cooperative societies are newly established; Nkawansira in 1988, Mungushi and Sanya in 1989. These cooperative, however, are not yet fully functioning.

25. There are eight small scale irrigation systems along the Sanya river in the lower reaches and two small irrigation systems in Boloti. The command area of these irrigation systems is about 1,500 ha in total, however areas actually irrigated are quite limited along existing canals due to shortage of water. All the existing canals are earthen-made and the quality is very poor. Most of canals suffer from structural deterioration, sedimentation and weed-growth. No or few structures are provided. No drainage systems are provided.

THE PROJECT

26. Due to the present constraints and based on the national and regional development policies, agricultural development plan for the Project area aim at:

    (1) Removal and/or improvement of the present constraints for agricultural development in the area suitable for intensive agriculture with maximum use of surface water resources,
    (2) Increasing the production of staple food crops such as maize and beans as well as cash crops such as vegetables by means of crop intensification and diversification through irrigated farming, so as to contribute to the policy for self-sufficiency in food, and
    (3) Raising the living standards of farmers by increasing crop production.

27. In order to determine the optimum development scale of the Project, development alternatives were set and a water balance study between available run-off and irrigation water demands and an economic evaluation were made. From this, a full development plan for Sanya plain (1,050 ha) by conjunctive use of surface water and groundwater resources to be developed was selected as the optimum scale of development on the assumption that priority of water allocation will be given to the Boloti and Mungushi areas in accordance with their present cropping patterns.

28. The National Agricultural Policy nominates the Kilimanjaro Region for Area Specialization in Production of 14 out of 32 nationwide priority crops. Among the

recommended crops, maize and beans are selected as the main crops for the Project area, since maize and beans are the most profitable crop among other possibly crops under present economic conditions and the farmers have long experience in the cultivation of such crops. In addition, vegetables, sunflower and bananas are selected as diversified crops considering the farmers' intention, soils, marketability and profitability of crops and farmers' ability in cultivation of these crops.

29. The optimum cropping calendar was planned on the basis of the climatic conditions, particularly rainfall distribution and air temperature. Future land use in the Project areas is based on the proposed cropping pattern and is estimated as follows:

(Unit: ha)

Area	Rainy Season	Dry Season	Total	Cropping Intensity(%)
Boloti Area				
Maize	160	0	160	-
Beans	130	0	130	-
Sub-total	290	0	290	100
Mungushi Area				
Maize	85	0	85	-
Beans	45	0	45	-
Sunflower	5	0	5	-
Vegetables	0	10	10	-
Banana	25	-	25	-
Sub-total	160	10	170	106
Sanya Plain				
Maize	530	530	1,060	-
Beans	210	420	630	-
Sunflower	50	50	100	-
Vegetables	210	420	630	-
Bananas	50	-	50	-
Sub-total	1,050	1,420	2,470	235
Total	1,500	1,430	2,930	195

30. Land preparation for the proposed crops will be made by tractor in the Sanya Plain. Land preparation in Boloti and Mungushi areas will continue to be made by oxen because of stony and shallow soil characteristics. High yielding varieties will be introduced for the proposed crops, even in Boloti and Mungushi areas.

The soils in the Project area are slightly alkaline so that ammonium sulfate as a nitrogen source, triple super-phosphate as a phosphorous and potash as potassium will be recommendable.

Systematic application of insecticides and pesticides using sprayers will be proposed as plant protection works. Use of herbicides is not recommended for the Project environmental reasons. Other works such as planting, weeding, harvesting by both family and hired labour forces will be proposed .

31. There will be no shortage of labour in Boloti and Mungushi areas. On the other hand, in Sanya plain there will be a labour shortage of 40,000 man-day/year, particularly during the harvesting of vegetables due to introduction of intensive farming under irrigation. However, labour will be available not only from adjacent villages but also from the high or middle zone in the region where high population pressure a problem.

32. Anticipated crop yields are estimated as follows:

(Unit: ton/ha)

Crops	Boloti	Mungushi	Sanya Plain
Maize	3.0	3.0	5.0
Beans	1.2	1.2	2.0
Sunflower	-	0.81	1.35
Tomato	-	8.5	25.0
Banana	-	3.9	3.9

33. Anticipated production of crops in the Project area was estimated on the basis of proposed land use, cropping pattern and anticipated yield of crops as follows:

(Unit: ton)

Area	Maize	Beans	Sunflower	Tomato	Banana
Boloti	450	156	-	-	-
Mungushi	255	54	4	85	98
Sanya Plain	5,300	1,260	135	15,750	195
Total	6,005	1,470	139	15,835	293

34. For the development of surface water sources, the Boloti dam, a diversion weir and a diversion canal from the Lawati river to the Boloti reservoir, and two outlet structures to release water to the Sanya river and to the Boloti area will be provided.

35. As for the irrigation and drainage systems, an open canal system is proposed, since it is familiar to the people and easy in operation and maintenance. The proposed irrigation canal system will consist of a conveyance system from Sanya Chini headworks, main canals, secondary canals, and distribution systems composed of night storage ponds, tertiary canals, and distribution canals. Tubewells will be provided along the main or secondary canals in the potential

groundwater area in the downstream half of the Sanya plain. The conveyance system is planned to convey water 24 hours a day. Tubewells are planned to be operated 24 hours a day at peak irrigation demand, while day-time operation of the irrigation water supply will apply in the distribution system. Major drainage canals only are proposed so as to remove excess water. The drainage requirement is estimated at 6.4 lit/sec/ha. Roads will be provided along the main irrigation canals for transportation of agricultural produce and inputs as well as for operation and maintenance of irrigation facilities.

36. The salient features of the Project works are as follows:

(1)	Boloti Dam and Related Facilities	
	Effective storage capacity	: 7.5 MCM
	Low water level (LWL)	: 1,072.6 m
	High water level (HWL)	: 1,078.0 m
	Flood water level (FWL)	: 1,078.38 m
	Dam type	: homogeneous earthfill
	Crest elevation of dam	: 1,080.4 m
	Crest length	: 2,450 m
	Spillway	: Ungated overflow type concrete weir, 10 m wide
	Lawati diversion weir	: Fixed overflow type, crest length 16 m
	Diversion canal	: 2.6 km
	Outlet canal	: 1.5 km
(2)	Tubewells	
	Number of tubewells	: 12
	Design discharge	: 50 lit/sec/well (average)
(3)	Irrigation and Drainage Facilities	
	Sanya Chini headworks	: existing structure to be rehabilitated
	Main irrigation canal	: 21.5 km
	Night storage ponds	: 32 nos
	Tertiary and distribution canals	: 92 km
	Drain	: 18.1 km
(4)	Road	: 38.0 km

37. For implementation of the Project, it is proposed to establish an Executing Organization tentatively called the Project Office at Boma Ng'ombe to carry out design

and construction supervision of the project works. Also for operation and maintenance of the Project works, an O&M Office is proposed to be established in the Project Office.

At the farmers' level, a farmer's association will be organized in each of the tertiary blocks for operation and maintenance of the tertiary systems.

38. A cooperative, tentatively called the Sanya River Basin Cooperative Society (SRBC) is proposed to be founded by reorganizing and combining existing rural cooperatives with KNCU branch office to fulfill such tasks as supply of farm inputs, provision of tractor ploughing, purchasing, storing and selling the crops, and promotion of the sales of vegetables.

39. Total Project costs were estimated at Tsh. 2,951 million (US$ 15.1 million) consisting of Tsh. 580 million of local currency and Tsh. 2,371 million of foreign currency including physical contingency of 10% of total direct construction cost and price contingency. Annual operation and maintenance costs were estimated at Tsh. 13.2 million at the full development stage.

40. The period required for the completion of all the works is estimated at three years including design and preparatory works.

41. The annual incremental benefits were estimated at Tsh. 454.0 million at full development stage.

42. The economic feasibility was assessed in terms of the economic internal rate of return (EIRR) on the basis of a 50 year economic useful life. The economic internal rate of return (EIRR) is estimated at 15.1%. Therefore the project is quite feasible.

43. The financial feasibility of the project was evaluated from the viewpoint of farmer's economy and capital cost repayment capability. From the farmer's view point, the project will bring about a great net reserve i.e. Tsh. 1.0 million for an average farmer in the Sanya plain, which will offer great a incentive to farmers.

44. For the repayment capability analyses, it is assumed that the capital required for project implementation would be arranged under the following conditions:

(1) Foreign currency portion

The capital will be financed by the Government through a financing institution at an assumed interest rate of 1.0% per annum for a repayment period of 30 years including a grace period of 10 years.

(2) Local currency portion

The capital will be financed by the Government from its own resources with no repayment.

The loan repayment amount by the Tanzanian Government is estimated at about Tsh. 140 million/year.

45. In addition to the direct benefits counted in the economic evaluation, various secondary and intangible benefits and/or favorable socio-economic impacts are expected from implementation of the project as follows:

(1) Increase in employment opportunities by the construction and the intensive farming,
(2) Increase in production of agricultural crops,
(3) Increase in farmer's income,
(4) Improvement of local transportation by the construction of roads,
(5) Secondary direct benefits to millers, merchants, and transporters,
(6) Mitigation of floods by the construction of the Boloti dam,
(7) Improvement of domestic water supply by tubewells and water supply tanks,
(8) Improvement of water supply to cattle grazing by irrigation water supply throughout the year,
(9) Introduction of fish farming in the Boloti reservoir, and
(10) Demonstration effects of the Project to other projects.

RECOMMENDATIONS

46. The agricultural development of the Project is technically and economically feasible. It is, therefore, recommended that the Project should be implemented as early as possible, so that the Project will substantially contribute to not only the district, but also the regional and national economy.

47. The groundwater aquifer irregularly distributes and the permeability of the aquifer in the Sanya plain is expected to vary place to place. Accordingly, for the groundwater development, it is necessary to understand the local distribution of hydrogeological structures in detail in order to effectively and precisely select drilling sites for production wells. In this connection, it is proposed to carry out detailed electric prospecting and test drilling during the detailed design stage. It is also necessary to perform pumping-up tests in each of the production wells during the construction stage to determine the exact capacity and the location of pumps and the required motor power.

48. Hydrological data on the Sanya river and the Boloti swamp are insufficient for making detailed analyses of surface water resources. These will be very important for the water resources development and irrigation scheduling. Therefore, it is proposed to continuously measure water levels and the discharge of the Sanya river and the Boloti swamp.

49. Foundation investigation of the Boloti dam site was carried out only to the depth of 4 m. For successful implementation of the Project, detailed investigation along the dam site and at the shoulders should be carried out.

50. There is little forest in the Sanya plain. When the Project is realized, the requirement for fire wood will increase as labour requirements increase. Therefore, fuel wood plantations should be created around the Sanya plain Project area.

51. Although there may be no potential for agricultural development in the Lower Rombo area, improvement of the existing rural water supply system can be recommended as an urgent project, since most of the beneficiaries, about 150,000 people and 200,000 head of livestock, are suffering from shortage of water supply caused by insufficient capacity of the water supply pipes, breakdown of valves, leakage of water, etc.

THE FEASIBILITY STUDY
ON
LOWER HAI AND LOWER ROMBO AGRICULTURAL DEVELOPMENT PROJECT

MAIN REPORT

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1. INTRODUCTION

1.1 Authority

This Report on the Feasibility Study on the Lower Hai and Lower Rombo Agricultural Development Project has been prepared in accordance with the "Scope of Work" agreed upon between Regional Development Director (RDD), Kilimanjaro Region of the United Republic of Tanzania and Japan International Cooperation Agency (JICA) on February 27, 1988.

This Final Report presents the results of field works and studies and contains findings on the present conditions in the Study area, the development concept and development plan of the Project, and proposed main project works, Project benefits and cost estimates, and the economic and financial justification of the Project in the selected areas.

The Study was carried out in three Phases. Phase-1 covered investigation of surface and groundwater resources, and understanding the present irrigation areas, with the aim of selecting, areas having agricultural potential from the view of water resources. Phase-2 covered selection of development priority areas among the selected potential areas for agricultural development. Phase-3 covered the feasibility study of the selected priority areas development. Members of the Feasibility Study Team, the counterpart personnel assigned by Regional Development Director, and members of the Advisory Committee are listed in Table 1.

1.2 Background of the Project

Agriculture of plays a most important role in the economy of the United Republic of Tanzania as it is provides about 45% of GNP and about 70% of exports earnings. Agricultural activities in recent years have been stagnant due to unseasonable weather, shortage of agricultural investment and agricultural inputs and so on. This has compelled Tanzania to import foods which has been a severe burden on the Tanzanian economy.

Kilimanjaro Region is largely divided into two zones: high land zone and low land zone. The high land zone is relatively well developed and has little room for further development. The low land zone, which is semi-arid has remained without intensive development due mainly to poor water resources. Even though the Regional Government of Kilimanjaro has pursued a policy to increase agricultural production, agriculture has been faced with low productivity and instability due to the lack of irrigation water and insufficient irrigation facilities in the low land. Especially in recent years, agricultural production has been severely hit by drought. In order to overcome such constraints and to realize stable agricultural production, the development of groundwater resources as well as surface water resources from small streams with irrigation facilities in the low land has been eagerly desired. Further, improvement of rural infrastructures is required to ameliorate farmers living standards and to enhance social welfare.

The Government of Tanzania accordingly requested the Government of Japan to provide technical assistance for a feasibility study on agricultural development project for the Lower Hai and Lower Rombo areas in March, 1985. In

response to this request, the Government of Japan sent a contact mission in April, 1987 and a preliminary survey team in February, 1988 and decided to provide technical services for the feasibility study on the Lower Hai and Lower Rombo Agricultural Development Project. The Scope of Work for the Study and the Minutes of Meeting were agreed upon and signed on February 27, 1988 between RDD and JICA. They are attached in this Report as Attachment 1.

1.3 Objectives of the Study

The objectives of the Study have been (1) to assess the availability of groundwater and surface water resources for agricultural development, (2) to identify areas seeming to have a potential of agricultural development from the view of water resources and land resources, (3) to select development priority area(s) among the identified areas, (4) to formulate agricultural development plan(s) for the development priority area(s), and to verify the technical and economic feasibility on the agricultural development in the development priority area(s).

1.4 Activities of the Study Team

The Study was carried out in three Phases over the period from October, 1988 to August, 1990 in accordance with the Scope of Work.

At the beginning of Phase-1, an inception meeting was held in RDD office between the Team and the Counterparts in the presence of the Advisory Team. The Minutes of the Inception Meeting are given in Attachment 2.

The Phase-1 work was carried out from October 1988 to February 1989 for clarifying the present conditions of the

Study area with emphasis on investigation of water resources for agricultural development and present irrigation conditions, and for identifying areas having agricultural development potential from the view point of available water resources. Based on the investigations and studies carried out in Phase-1, Progress Progress Report (1) was prepared and submitted to RDD at the beginning of Phase-2 work.

The Phase-2 work, which was carried out from February, 1989 to January, 1990 was concentrated on investigation and studies in the areas identified as an agricultural development potential area. Test drilling and pumping-up tests were carried out at four points; two points each for the Lower Hai and Lower Rombo. Then availability of groundwater resources was estimated as well as the surface water resources of major rivers flowing through the Study area, including the possibility of reservoir creation from the viewpoint of topography. Land capability was preliminarily investigated and assessed for the identified areas. Agricultural and socio- and agro-economic surveys were conducted in order to assess the present agricultural and socio- and economic situations at national, region, and study area levels.

From the results of these water resources investigation results, further investigations and studies were undertaken in the Lower Hai area, especially as decided at the Sanya river basin areas in the meeting held in October, 1989 between the Study Team and RDD in the presence of the Advisory Team. The Minutes of that Meeting are given in Attachment 3. Based on these investigations and studies, basic development plan was formulated for each of the identified areas and from which the Sanya river basin areas, namely the Sanya plain, Mungushi area and Boloti area were selected as the

development priority area (the Project area) through exchange of views with the Regional Authorities concerned. The results of these investigations and studies were presented in the Interim Report, which was submitted to RDD in January, 1990. Meanwhile JICA had dispatched a mapping team to prepare detailed maps at a scale of 1 : 5,000 for the development priority areas. These maps were completed in January, 1990.

The Phase-3 work, which was carried out from January to August, 1990 was concentrated in the development priority areas (the Project area). Progress Report (2) was prepared and a meeting on Progress Report (2) was held between the Regional Authorities and the Study Team at the end of the field work of the Phase-3. The Study Team then formulated a development plan for the development priority areas taking into account the comments and suggestions offered by the Regional Authorities concerned at the meeting and compiled the Final Report.

2. AGRICULTURAL AND ECONOMIC BACKGROUND

2.1 General Features of Tanzania

The United Republic of Tanzania consists of Mainland, Zanzibar island and Peruba island with a total land area of 945,050 km^2. The total population was estimated at 23.2 million in 1988 giving an average population density of 25 persons per km^2. The annual growth rate was 2.9% during 1978 to 1988 period. Tanzania mainland encompasses some 881,289 km^2 and had an estimated population of 22.5 million in 1988.

The economy of Tanzania has grown steadily during the last decade and the Gross Domestic Product (GDP) at 1976 constant prices attained around Tsh. 27,039 million in 1988. The GDP grew at an annual rate of 1.9% during 1978 to 1988. Per capita GDP was estimated at Tsh. 1,201. The value of exports was US$ 372.0 million. However, the value of imports was US$ 1,185.0 million. In consequence, the country's balance of trade had a deficit of US$ 813.0 million in 1988.

Agriculture is still the largest sector in the Tanzanian economy. It provides about 45% of GNP, about 70% of exports earnings and over 80% of total employment. The main cash crops are coffee, cotton, sisal, tobacco, tea, cashewnut, pyrethrum and cloves, and the principal food crops are maize, sorghum, millet, rice, grain legumes, cassava, banana, wheat and sugarcane. Coffee, sisal, cotton, cashewmut, tea, and tobacco amounted to about 109,000 tons in 1988. Of these main six (6) items coffee and cotton are major foreign currency resources of the agricultural sector.

2.2 Kilimanjaro Region

2.2.1 Regional economy

Kilimanjaro Region, in the northeast of Tanzania, borders on Kenya to the north and northeast, Tanga Region to the southeast and Arusha Region to the south and west, and covers an area of 13,209 km^2. This corresponds to 1.4% of the total area of Tanzania.

According to the population censuses, the population in Kilimanjaro Region increased from 902,394 in 1978 to 1,108,699 in 1988 with an annual growth rate of 2.1%. In 1988 the regional population accounted for about 4.8% of the national figures and had a population density of 84 persons per km^2, which is considerably higher than the national average of 22.5 persons per km^2 and forms the region's most pressing problem.

Administratively, Kilimanjaro Region is divided into five (5) districts, i.e. Moshi, Hai, Rombo, Mwanga and Same, and the regional headquarters which is a municipality council is located in Moshi township.

The gross regional domestic product (GRDP) in Kilimanjaro Region attained Tsh. 9,992 million in 1988 at current prices, and accounted for 3.67% of GDP in Tanzania mainland. The GRDP ranked 12th in the 20 regions in the mainland. Per capita GRDP of the region attained Tsh. 9,010 in 1988, beside those of Arusha Region and Dar es Salaam are Tsh. 14,990 and Tsh. 27,431, respectively.

2.2.2 Agriculture in the region

Agriculture in Kilimanjaro Region has played an important role in both the national and regional economy. The region is one of the main producers of cash crops in Tanzania, and among these coffee is predominant. Production of coffee accounts for approximately 50% of total national production. Besides, more than 90% of the population is estimated to engage in agriculture either directly or indirectly. In 1988, net cultivated lands were estimated at about 2,800 km^2 which corresponds to only 43.5% of the total arable lands. Over 60% of the farms are under 2.0 ha with an average farm size of 1.1 ha.

Kilimanjaro Region can be divided into the following four (4) distinctive agro-ecological zones:

(1) The higher zone: lies between EL 1,800 m and Kibo peak of Mt. Kilimanjaro at EL 5,895 m in altitude. Annual rainfall of this zone ranges from 600 mm in the higher part to 2,000 mm in the lower part. It is gazetted as Forest Reserve and National Park. No agricultural activities are done in this zone.

(2) The high zone: lies between EL 1,100 m and 1,800 m of Kilimanjaro and Pare mountains with rainfall ranging from 1,250 mm to 2,000 mm per annum. This is the most densely populated (about 650 persons/km^2) zone in the region. Because of favorable conditions, intensive cultivation of coffee, bananas, fruits and vegetables has been practiced for many years. There is traditional small holder irrigation for growing fruit and

vegetables. Livestock are mainly zero grazing dairy cattle and pigs.

(3) The middle zone: lies between EL 900 m and 1,100 m on the slopes of Mt. Kilimanjaro and the Pare mountains. Annual rainfall ranges from 800 mm in the lower part to 1,250 mm in the upper part. This zone is also densely populated (about 250 persons/km^2). The main crops cultivated in this zone are coffee, bananas, maize, beans and vegetables. Traditional small holder irrigation is extensively used for bananas, coffee and vegetables to supplement rainfall. Livestock is mainly zero grazing dairy cattle.

(4) The lower zone: lies below EL 900 m and receives annual rainfall between 400 mm to 800 mm. Because of low rainfall and seasonal floods in some areas, this zone is relatively sparsely populated (less than 50 persons/km^2), but increasing rapidly as a result of pressure on the upper zones. Crops includes maize, beans, finger millet, sorghum, cotton and cassava. Livestock (beef cattle, goats and sheep) mostly graze and this zone is the main source of fodder and other grasses for zero grazing livestock in the high and middle zones.

Kilimanjaro Region suffers a food deficiency because of low productivity and instability of food crops due to shortage of water resources, insufficient irrigation facilities and a rapid growth in population. There has been a severe food deficit in the region in the recent years because food crop production has been severely hit by drought.

2.2.3 Regional development plan

The Second Five Year Regional Development Plan (1988/89-1992/93); the second phase of the 4-phase package long term development program from 1981/82 to 2001/02, was established by Kilimanjaro Region in line with the party's program aimed at promoting social economic development in Tanzania for the period of 1987 to 1992.

The main targets for the Second Five Year Regional Development Plan are as follows:

(1) To increase production of food and cash crops so as to achieve self-sufficiency in food production, and to increase foreign currency reserves, and
(2) To strengthen and increase the vital social and economic services needed in order to promote productivity.

The fund requirement of this development plan has been estimated at Tsh. 12 billion.

Agricultural sector, the backbone of national and regional economy, which is an integral part of Second Five Year Regional Development Plan has been allocated the highest amount of Tsh. 10 billion or 83% of total fund requirement. The targets for the regional agricultural development were established in consideration of the results of promoting increased agricultural production in the last Five Year Development Plan (1981/82 to 1985/86) as follows:

(1) To increase the unit yield of crops,
(2) To satisfy the demand for farm inputs and distribution to the farmers, and

(3) To improve storage facilities and transportation of agricultural products in the region.

In order to achieve above targets, the following strategies have been worked out:

(1) To ensure availability and distribution of farm inputs at the right time,
(2) To ensure proper crop husbandry and proper use of farm inputs through improvement of extension services such as farm visits, demonstrations, trials and other visual aids so as to transfer knowledge to the farmers,
(3) To increase the amount of irrigated land and to reduce serious drought problems through renovation and rehabilitation of traditional and small holder irrigation projects, and construction of new small, medium and large scale irrigation projects,
(4) To ensure that the farmers get money immediately they sell farm products through supervision of crop purchases, transportation, storage and processing of the farm products under the cooperative unions, private companies, and organizations set up by Ministry of Agriculture and Livestock, and
(5) To ensure proper land use and crop calendars in the concerned areas through farmers education.

3. THE STUDY AREA

The Study area consists of two areas; the Lower Hai area of about 600 km^2 and the Lower Rombo area of about 300 km^2.

3.1 Lower Hai Area

3.1.1 Physical conditions

(1) Location

The Lower Hai area is located in Hai District on the southern foot of Mt. Kilimanjaro between East longitude 37°02' and 3°19' and between South latitude 3°14' and 3°30' as shown on the Location map. The Study area is bordered by the Karanga river in the east, the Kikuletwa river in the south, and the border with Arusha Region in the west. The area is about 600 km^2 at an altitude of from 750 m to 1,050 m.

(2) Topography

The Lower Hai area is undulating except in the south-west (south of Arusha-Moshi highway and the west of the Sanya river), the irrigation area served by Rundugai spring, and the east side of an escarpment developing along the Karanga river. Undulation is predominant with small isolated hills especially in the area formed with volcanic deposits and/or outwashes. The gradient of the ground surface ranges from 1:150 to 1:600 in the south-west flat area and from 1:150 to 1:10 in the hilly and undulating areas.

(3) Climate

There are two seasons; the dry season from June to September and the rainy season from October to May. The seasonal rainfall pattern moreover is bi-modal having two peaks from November to December and from April to May. Rainfall decreases from north to south or lowering of altitude. Mean annual rainfall is 970 mm at Moshi or 520 mm at Kilimanjaro International Airport (KIA), of which about 60% and 65% respectively is concentrated in the main rainy season in April/May.

The mean temperature is 20 to 22°C at both stations throughout the year, but the temperature at KIA is slightly lower than that at Moshi in the dry season. Relative humidity ranges from 55% to 75% at KIA and from 45% to 65% at Moshi. A-pan records indicate that evaporation ranges from 6 mm/day to 7 mm/day in the rainy season and 2 to 3 mm/day in the dry season.

(4) Hydrology

The amount and seasonal pattern of rainfall varies in and around the Study area in accordance with altitude from the peak of Mt.Kilimanjaro through the skirt to the lower plain and with locations such as the east, south and west skirts of Mt. Kilimanjaro as shown in Fig. 1. In the south skirt, the rainy season starts in November and peaks in April and May. Annual rainfall is 500 mm or less in the south end of the Study area and 2,000 mm or more in the lower end of the forest zone in which altitude is around 1,700 m above sea level. In the west skirt, the seasonal pattern of rainfall is quite

similar to that in the south skirt, however the annual rainfall amount ranges from 400 mm in the low land to 1,000 mm in mountainous area which is less than that in the south skirt. The main rainy season is in April and May.

There are five main rivers flowing through the Study area from Mt. Kilimanjaro southwards, which are the Karanga, Weru Weru, Kikafu, Kware and Sanya Rivers. In contrasting to these the Kikuletwa River runs west to east along the southern border of the Study area. The locations and the mean monthly discharge of these rivers are shown in Fig. 2.

The Weru Weru river joins the Karanga and the Kikafu at the eastern tip of the zone and flows south. The Kikuletwa joins the Kware and the Sanya and flows east. Then both principal rivers join in the southeast portion of the Study area.

In the area where the Kikuletwa river joins with the Kware and the Sanya, a cluster of springs called the "Rundugai Springs" is found. Water from these springs flows into these three rivers. The discharge of spring water is about 12 m^3/sec in total.

The Kikuletwa River is perceived as a perennial river in Arusha Region, however the entire flow is taken for irrigation in Majengo village of Arusha Region in the dry season and the area astride the river in Majengo village is vastly flooded in the rainy season. Due to this, the river is dry up or has little water in the Study area until the reaches where spring water flows into from the Rundugai Springs.

Annual runoff of the major rivers are as follows:

	Station	Annual Runoff (MCM)	Catchment (km^2)
Karanga river	1DD3	81	211
Weru Weru river	1DD5A,1DD7	48	141
Kikafu river	1DD8	173	198
Kware river	1DD9	11	34
Sanya river	-	31	199
Kikuletwa river	1DD54	786	2,220

Note: Data obtained from Hydrological Year Book except Sanya river, of which runoff is estimated.

Of the annual runoff, about 60 to 70% flows from April to June except for the Kikuletwa of which the runoff does not fluctuate so much due to the contribution of spring water.

(5) Hydrogeology

From the eastern to the middle portion of the Study area there is a continuous gently sloping volcanic deposit plateau, and in the western section is the wide Sanya Plain.

The geology of the Lower Hai consists of Precambrian basement rock, post-Neogene volcanic deposits, river deposits, lahar, outwash and alluvium as shown in Fig. 3. The principal aquifer is composed of lahar, outwash and alluvium, and widely spreads along the Sanya river.

The hydrogeological structures are regulated by the Precambrian basement rock widely distributed in the south of the Study area and by the volcanic deposits washed down from Mt. Kibo. Due to the basement rock and the Mt. Kibo volcanic deposits, the eastern section

of the Study area was dammed up, and to the west of this (Sanya Plain), a lake was forming with accumulation of river deposits. During sedimentation of the river deposit, there have been occasional lahar deposits which have resulted in alternating layers of river deposit and lahar.

The groundwater in Lower Hai is found in one of these layers or in several of them acting as aquifer. The groundwater recharge zone and flow direction are largely divided into two. One of these is the zone along the Kikuletwa River and the other is that along the Sanya River.

The former recharge zone originates from the Kikuletwa River at the southern foot of Mt. Meru, and from the western edge of the Precambrian basement rock which is widely spread throughout the Study area in a southerly direction. The groundwater flows along the western and northern outer edge of the basement rock, and, in Lower Hai, moves in an easterly direction along the northern edge of the basement rock.

The latter recharge zone runs along both the main and branch rivers of the Sanya River located at the eastern foot of Mt. Meru and western and southwestern foot of Mt. Kibo. This groundwater runs through alternating layers of river deposit and lahar, outwash, and alluvium and flows from the northwest to the southeast in the Study area.

The above-mentioned groundwater is thought to originate from a groundwater basin in the middle of the Sanya Plain, however it then disperses and flows into

the numerous underground channels. The water systems offer the highest potential for groundwater development.

3.1.2 Administration and population

The Lower Hai area administratively belongs to Hai District and is related to two wards. The population in the Lower Hai area is estimated to be around 42,000 and the population density about 70 persons per km^2.

3.1.3 Agriculture

Areas except the area extending along the west side of the Sanya river, the so-called Masai Steppe, bush land, and area covered by Lahar are utilized for agricultural farming as shown in Fig. 4. Agricultural land accounts for 35% of the Study area. The main cropping season is the period of the rainy season from March to July. The predominant crop is maize which is planted in the rains in March/April and harvested in July/August. It is usually intercropped with either beans or other crops. Dry season cropping from September to February is limited because of shortage of water. The main crops of this season are also maize, planted in October/November and harvested in January. Paddy is cultivated in the limited places where ample water is available such as Rundugai area and Kikafu Chini area. It is planted in seed beds in September for transplanting in October/November. Small areas are utilized for cultivation of vegetables throughout the year. Land preparation for maize is usually conducted by tractors, but other inputs such as fertilizers and agro-chemicals are rarely used.

3.1.4 Irrigation

There are small-scale irrigation systems along the main rivers flowing through the Lower Hai area. The scale of each irrigation area is small due to lack of irrigation water resources as well as land resources. The only large scale irrigation system is the Rundugai system which is commanded by an irrigation system fed by springs located in the Kware river. The total irrigation area in the Lower Hai area was roughly estimated at 5,800 ha. Location of the main irrigation systems is shown in Fig. 5 and may be summarized as follows;

Irrigation System	Area (ha)	Condition of Water Source
Sanya river		
Mungushi	210	Perennial
Ernest and Station	280	Seasonal
Nzegazega	100	Seasonal
Palestine	180	Seasonal
Mayaseki	90	Seasonal
Hemedi	290	Seasonal
Tindigani	170	Seasonal
Kware river/Rundugai		
Rundugai (Mtambo & Ismael)	1,400	Perennial, spring
Longoi river		
Longoi/Masama	370	Perennial, spring
Kikafu river		
Kikafu Chini	250	Perennial
Weru Weru river		
Kimashuku	1,600	Perennial
Musa Mwijanga	570	Perennial
Kikuletwa river		
Mtakuja	300	Seasonal

Of the above irrigation systems, the Rundugai, Kikafu Chini and Musa Mwijanga are to be rehabilitated by the Zonal Irrigation Unit (ZIU) with technical and financial assistance of FAO.

Each irrigation system has a water committee under a village chairman for operation and maintenance of the facilities. The committee is composed of four (4) to six (6) persons elected by villagers. No water charge is collected from farmers and the operation and maintenance works made by the water committee are at present carried out as voluntary service.

Most of irrigation system have no or few control structures such as intake gates, checks, turnouts, division box and measuring devices and no on-farm irrigation facilities. Accordingly no systematic irrigation operations are actually being made at present. Irrigation water is taken often without any control. No drainage systems are available.

3.1.5 Rural infrastructures

(1) Roads

There is a highway which runs between Arusha and Moshi in the mid-northern part of the Lower Hai area in an east-west direction. A road branching off from the above trunk road at Boma Ng'ombe runs to northwards to Sanya Juu. An access to the Kilimanjaro International Airport branches away from the Arusha-Moshi highway at the western part of Boma Ng'ombe. These trunk roads are paved with asphalt. No other roads are paved. Most of other roads are not well built up, and just have wheel tracks. So it is difficult to drive on traditional roads in the rainy season when the road surface is wet with rain water causing slippage even in four-wheel-drive vehicles. Many of the crossing points with rivers have no crossing structures.

(2) Railway

There is a railway running through the Lower Hai area in the east-west direction connecting Moshi and Arusha. The railway is single line and used only for freight transportation between Moshi and Arusha. One station is provided at Sanya Chini which is located in almost the center of the Study area, but it does not seem to be used.

(3) Domestic Water Supply

There are poor domestic water supply systems in main villages such as Sanya Juu, Sanya Chini, and Rundugai and in the villages located along the foot of Mt. Kilimanjaro. Even in such main villages, however, most of the villagers rely directly on rivers and springs. There are not enough systems in other villages too, so villagers rely on rivers and springs around Rundugai, and on wells in the area near the border with Arusha Region along the Kikuletwa river.

(4) Electrification

The main towns such as Boma Ng'ombe, Sanya Juu and Rundugai are served with electricity, but most of small towns have no electric facilities.

3.2 Lower Rombo Area

3.2.1 Physical conditions

(1) Location

The Lower Rombo area is located on the eastern foot of Mt. Kilimanjaro along the Kenyan border from East longitude 37°35' to 37°42' and from South latitude 03°00' to 03°20' in Rombo District. The Study area is about 7 km wide east and west and about 35 km long south-north. The altitude of the Study area ranges from 1,000 m to 1,500 m.

(2) Topography

The lower Rombo area slopes from the west to the east and there are many small streams running through the Study area. The eastern part along the Kenyan border is a vast plain, but western part is hilly. There is a crater lake named Chala lake in the south east corner of the Study area on the Kenyan border and a succession of parasite volcanoes is found on the line from Mawenzi peak of Mt. Kilimanjaro to Chala lake.

(3) Climate

No meteorological observations have been conducted in the Lower Rombo area yet by any official agency. From the high land climate (Narnjara Secondary School, etc.), it may be assumed that the seasonal rainfall pattern is bi-modal having two peaks from November to December and from March to May. Rainfall decreases from south to north or lowering of altitude. Mean annual rainfall is

700 mm in the lower area and 1,500 mm in the upper area. Otherwise the climate conditions are almost the same as those in the Lower Hai area from January to September. In November and December, the temperature seems to be slightly lower than that in Lower Hai area.

(4) Hydrology

There are many small streams flowing through the eastern skirt of Mt. Kilimanjaro from west to east. The Lume river which flows through the center of the Study area is the only perennial river of which the discharge has been roughly estimated at 0.3 m^3/sec on an average in the rainy season and 0.1 m^3/sec or less in the mid-dry season. Streams other than the Lume river are seasonal and water can be found in them only in the peak rainy season.

The water of Chala lake is recharged by groundwater from upstream and discharges as spring water on the Kenyan side. The water level is about 120 m below the ground surface.

(5) Hydrogeology

The geology of the Lower Rombo consists of Precambrian basement rock, post-Neogene volcanic deposit, talus deposit, pulverized deposit, fan deposit, terrace deposit, alluvium and riverbed deposit.

There is no good aquifer in the shallow zone estimated to be found in Lower Rombo. The aquifer at Shoshoro

boring well, which is the only well presently used, is estimated as being post-Neogene volcanic deposit.

3.2.2 Administration and population

The Lower Rombo area administratively belongs to Rombo District and is divided into twelve wards. The population in the Lower Rombo area is estimated at around 37,000 and the population density is 123 person per km^2.

3.2.3 Agriculture

About two thirds of the Lower Rombo area is extensively utilized for agricultural farming as shown in Fig. 6. The main cropping season is the rainy season. In the period from October to February, maize is predominant. Maize, usually intercropped with beans, cowpeas and other crops, is planted in September/October and these crops are harvested in January/February. During the period from March to June, finger millet is predominant. This crop is grown in pure stands in general. Minor crops such as sunflower and vegetables are planted during both seasons. The crops are almost entirely cultivated under rain-fed conditions and fertilizers and other inputs are rarely applied in general. Some mechanized primary cultivation is undertaken and is increasing as a result of the Region's agricultural mechanization programme.

3.2.4 Irrigation

There is only one existing irrigation system in the Lower Rombo Area. It is the Ikuini irrigation system. Water is diverted from the Lume river. This system serves the area bordered by the Lume river in the east and the Kifunuka river

in the west, about 300 ha. The intake is a concrete-made fixed weir and a gated intake. The main canal goes down along the Lume river. On the way, some 0.5 km downstream of the intake, there is a night storage pond made by earth. The outlet is equipped with a slide gate. This irrigation system has no on-farm facilities. The Zonal Irrigation Unit carried out rehabilitation of this system with technical and financial aid from FAO in 1989.

3.2.5 Rural infrastructure

(1) Road

In the Lower Rombo area, a trunk road runs along the foot of Mt.Kilimanjaro at the western end of the Study area. This road branches away from the highway, which connects Moshi and Taveta in Kenya, and leads into Kenya. The area along this road has become a center of agricultural production and has provided homesteads for many inhabitants. The road is about 6 m wide and paved with morrum. Most of the river-crossing structures are so-called cause-ways, which are submerged at flood time, except for one road bridge over the Lume river. Other than the above road, there is a road running along the foot of Mt. Kilimanjaro in the lower part of the Study area near the Kenyan border after branching off from the above trunk road to the south of the Study area. This road has not yet been paved. There are a few earth roads connecting the above two roads in the study area. These roads are also in the same poor condition as those in Lower Hai areas.

(2) Domestic water supply

East Kilimanjaro Trunk Main Scheme (EKTM) was constructed in 1966. The total length of main pipe line is about 37.5 km long. About 30 branch lines totalling approximately 310 km branch off the EKTM to distribute water to about 150,000 people and about 200,000 head of livestock. At present, except for the people living near the upper EKTM, most of beneficiaries are suffering from shortage of water supply, particularly those near the downstream ends of the branch lines, mainly due to insufficient capacity of pipes, poor management of water supply, breakdown of valves, leakage of water, etc.

In the northern District, there are about 6 small scale pipe lines, i.e. Mashati, Olele, Nanjara,Nolemoru, Njoro and Kimengelia. Except for the Mashati scheme, most of the schemes provide less than 40% of water needed for consumers due to the insufficient capacity of pipe lines, breakage of pipes and valves and leakage of water.

(3) Electrification

Distribution lines have only been constructed along trunk roads and major towns only can use electricity.

4. SELECTION OF THE PROJECT AREA

4.1 General

Rainfall amount is limited to 400 mm to 800 mm per annum in the lower Hai area and 700 mm to 1,000 mm in the lower Rombo area. The most of rainfall comes in the limited period from April to May in the lower Hai area and from November to May in the lower Rombo area. The surface water resources in the Lower Hai area are quite limited in the dry season and almost fully utilized for agriculture. In the lower Rombo area, surface water resources are available only in the Lume river. Under such constraints of water resources, agriculture remains at very low productivity in the most parts of the area.

The available groundwater resources and surface water resources for agricultural development were estimated taking the above situations into account. The areas with development potential from the viewpoints of land resources as well as water resources were identified except for areas where existing irrigation facilities are planned to be rehabilitated or were rehabilitated by the Zonal Irrigation Unit (ZIU) with technical and financial assistance from FAO. Then among the identified areas, development priority areas were selected through formulation of preliminary development plans for each of the identified areas.

4.2 Area with Development Potential

4.2.1 Lower Hai area

(1) Potential area for groundwater development

The following two areas are expected to have groundwater.

1) Sanya plain; downstream of Sanya river, and
2) Mtakuja area; along the Kikuletwa river near the border with Arusha Region.

The Mtakuja area, however, will be able to obtain only about 5 lit/sec per tubewell, which is too small for irrigation. In the Sanya downstream area, groundwater resources are expected to be abundant along the lower reaches of the Sanya river as shown in Fig. 7.

(2) Potential area for surface water development

Irrigation water for agricultural development is expected to be obtained from the following sources:

1) Sanya river and Boloti swamp by creation of a dam,
2) Weru Weru river, and
3) Kikuletwa river.

Boloti swamp located at the foot of Mt.Kilimanjaro at the northern end of the Study area is the only the place suitable for creating a reservoir and it is proposed to store excess water there in the rainy season. The catchment area is as small as 14 km^2. It is, however,

conceivable to divert water from the Lawati river, which is one of main tributaries of the Sanya river, to the swamp. From the view point of the land resources to utilize the water resources of the Sanya river and Boloti swamp, three areas are conceivable. One is an irrigation area of about 290 ha which extends to the downstream of Boloti swamp, hereinafter called Boloti area, the second is Mungushi irrigation area, about 210 ha located along the right bank of the Sanya river in the middle reaches, and third is an area of about 1,100 ha astride the Sanya river downstream reaches to the south of the Arusha-Moshi railway, hereinafter called Sanya plain.

As for the Weru Weru river, an area, about 1,600 ha served by an existing irrigation system known as Kimashuku system is selected as a development potential area, since the area suitable for irrigation farming in terms of topography and soils is limited along the Weru Weru river.

The Kikuletwa river has been flooding every rainy season since 1977 in Arumeru District, Arusha Region. No or little water is flowing into Hai District even in the rainy season. Under such conditions, the Mtakuja area, which is the only area suitable for irrigated farming along the Kikuletwa river has suffered from shortage of irrigation water. If river training is carried out, the flooding in Arumeru District can be mitigated and subsequently irrigation water for the Mtakuja area may be obtainable.

The locations of the development potential areas identified are shown in Fig. 8.

4.2.2 Lower Rombo area

Boring tests were carried out at two points where groundwater resources were expected as the results of an electric prospecting survey. However the tests indicated that no or little groundwater is available in the shallow zone. There is deep groundwater in volcanic deposits; 100 to 200 m below the ground surface, but it is not suitable to develop such deep groundwater resources from the economic veiw point.

The Lume river is the only source of surface water and serves an existing irrigation area, the so-called Ikuini scheme, of about 300 ha in which rehabilitation of irrigation facilities is being done with assistance from FAO. The river discharge is 0.3 m^3/sec on average in the rainy season 1988/89. However the discharge fluctuates greatly during the rainy season due to the steep gradient of the river and small catchment area. It will be difficult to stably irrigate the entire area of 300 ha in Ikuini scheme even in the rainy season. In the dry season, the discharge becomes less than 0.1 m^3/sec. Due to such limited water resources, no extension of the irrigation area is expected. In order to get surplus water for irrigation, it is necessary to provide a reservoir to store excess water in the rainy season. However, no place suitable for a reservoir can be found on the Lume river as on other rivers. It is, therefore, concluded that no water resources are available for agricultural development in the lower Rombo area.

4.3 Selection of the Development Priority Area (the Project Area)

For each of potential agricultural areas identified from available water resources and preliminary study of land resources, preliminary development plans for both agricultural and irrigation developments were formulated for (1) Sanya river basin development plan consisting of Boloti scheme, Mungushi scheme, and Sanya plain scheme, (2) Mtakuja scheme, and (3) Kimashuku scheme.

Sanya plain extending along the downstream reaches of the Sanya river is one of the most suitable area in terms of topographic and soil conditions for irrigated farming in the lower Hai area. This area is located near the Arusha-Moshi highway, and the Kilimanjaro International Airport. Sanya Chini railway station connecting Arusha, Moshi, and Dar es Salaam is located within this area. Thus agricultural products are easily transported to Moshi and Arusha even to Kenya by road and to Dar es Salaam by rail. Also, the area is located nearest to Boma Ng'ombe, the headquarters of Hai District, where one of the main markets of the District is situated. A 33 kV electric transmission line crosses the Sanya plain, thus it should be easy to get electric power for pumping-up of groundwater.

Boloti area and Mungushi area are not so suitable for irrigated farming in terms of topography and soil conditions. However, the water resources of the Boloti swamp and the Sanya river have been used in the Boloti and Mungushi areas for a long period. Accordingly, when the Boloti swamp is developed as a reservoir for irrigated farming in the Sanya plain, an amount of water corresponding to the present use of

water resources should be allocated to the Boloti and the Mungushi areas.

Kimashuku area is located near Moshi city; the headquarters of Kilimanjaro Region and Arusha-Moshi highway crosses the upper part of the Kimashuku area. Therefore, the area is geographically the most advantageous among the potential development areas. However, the amount of water granted by the water right is only 2 cusec (0.057 m^3/sec), and irrigation application is limited to the rainy season according to the results of a water balance study between available water resources and irrigation demands.

Mtakuja area is isolated from the center of Hai District and has been left behind in development. As mentioned earlier in Section 4.2, flood mitigation benefits in Arumeru District and irrigation benefits in Mtakuja area are to be expected from river training. However irrigation will be limited to the rainy season.

Taking the above into account and through estimation of construction costs and benefits, the Sanya plain scheme consisting of the Boloti, Mungushi and Sanya plain areas are selected as a development priority area (the Project area).

5. THE PROJECT AREA

5.1 Location

The Project area, consisting of Boloti and Mungushi areas and Sanya Plain, is located along the Sanya river. The Boloti and Mungushi areas are located an the northern side of the Study area in the Lower Hai. The Boloti swamp is located at the foot of Mt. Kilimanjaro in the upper reaches of the Mungushi river, which is one of the tributaries of the Kware river. the Sanya plain which is a major development area in the Project is located astride the Sanya river downstream of its crossing of the Arusha-Moshi highway. Their locations are shown in Fig. 9.

5.2 Water Resources

5.2.1 Rainfall

There are two seasons; the rainy season and the dry season. The peak of the rainy season is in April. Annual rainfall is about 600 mm on the Sanya plain and about 750 mm in the Mungushi and Boloti areas. Of the annual rainfall, about 60% and about 50% fall from March to May on the Sanya plain and Boloti and Mungushi areas, respectively.

5.2.2 Surface water resources

The surface water sources for the Project will be the Sanya river including the Fuka river and the Lawati river, which are tributaries of the Sanya river, and the Boloti swamp. The surface water resources are estimated at 35 MCM (1.11 m^3/sec) on average as shown below and 21 MCM in

drought year 1983/84, which almost corresponds to the 10 year probable drought year.

(Unit: m^3/sec)

River	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Sanya	0.22	0.14	0.21	0.83	1.07	0.35	0.10	0.07	0.05	0.03	0.22	0.43	0.31
Fuka	0.08	0.17	0.11	0.58	0.76	0.39	0.18	0.08	0.05	0.04	0.13	0.14	0.23
Lawati	0.15	0.32	0.22	1.12	1.46	0.74	0.34	0.16	0.09	0.08	0.24	0.28	0.43
Rawashi	0.05	0.10	0.07	0.36	0.47	0.24	0.11	0.05	0.03	0.03	0.08	0.09	0.14
Total	0.50	0.73	0.61	2.89	3.76	1.72	0.73	0.36	0.22	0.18	0.67	0.94	1.11

Note: The Rawashi river flows into the Boloti swamp.

As indicated in the above table, out of the annual runoff, about 65% flows during three months from April to June.

5.2.3 Groundwater resources

A huge amount of water estimated at 320 MCM/year is expected to be recharged in the Sanya river basin of 975 km^2. The groundwater resources are expected to be realizable in the lower reaches of the Sanya river as shown in Fig. 7.

5.3 Land Resources

The Sanya plain has flat topography sloping constantly at 0.5% to 0.7% north-west to south east. The soil is of medium texture and the soil depth is deep along the Sanya river. While the Boloti and Mungushi areas are undulating. The ground surface slope ranges from 1% to 5%. The soils are shallow and contain many stones.

1,380 ha or 43% of the total area classified as arable (Class I to III) for irrigated farming is located on the Sanya plain. It is anticipated that year-round cropping of these arable lands can be achieved with high crop yields through good management by use of high yielding varieties, regular

fertilizer application, and proper irrigation and drainage management.

All the land in Boloti and Mungushi areas (570 ha) and 1,050 ha of the land on Sanya plain are classified as restricted arable due mainly to shallow soil depth, stoniness and sodicity. These lands cannot be expected to yield a high return even with the farming management mentioned above. The results of land classification are summarized below:

Land Class	Boloti Area (ha)	Mungushi Area (ha)	Sanya Plain (ha)	Total (ha)	Total (%)
Arable					
Class I	0	0	200	200	6
Class II	0	0	630	630	20
Class III	0	0	550	550	17
Sub-total	0	0	1,380	1,380	43
Restricted arable					
Class IV	320	250	1,050	1,620	51
Non-arable					
Class V	0	0	170	170	6
Total	320	250	2,600	3,170	100

5.4 Social Conditions

5.4.1 Administration and population

Administratively, the Project area comes under the Hai District and is divided into two (2) wards and further sub-divided into three (3) villages as follows:

Area	Ward	Village
Boloti	Masama North	Nkwansira
	Masama South	Mungushi
Mungushi	Masama South	Mungushi
Sanya Plain	Masama South	Sanya Station

The population and available labour force in the Project area was estimated on the basis of the population census in 1978 and 1988, the data obtained from each village office, and from farmers' list obtained from the traditional furrow leaders in the Project area. Estimated figures are given in the following table:

	Boloti Area*	Mungushi Area	Sanya Plain
Number of Households**	159	253	384
Persons per Household	5.2	6.1	5.3
Population	873	1,543	2,035
Available Labour Force	393	728	999

Remarks: *; Using average of Nkwansira and Mungushi villages

**; Estimated on the basis of farmers' list

Available labour force per household in the Boloti area, Mungushi area and Sanya Plain was estimated at 2.4, 2.9, and 2.6, respectively.

5.4.2 Education

The education system in Tanzania basically consists of seven (7) years primary school, four(4) years secondary school, two (2) years high school and three (3) years university.

In Kilimanjaro Region, consolidation of the educational structure has progressed well in recent years. Primary schools have been established at 696 locations and about 217,103 pupils, corresponding to almost 100% of school-aged children in 1987 were engaged in schooling. The number of school teachers also increased from 4,490 to 7,216 during the period from 1981 to 1987, and hence, the

ratio of pupils to teachers reached to a desirable range at about 1:30.

Present conditions of education in villages related to the Project area are summarized as follows:

	Nkwansira	Mungushi	Sanya Station
Number of Schools	1	2	2
Enrollment	454	443	274
Number of Teachers	13	20	11
Ratio	1:35	1:22	1:25

5.4.3 Health

Endemic diseases in the rural area are measles, malaria, bilharzia, diarrhoea and typhoid. Measles are very troublesome with babies and children, and diarrhoea and typhoid are epidemic diseases. Both diseases are largely caused by contaminated drinking water and are the main causes of the high infant mortality rate in the rural area.

As far as the urban areas such as Moshi town and the headquarters of each district are concerned, the medical health services are well organized at present. However, the facilities of medical and health centers and dispensaries show extreme disparity in the rural areas. Although small dispensaries have been recently constructed in certain areas, their operation is in effective due to the lack of adequate facilities and medical personnel.

There are only two (2) dispensaries are available near the Project area. The nearest health centers are located at Kware village and Boma Ng'ombe. Hospitals used by farmers are located in Kibongoto and Moshi.

5.5 Agriculture and Agro-economy

5.5.1 Agricultural conditions

(1) Cropping pattern and crop intensity

Farmers in the Project area plant maize, beans, sunflower, banana, vegetables and other minor crops. Of these, maize and beans are the predominant crops as staple foods of the local inhabitants and also a cash crops in the Project area. Most of the crops in the Project area are planted at the start of the rainy season in March/April depending on rainfall. Planting of crops during the dry season is very limited in the area where irrigation water is available.

The present cropping pattern prevailing in the Project area is schematically shown in Fig. 10.

Cropping intensity in the Project area is very low and fluctuates much from year to year, and present crop yields are remain at a low level. The cropping intensity in the Project area ranges from 60% to 89% for the cultivated area.

(2) Farming practices

Oxen are mainly used for land preparation Boloti and Mungushi areas used because of the stony soils, while use of tractors is common on the Sanya Plain. The tractors are generally hired from a branch office of KNCU. Planting, weeding and harvesting are mainly carried out by hand.

Improved and hybrid varieties are commonly planted. However, the farmers use their own seeds or purchase from other farmers for planting due to low availability of certified seed.

Direct seeding is common for maize. For beans, broadcasting is generally practiced in the Mungushi area and the Sanya plain, while direct seeding is generally done in the Boloti area. Vegetables are transplanted from nurseries.

Generally, weeding for food crops is done two (2) times for the Boloti and Mungushi areas and one (1) time for the Sanya Plain. About three (3) times of weedings are done for vegetables.

Fertilizers are used for maize and vegetables in the Boloti and Mungushi area, but not commonly for other crops. In Sanya Plain, most of the farmers don't use fertilizers. Agro-chemicals are only used for vegetables.

(3) Crop yield and production

The present yields of crops remain at a very low level as shown below:

Crop	Yield (ton/ha)
Maize	0.8 - 1.5
Beans	0.1 - 0.5
Sunflower	0.4
Vegetables (Tomato)	8.5
Banana	3.9

Present crop production from the Project area, estimated from net cultivated land, cropping intensity and the above crop yields is summarized below:

(Unit: ton)

Area	Maize	Beans	Sunflower	Vegetables	Banana
Boloti	276	35	-	-	-
Mungushi	101	10	3	85	98
Sanya Plain	545	82	12	-	-
Total	922	127	15	85	98

(4) Livestock production

In the Project area, livestock plays an important role for the farmers as the main source not only of diet protein but also of cash to supplement the farm economy. Cattle, goats and sheep are dominant in the Project area. In general, livestock are grazed extensively in the savanna and/or Masai steppe on the Sanya Plain. While, zero grazing is commonly practiced in the Boloti and Mungushi areas. Small scale poultry is extensively managed by individual farmers in the Project area.

5.5.2 Agro-economic condition

(1) Agro-economic background

The present conditions of farm economy in the Project area differ between north and south of the Moshi-Arusha highway.

On the southern side of the highway is pasture land centering on the Sanya plain where traditional migrating stock raising is currently dominant in the Hai District. this will gradually give way to settlements,

with the area eventually being divided into farmland for settlers and areas for collective stock raising. The latter area will become a stable meat and egg supply base for Moshi as well as for Hai District as a whole. The southern part of the Project area will gradually be incorporated into the Boma Ng'ombe (capital of Hai District) economic zone as a food production base and residential areas in accordance with the expansion of Boma Ng'ombe urban functions.

The northern part of the Project area will be developed into an economic zone with Boma Ng'ombe and Sanya Juu, the previous capital of Hai District, forming an axis. The commercial production of staple crops will be enhanced in addition to coffee and bananas in mountainous areas. The production volume of various vegetables such as tomatos, aubergines and onions, etc. will increase.

Boma Ng'ombe will become a center of domestic or foreign trades if commercial production of high quality products is advanced in the future.

(2) Land tenure

According to the information obtained from village chiefs through interview, all the lands in the Project area which belong to each village is owned by the villagers under the traditional cultivation right known as the Shamba tenure system.

(3) Land holding size

About 90% of farmers in the Boloti and Mungushi areas have less than 2.0 ha of land and occupy about 65% to

75% of the total areas. Although about 70% of the farmers on the Sanya Plain have less than 2.0 ha, farmers occupy only about 33% of the total area. However, farmers holding more than 10 ha of land account for about 3% and occupy about 22% of the total area.

(4) Markets and prices

There are five local markets in Hai District, i.e. Kwa Sadana and Boma Ng'ombe along the Arusha-Moshi highway, Lawati and Sanya Juu to the north of Boma Ng'ombe and Rundugai along the Arusha-Moshi railway. Of these, the Sanya Juu market is the largest and the market in Lawati can be described as a sub-market of the Sanya Juu market. There is no market at Sanya Station. Except for the market at Sanya Juu, all the markets mentioned above are consumer markets and do not have any function as a collecting base for agricultural products.

The main agricultural products, such as the staple crops of maize and beans, are sold on farm to the local office of the cooperative union or the buying agents of the urban markets at harvest time. Surplus farm products such as the unsold balance of grains and vegetables are sold in heaps or tins along the highway or are transported to Boma Ng'ombe on foot.

For livestock, the Weru Weru livestock market is located at Kimashuku in Hai District. The Weru Weru market, about 11 km from Moshi to the west, plays an important role as a meat supply base for the Moshi

economic zone. The annual handling volume of the Weru Weru market was 25,195 heads in 1988/89.

The farm gate prices in the Project area are shown below:

Crop	Farm Gate Price (Tsh./kg)
Maize	21.9
Beans	48.9
Tomato	35.0
Sunflower	51.0
Banana	7.4

5.5.3 Agricultural support services

(1) Agricultural extension

Agricultural extension services are controlled by the District Agriculture and Livestock Development Officers (DALDO). Extension activities are carried out by the Agricultural Field Officer (AFO) appointed to each ward which generally consists of three (3) to four (4) villages with about 1,000 farmers. AFOs are supported by trained Assistant Field Officers. In addition to the extension activities, the AFO has responsibility for reporting to the DALDO on areas cultivated, yields of crops, fertilizer consumption, etc.

At present, the number of agricultural staff working in the Hai District is 110. Of these 25 are working in Hai District office, 10 are in the wards and 75 are in the villages. According to the District Agricultural and Livestock Development Officer (DALDO), at least one (1) agricultural officer is allocated to the each village.

In addition, a Zonal Irrigation Unit (ZIU) is located in the region and covers the three(3) regions of Kilimanjaro, Arusha and Tanga. Because of its zonal responsibilities, the ZIU does not come under the control of the RDD office, but is centrally controlled under Assistant Commissioner of Irrigation of the Ministry of Agriculture in Dar es Salaam. The ZIU, through technical centers for irrigation development, assists the respective regions in carrying out feasibility studies, design and construction, and provides advice on proper operation and maintenance of the irrigation project. The organizational structure for agricultural extension is illustrated in Fig. 11.

(2) Cooperatives

In Kilimanjaro Region, the Kilimanjaro Native Cooperative Union (KNCU) and the Vuasu Cooperative Union (VCU) were established in 1984. The former covers the Project area. Under KNCU, every village or group of villages has a cooperative. The functions of a cooperative are:

1) purchase of farm inputs,
2) provision of services such as tractor ploughing, and
3) storage and sale of marketable surpluses.

At present, three (3) rural cooperative societies are operating in the Project area. All the cooperative societies are newly established; Nkwansira in 1988, Mungushi and Sanya in 1989. Therefore, these cooperatives are not yet fully effective.

About 400 tractors are in good and/or serviceable condition at present in Hai District and are properly operated under the regional farm mechanization programme through KNCU Hai branch office. There is no storage facility in the Project area.

(3) Agricultural credit

Under the Economic Recovery Program (ERP), the credit structure has been liberalized to allow greater freedom of access to more sources. The main sources of credit for the Agriculture sector are the Co-operative and Rural Development Bank (CRDB), the National Bank of Commerce (NBC), the Tanzania Investment Bank (TIB) and the Tanganika Development Finance Company (TDFC).

The CRDB is essentially oriented towards small farmers and traditional export crops. The NBC is also essentially oriented to small farmers. Both the CRDB and the NBC have a good distribution of outlets throughout the country. Both provide seasonal finance and medium term loans. The latter are usually limited to six (6) or seven (7) year periods, say two (2) grace years plus four (4) to five (5) years for repayment. Interest rates at the time of the study were 29% for overdrafts and 27% for term loans. Although these seem to be high rates, in real terms they are not high, because inflation is projected at 20% to 30% a year.

5.5.4 Farm economy

In order to assess the farmers and their livelihood, a farm economic survey was carried out in the Project area

using a random sampling method for about 10% of the resident farmers. The findings are summarized as follows:

(1) The ratio of marketed crop production of maize is about 25% in Boloti and Mungushi areas and 35% in Sanya Plain and of Beans is about 30% and 45% respectively. It is considered that the difference between Boloti/Mungushi and Sanya Plain is mainly due to the difference in land holding size. Other food crops are mainly used for home consumption. On the other hand, most vegetables are produced for sale.

(2) In Boloti and Mungushi areas, more than 50% of marketed crops is sold through the rural cooperative societies. However, more than 90% is marketed to private sectors on the Sanya Plain.

(3) The farm households in Boloti and Mungushi are mainly dependent on farm and non-farm income whereas farm households on the Sanya Plain not only have farm income but also livestock income. The ratio of agricultural and livestock incomes to total income is estimated to be about 80.

(4) No farmers use agricultural or other credits in the Project area. Farmers, cannot use mortgages because all farm lands are cultivated under traditional cultivation rights and have not been registered yet.

In regard to farm economy, the results are summarized below:

(Unit: Tsh.)

	Boloti	Mungushi	Sanya
Farm Size (ha)	1.1	0.8	1.9
Net Income			
Farm income	23,790	32,730	23,780
Livestock income	2,330	2,130	25,450
Non-farm income	22,270	25,450	11,460
Sub-total	48,390	60,310	60,690
Living Expenses	45,480	58,230	59,660
Tax and others	550	630	610
Net Reserve	2,560	1,450	420

5.6 Irrigation

5.6.1 Existing irrigation and drainage system

There are eight small scale irrigation systems along the Sanya river in the Lower Hai area, known as Mungushi, Ernest, Station, Nzegazega, Palestine, Mayaseki, Tindigani, and Hemedi furrows. Except for Mungushi irrigation system, all the irrigation systems are located downstream of the Arusha-Moshi railway crossing as shown in Fig. 12, where land is alluvial flat plain and the soils are of medium texture. All the irrigation systems obtain their water from the Sanya river.

In the dry season, the river flow is extremely low and most of the river water is taken by the Mungushi intake and the Sanya Chini intake which is the headworks of the Ernest and Station furrows. Thus no water is available further downstream in the dry season. Irrigation is applied mainly in the rainy season from April to June when the river water increases. The total area commanded by irrigation canals along the Sanya river is estimated at about 1,120 ha.

Downstream of the Boloti swamp, there are two small furrows feeding water from the Boloti swamp, one is the Mwangaza furrow and another is the Nkwansira furrow. Both are small earthen channels serving areas of about 210 ha and 80 ha, respectively.

5.6.2 Irrigation practice

There is a traditional water committee in each of irrigation systems in accordance with a Bylaw of Hai District. Operation and maintenance are planned and supervised by the water committee. The committee has a staff of four to six persons generally including the head of the canal, secretary/treasurer, canal inspector, water allocator, alarm man who calls people for work, and two security guards.

According to the interview survey, the committee usually holds meetings with water users every week when river water is available. At this meeting, the water supply schedule is set and water is distributed in accordance with the schedule. Members of the committee carry out the operation of water distribution as well as minor repairs and maintenance. In order to distribute evenly the limited water of the Sanya river or water of the Boloti swamp, rotational water supply is applied among the small furrow systems. If a major repair is required in the main irrigation facilities, the committee requests the District Office (District Irrigation Officer) through the village chairman to repair the damaged portion. No water charge is collected from farmers and the operation and maintenance made by the committee is made as voluntary service at present.

5.7 Infrastructures

(1) Roads

There are two roads connecting the Project area of Sanya plain with the Arusha-Moshi highway. One runs along the western side of the Sanya river, and the other directly connects with Boma Ng'ombe, the capital of Hai District via Sanya Chini railway station. Both roads are very poor with no pavement. In the Sanya plain area there are few earthen roads. As for the Mungushi and Boloti areas, an asphalt road branching off the Arusha-Moshi highway at Boma Ng'ombe to Sanya Juu is available.

(2) Railway

A railway connecting Moshi, Arusha, Tanga, and Dar es Salaam, crosses the Sanya plain. The railway is single line and used only for cargo transportation between Moshi and Arusha. There is one station at Sanya Chini which is located in the upper part of the Sanya Project area. On the present operation programme, trains run once a day to Arusha and Dar Es Salaam and twice a day to Tanga.

(3) Air

Kilimanjaro international airport is located between Kilimanjaro and Arusha Regions. At present, air-freight capacity is limited.

(4) Domestic water supply

There is only a small domestic water supply system serving Sanya Chini railway station. Most people rely directly on the Sanya river. Boloti and Mungushi areas have domestic water supply systems from the mountains by pipe lines.

(5) Electrification

33 kV and 66 kV transmission lines from Kikuletwa hydropower station to Arusha across the Project area of Sanya plain, but there is no distribution system in the Project area of the Sanya plain. An 11 kV transmission line follows the asphalt pavement road to Sanya Juu, and there are a few distribution lines in the Boloti and Mungushi areas.

6. THE PROJECT

6.1 Basic Development Concept

The main constraints for agricultural development in the Project area at present are shortage of available water resources and poor irrigation facilities. Therefore, the farmers are obliged to practice extensive farming and production remains at a low level.

In view of the present constraints and in line with the national and regional development policies, the agricultural development plans for the Project area are formulated to:

(1) Remove and/or improve the present constraints for agricultural development in the area to facilitate intensive agriculture with maximum use of surface water resources,
(2) Increase the production of staple food crops such as maize and beans as well as cash crops such as vegetables by means of crop intensification and diversification through irrigated farming, so as to contribute to the policy for self-sufficiency in food, and
(3) Raise the living standards of farmers by increasing of crop production.

6.2 Development Alternatives and Development Scale

In order to determine the optimum development scale of Sanya river basin the Boloti, Mungushi, and Sanya plain schemes including Boloti swamp, development alternatives

were considered and a water balance study made between available run-off and irrigation water demands.

6.2.1 Development alternatives

The water balance calculations took into account the land resources in Boloti, Mungushi and Sanya plain, and their surface and groundwater resources. The surface water resources are the Sanya river and the Boloti Swamp which is the only site suitable for a reservoir in the Lower Hai area. The catchment area, however, is limited to 14 km^2 and thus the water resources are limited to about 3 MCM/year in the drought year. Thus in case of development alternatives with the reservoir, water available in the Lawati river is planned to be diverted into the reservoir as shown in Fig. 13. Groundwater resources are expected in the lower half of the Sanya plain.

The Boloti and Mungushi areas are mostly classified as Class 4 in the land classification as described in Section 5.4, which means that high returns by irrigation farming may not be expected in these areas. Thus in order to evaluate such a situation, alternatives for the development are set for (1) with development of the Boloti and Mungushi areas, and (2) without their development. The benefited areas of both Boloti and Mungushi areas are estimated at 290 ha and 160 ha net, respectively considering their existing irrigation systems.

The Sanya plain is divided into two areas in terms of water resources, there are 440 ha net upstream which are expected to be served by surface water resources alone and 610 ha net downstream area, which can be served by groundwater resources or by the conjunctive use of surface water and groundwater resources. If the downstream area is

developed independently from the upstream area by conjunctive use of surface and groundwater resources, an intake will be built at a place suitable for river water supply. In this case, the irrigated area will be 570 ha net instead of 610 ha.

In the event of conjunctive use of groundwater and surface water resources on the order to reduce the operation cost of tubewells, surface water resources would be utilized as much as possible. Since the water of the Sanya river is already being utilized on the Sanya plain, including its lower half where groundwater is expected to be abundant, the alternative of conjunctive use is considered here.

Alternative studies were made for the following five cases:

Case	Condition
1	Development of Sanya plain without dam development, (Boloti area is not taken account because of no dam development. Priority of water allocation is put on Mungushi area without its development.)
2	Development of Sanya plain with dam development.(Priority of water allocation is put on Boloti and Mungushi areas without their development.)
3	Development of Boloti, Mungushi and Sanya with dam development.
4	Development only in Sanya downstream area(groundwater area) by conjunctive use of surface and groundwater resources without dam development. (Boloti area is not taken into account because of no dam development. Priority of water allocation is put on Mungushi area without its development.)
5	Full development of Sanya plain by conjunctive use of surface water and groundwater resources development.(Priority of water allocation is put on Boloti and Mungushi areas without their development.)

6.2.2 Water balance study

(1) Condition of water balance calculation

The water balance study was made on the basis of the estimated monthly run-off of the Sanya river and the Rawashi river, which is a river flowing to the Boloti swamp, for the 17 years period from 1972 to 1988 and with the irrigation water demands estimated from the cropping patterns, with priority of water allocation given to the Mungushi and Boloti areas in accordance

with present cropping pattern, since these areas are situated in the upstream of the Sanya plain and irrigation is actually practiced cropping season.

(2) Calculation results

The results may be summarized as follows:

In Case 1, without water resources development, only about 250 ha of the Sanya plain can be irrigated in the rainy season with about 80% dependability. In the dry season, even the Mungushi area which is situated upstream of the Sanya plain suffers from water shortage.

Case 2 indicates that if surface water resources are used to almost the maximum possible extent, 440 ha of the Sanya plain can be irrigated for two croppings in the dry season as well as whole area in the rainy season and that the required reservoir capacity becomes 7.5 MCM.

In Case 3, in which the Boloti and Mungushi areas are developed in addition to development of the Sanya plain in Case 2, the reservoir capacity becomes 6.6 MCM against 7.5 MCM in the Case 2, since the irrigation water demands decrease by improvement of irrigation efficiency in the Boloti and Mungushi areas, which is assumed to be 25% under present conditions and 40% with project conditions.

In Case 4, which aims to develop the groundwater area of the Sanya plain, all the areas are irrigated in accordance with proposed cropping patterns with surface and groundwater resources. The groundwater

demands are 4.7 MCM/year for 570 ha or 8,300 m^3/ha/year.

Case 5, "conjunctive use of surface water and groundwater" is the case combined Case 2 and Case 4. The calculation results indicate that all the areas can be irrigated by surface water resources to be developed by dam having a reservoir capacity of 7.5 MCM and groundwater resources. The groundwater demands are about 5.2 MCM/year for 610 ha or 8,300 m^3/ha/year. This amount is almost the same as in Case 4.

6.2.3 Optimum development scale

Based on these results of the water balance study and preliminary design of facilities, the development scale is determined through the economic comparison of alternatives.

In Case 1, in which surface water resources without dam development is utilized for irrigation, the irrigable area is estimated to be about 250 ha only in the rainy season on the Sanya plain as described in the previous Section, which is only about one quarter of the present agricultural area of 1,040 ha suitable for intensive agricultural farming. Accordingly development in line with the Case 1 is not judged to be a prospective development plan.

In Cases 2 and 3, all the areas suitable for intensive agriculture on the Sanya plain can be irrigated by surface water resources in the rainy season and about 40% of the area be irrigated in the dry season. The required reservoir capacity is 6.6 MCM in Case 3 against 7.5 MCM in Case 2. Thus the dam embankment volume in Case 3 is smaller by about 30,000 m^3 than in Case 2. However, in regard to the

development cost for Boloti and Mungushi areas, about 450 ha must be incorporated into the costs in Case 3. Accordingly the direct construction cost in Case 3 becomes higher than that in Case 2 by Tsh. 128 million. Mungushi and Boloti areas are classified as Class IV "Restricted Arable" in the land classification. As irrigation water is guaranteed in both areas, benefits coming from irrigation are expected to be almost the same between both cases. It is accordingly recommended in line with Case 2 that only water for irrigation of both Boloti and Mungushi areas should be guaranteed by construction of a dam having a capacity of 7.5 MCM and that development should be concentrated on the Sanya plain.

Case 4, which is a plan to develop the lower half of the Sanya plain with groundwater exploitation and to leave the upper half without development, will introduce partiality between the upper and lower halves of the Sanya plain area of the 1,050 ha suitable for intensive agricultural farming.

Case 5, which is the full development case on the Sanya plain with irrigation throughout a year with dam development and groundwater exploitation, will bring maximum benefit with maximum development costs.

Taking the above into account, an economic evaluation was made for comparing the Alternatives of Case 2, 4, and 5. The results are as follows:

Case	Benefit - Cost*	Benefit/Cost*	EIRR**
	(million Tsh.)		(%)
2	307	1.17	11.7
4	573	1.48	15.4
5	1,156	1.55	15.1

Remark: *; Using the discount rate of 10%
**: Economic internal rate of return

From the economic viewpoint of internal rate of return, all the three Alternatives especially the Case 4 and 5 are economically feasible. As previousely stated, the Case 4 is a plan to develop the lower half of the Sanya Plain with groundwater resources and the upper half is left without development. If the Case 4 is remarkably better than the Case 5 in terms of EIRR, the Case 4 would be selected as a project. However, the Case 5 is similar to the Case 4 in terms of EIRR and will, of course, give the maximum returns with maximum use of available surface water resources and suitable land resources. Therefore, in line with the development concepts, the agricultural development plan is formulated for Case 5.

6.3 Water Resources Development Plan

6.3.1 Boloti dam and the related facilities

The required capacity of the Boloti reservoir is estimated at 7.5 MCM, but the inflow to the Boloti from the own catchment area is only 3.1 MCM in drought year. Thus water available in the Lawati river of which the annual runoff is estimated at 9.7 MCM in drought year is diverted by a diversion weir and a diversion canal to be constructed to the reservoir.

In order to convey water from the reservoir to the Sanya river, an outlet canal is planned with an outlet structure. Also an outlet structure is planned to release water to the existing canal of Boloti area. A spillway will be provided in the left side end of the dam. Fig. 13 shows the general layout of the dam and the related facilities.

The dam height required for storing 7.5 MCM of water is estimated at 7.8 m including a freeboard of 2.4 m. The dam would be an earthfill type dam in view of the availability of embankment materials and the topographic and geological conditions of the dam site.

The diversion weir to divert water from the Lawati river would be constructed about 800 m upstream of the crossing point of the Lawati river with the Sanya Juu road on account of considering the topographic and geological conditions. The length of the diversion canal would be 2.6 km. The design discharge would be 3 m^3/sec so as to divert almost all the water of the Lawati river except during peak flood time.

The design discharge of the spillway is estimated at only 4.8 m^3/sec against the flood of 200 year return period in view of the storage effect in the reservoir. The features of these facilities are described in Section 7.1.

6.3.2 Groundwater resources

Tubewells are planned to be provided for about 610 ha on the Sanya plain in the downstream area where abundant groundwater is expected to be available. The capacity of one tubewell is estimated to be 50 lit/sec on average and the peak irrigation requirement is estimated at 0.9 lit/sec/ha. Thus 12 tubewells are to be provided. The proposed sites of the tubewells are shown in Fig. 14 and the features are described in Section 7.2.

6.4 Agricultural Development Plan

6.4.1 Proposed cropping pattern

According to the Implementation Programme of the National Agricultural Policy in Tanzania, Kilimanjaro Region is nominated as the Area of Specialization in Agricultural Production for 14 crops out of 32 nationwide priority crops.

Among the recommended crops, maize and beans are selected as the main crops for the proposed cropping pattern of the Project area, since maize and beans are the most profitable crops among the crops possible to grow under present economic situations and the farmers have long experience in the cultivation of such crops. In addition, vegetables, sunflower and bananas are selected as diversified crops after considering the farmers' intentions, soils, marketability and profitability of crops and farmers' ability to cultivate the crops.

The optimum cropping calendar was planned to suit the climatic conditions, particularly rainfall distribution and air temperature. The future land use in the Project areas based on the proposed cropping pattern shown in Fig.15 is estimated as follows:

(Unit: ha)

Area	Rainy Season	Dry Season	Total	Cropping Intensity(%)
Boloti Area				
Maize	160	0	160	-
Beans	130	0	130	-
Sub-total	290	0	290	100
Mungushi Area				
Maize	85	0	85	-
Beans	45	0	45	-
Sunflower	5	0	5	-
Vegetables	0	10	10	-
Banana	25	-	25	-
Sub-total	160	10	170	106
Sanya Plain				
Maize	530	530	1,060	-
Beans	210	420	630	-
Sunflower	50	50	100	-
Vegetables	210	420	630	-
Banana	50	-	50	-
Sub-total	1,050	1,420	2,470	235
Total	1,500	1,430	2,930	195

6.4.2 Proposed farming practices

Proper farming practices will be essential for realizing full exploitation of the agricultural potential. The proposed farming practices and farm inputs for maize, beans, sunflower and tomato under the "with project" condition were planned on the basis of the data obtained from the authorities concerned. The main farming practices proposed are outlined as follows:

(1) Land preparation

Land preparation for the crops proposed will be made by tractor in the Sanya Plain, while, land preparation in

Boloti and Mungushi areas will be made by oxen because of the stony and shallow soil characteristics.

(2) Seeds

High yielding varieties will be introduced to the proposed crops, even in Boloti and Mungushi areas.

(3) Fertilizers

The soils in the Project area are slightly alkaline so that ammonium sulfate as a nitrogen source, triple super-phosphate as a phosphorous and potash as potassium will be recommendable. A split application method of fertilizers is proposed to optimum crop growing.

(4) Agro-chemicals

Application of insecticides and pesticides is required for control of stem borers, plant hoppers, blast, etc. for plant protection and to attain high yields. Systematic application of insecticides and pesticides using sprayers is proposed for the plant protection works. However, herbicides are still harmful for not only human beings but also animals; livestock and wild life. Therefore, use of herbicides is not recommended for the Project for environmental reasons.

(5) Others

Other work such as planting, weeding, and harvesting are proposed to be carried out by both family and hired labour forces. This will be expected to create employment opportunities for the local people and to

contribute to the regional policy of moving people from the hilly zone to low the zone.

6.4.3 Labour requirements

No shortage of labour force will occur in Boloti and Mungushi areas even under the "with project" condition. However on Sanya plain there will be a labour shortage of 40,000 man-day/year, particularly during the harvesting of vegetables due to introduction of intensive farming under irrigated conditions. However, the labour force not only of adjacent villages but also of the high or middle zone in the region where high population pressure is a problem will be enough to cover the labour shortage on Sanya plain.

6.4.4 Anticipated crop yields and production

On the Sanya plain, anticipated yields of maize and beans have been estimated on basis of the experimental data obtained from the Agricultural Research Center in Lyamungu. The anticipated yields of tomatos are of maximum present yields in the Hai District. In the Boloti and Mungushi areas, the anticipated yields except those of tomatos are assumed to be 60% of those in the Sanya plain.

(Unit: ton/ha)

Crops	Boloti	Mungushi	Sanya Plain
Maize	3.0	3.0	5.0
Beans	1.2	1.2	2.0
Sunflower	-	0.81	1.35
Tomato	-	8.5	25.0
Banana	-	3.9	3.9

Anticipated production of crops in the Project area was estimated on the basis of the proposed land use, cropping pattern and anticipated yield of crops as summarized below:

(Unit: ton)

Area	Maize	Beans	Sunflower	Tomato	Banana
Boloti	450	156	-	-	-
Mungushi	255	54	4	85	98
Sanya Plain	5,300	1,260	135	15,750	195
Total	6,005	1,470	139	15,835	293

6.4.5 Marketability

(1) Staple food crops (maize, banana and beans)

The marketability of the staple food crops proposed was studied from the demand and supply conditions of the Kilimanjaro Region, Hai District and Project area.

The demand and supply situation in the Kilimanjaro Region and Hai District was calculated on the basis of the per capita consumption of food and population in the year 1988 and projected population in the year 2000 using the annual growth rate (2.1%) of the region from 1978 to 1988. The results are summarized below:

(Unit: ton)

	Kilimanjaro Region	Hai District	Project Area
Supply			
Maize	83,107	25,694	922
Bananas	593,608	298,125	98
Beans	14,595	5,115	127
Demand			
Maize	162,191	29,278	1,045
Bananas	591,998	106,864	938
Beans	51,930	9,374	208
Balance			
Maize	-79,084	-3,584	-123
Bananas	1,610	192,261	-840
Beans	-37,335	-4,259	-81

From the above results, the expected surplus production of staple food crops from the Project area after implementation of the Project will be fully consumable within the region or within the Project area.

(2) Horticultural crops

At present, horticultural production has been considered primarily as a means to improve the diet and nutritional standards of the local population in Tanzania. A detailed study for the development of horticultural crops was made by the Tanzania Investment Bank (TIB) and compiled as "Sector Study for the Development of Selected Horticultural Crops" in November 1988.

For Kilimanjaro Region, this study identified that the Kilimanjaro Region had a greater potential for horticultural production than any region in Tanzania

because the soils and climate and availability of water for irrigation would enable a wide range of horticultural crops to be grown in a number of locations. It is indicated that the following outlets are open to Kilimanjaro Region from a marketing point of view:

1) The local market	:	oranges, pineapples
2) Regional trade	:	potatoes, bananas, tomatos, onions, peas, carrots, etc.
3) Export to Kenya	:	vegetables
4) Export to Europe	:	horticultural products

Thus, the anticipated surplus horticultural crop production be expected to be traded in the local and/or domestic market in the short term and for export to Kenya and Europe as well in the long term.

6.4.6 Price prospect

Economic farm gate prices are used in the economic evaluation of the Project in view of its place in the national economy. Economic farm gate prices of trading commodities such as maize and fertilizers were estimated on the basis of the projected world market prices of the World Bank in the long range for the period of 1988 to 2000. The World Bank forecast prices of trading commodities were adjusted to 1990 constant prices using the manufacturing unit value (MUV). Economic farm gate prices of other trading commodities were valued at their financial prices. On the other hand, economic farm gate prices of non-trading agricultural commodities were estimated at five (5) years average by applying the deflator.

6.4.7 Project benefit

Applying the primary profit per crop estimated to crop area, the total primary profits accrued from agricultural production by the Project were estimated both under with and without project conditions. The annual incremental benefit at full development stage is estimated at Tsh. 483 million.

(Unit: 1,000 Tsh.)

	Boloti	Mungushi	Sanya Plain	Total
With project	5,205	5,346	477,890	488,441
Without project	588	3,414	1,454	5,457
Increment	4,617	1,932	476,436	482,984

6.4.8 Farm economy

The annual net reserve or the capacity-to-pay under "with project" condition is expected to be substantial on the Sanya plain as summarized below:

(Unit: Tsh.)

	Boloti	Mungushi	Sanya
Farm Size (ha)	1.1	0.8	1.9
Net Income			
Farm income	51,930	48,740	1,044,250
Livestock income	2,330	2,130	25,450
Non-farm income	22,270	25,450	11,460
Sub-total	76,530	76,320	1,081,160
Living Expense	45,480	58,230	59,660
Tax and others	550	630	610
Net Reserve	30,700	17,460	1,020,890

6.5 Irrigation and Drainage Development Plan

6.5.1 Irrigation development plan

(1) Irrigation water requirement

The irrigation water requirement was estimated based on the present and the proposed cropping patterns on a monthly basis using monthly climatic and rainfall data applying the method mentioned in the FAO Irrigation and Drainage Paper No.24. The estimate procedure is as follows:

1) Estimate consumptive use of water (Cu) by multiplying potential evapo-transpiration (ETo) by crop coefficient (k),
2) Estimate effective rainfall (Er) by USDA method and obtain net irrigation water requirement (NIR) deducting Er from Cu, and
3) Estimate irrigation water requirement by dividing NIR by overall irrigation efficiency.

Potential evapotranspiration is calculated by Modified Penman method using meteorological data obtained at Kilimanjaro International Airport (KIA) meteorological stations.

In order to estimate effective rainfall for each crop, rainfall data obtained from KIA are used for Sanya plain and rainfall data at Kibongoto or Lerongo if Kibongoto rainfall data are not available, are used for Boloti and Mungushi areas, since these stations are located near the Project areas. The effective rainfall is calculated by USDA SCS method.

(Unit: %)

	Sanya	Boloti/Mungushi
Application efficiency	70	55
Field canal efficiency	85	80
Conveyance efficiency	90	90
Overall irrigation efficiency	54 (60)	40

Remark: Figure in parenthesis for Sanya plain is for groundwater irrigation.

Peak irrigation requirements are 1.0 lit/sec/ha at the head of irrigation system and 0.9 lit/sec/ha at the tubewells in the Sanya plain.

(2) Irrigation schedule

The irrigation interval of each of cropping at the period of peak irrigation water requirement and depth of irrigation application are summarized as follows:

Cropping	Irrigation Interval	Depth of Irrigation Application
	(days)	(mm)
Maize-1	22	121
Maize-2	13	121
Sunflower-1	20	1
Sunflower-2	10	1
Beans-1	13	7
Beans-2	7	7
Beans-3	7	7
Vegetables-1	7	0
Vegetables-2	4	0
Vegetables-3	4	0
Banana	7	3

(3) Daily operation of on-farm level

It is clear that operation of 24-hr supply makes the minimum canal system capacity and thus leads to minimum cost of initial investment, however, irrigation for upland crops needs timely rotation of water from plot to plot or furrow to furrow to avoid water-logging and water shortage and to efficiently use irrigation water. It is however difficult to carry out proper water distribution at night when no farmers work in their fields and thus night irrigation would cause not only water-logging in some of the fields and water shortage in other areas, but also a lot of losses of limited water resources especially in the dry season in the Sanya basin. Taking the above into account, only day-time irrigation is contemplated at the field level.

The time of daily operation is analyzed in relation to irrigation water requirements and the daily working hours of farmers. As afore-mentioned, the longer the daily irrigation operation is planned, the less investment due to the smaller canal capacity. In general the daily working time is 8 hours in the fields and so in the off-season period of irrigation, the operation hour is determined so as to be about 8 hours. According to this criteria, the irrigation operation hours per day in a normal year is estimated as follows:

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
12.0	7.9	3.7	1.3	4.5	10.5	8.2	7.1	10.5	16.0	14.0	12.8	9.0

The peak operation hours will be 16 hours in October

(4) Irrigation system

An open canal system is proposed, since it is familiar to the people and easy in operation and maintenance. The proposed irrigation canal system consists of a conveyance system from Sanya Chini headworks, main canals, secondary canals, and distribution systems composed of night storage ponds, tertiary canals, and distribution canals. The storage ponds are to be provided at the head of tertiary canals between the secondary canals and tertiary canals. Tubewells are provided along the main or secondary canals in the groundwater proposed area in the downstream half of the Project area.

The conveyance system is planned to convey water 24 hours/day. Tubewells are planned to be operated 24 hours/day at peak irrigation season, while day-time operation of the irrigation water supply is applied in the distribution system taking into account the improvement of irrigation efficiency as described before.

From the view point of infiltration rate, any irrigation methods are applicable in the Project area. However, considering the self-maintenance and operation, surface irrigation methods such as furrow irrigation and basin irrigation methods are recommendable. The furrow length is determined to be 150 m from the infiltration test results in accordance with the criteria of USDA.

The distribution canals are laid out at night angles to the furrow direction at intervals of 150 m or nearly parallel to the contour line and their length is